# Mammals in Late Neolithic Orkney

(With reference to mammal bone
recovered from Links of Noltland,
Westray)

By

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

PhD

University of Edinburgh,
School of
History, Classics and
Archaeology,
Department of Archaeology

2015

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# Abstract

Excavation of thirty skulls, twenty-eight cattle and two sheep from the foundation course of a Late Neolithic structure at Links of Noltland (LON), Structure 9, is the starting point for this thesis, which investigates the economic and socio-cultural relationships of cattle and other mammals on Orkney communities between 3000 and 2500 BC. The LON settlement was located on a machair plain in Westray, the most N-W island within the Orkney archipelago (HY 428 493).

Male and female cattle skulls were inter-mixed within the LON foundation course so a “bull cult” is not represented. The sequence from living skulls to skulls “animating the building is (i) breed/acquire (ii) nurture (iii) cull/butcher (iv) consume (v) transform to object (vi) curate (vii) deposit. A skull deposit infilling an internal passageway from another LON, Structure 18, is compared and contrasted with the Structure 9 foundation deposit. Special treatment of cattle skulls from a wide range of European and Near-East sites is also reviewed to emphasise the widespread use of this symbol during the Neolithic period.

Orkney was separated from mainland Scotland prior to the establishment of the LON settlement so consideration is given to modes of arrival for mammals and their impact on this depauperate archipelago. Cattle and sheep dominated the domestic mammal remains examined, pig and dog were rare and goat and horse absent. The most abundant non-domestic mammals were red deer and Orkney voles, but otters and sea mammals were also present in low numbers. Genetic studies indicate that one cattle skull carried genetic material from aurochs, wild cattle. To date there is sparse evidence of interbreeding between wild aurochs and Neolithic domesticated cattle in Europe and none in Britain. The alterative explanation that aurochs were already present on Orkney during the Neolithic is explored.

Articulated red deer deposits from LON were also examined. Although previous publications explored the possibility that these deposits are “ritual” other possible explanations for these deposits are outlined. No parallels were noted between the cattle skull and articulated red deer deposits, but the importance of antler for practical and symbolic use in Neolithic Orkney may be under-estimated.

Stature of cattle remained relatively stable during the Mid to Late Neolithic in Orkney but underwent diminution by the Iron Age. A similar, but less marked reduction was also noted for sheep, but red deer already had small stature compared with early Holocene mainland Scotland red deer. The thesis concludes that cattle, sheep and red deer were of fundamental importance to the Neolithic society of Orkney, providing surplus food, tools and possibly

traction, to support an increasingly sophisticated Neolithic society undertaking construction of complex structures and monuments. In addition, cattle fulfilled an important role in their cultural and spiritual life.

# Acknowledgements

Investigations reported in this thesis were undertaken when I was a post-graduate student, sponsored by Historic Scotland, in the Department of Archaeology, School of History, Classics and Archaeology (HCA), University of Edinburgh. I would like to thank Dr László Bartosiewicz and Dr Kath McSweeney, for their encouragement, assistance and active support. I consider myself fortunate that they offered to carry out the role of supervisors for this thesis. Many other staff and post-graduates at the HCA School ensured my tenure as a post-graduate student was rewarding, intellectually stimulating and administratively trouble-free and I am indebted to them all. I would particularly like to thank Karen Howie for her advice regarding data management and storage and Professor Dennis Harding (retired) who gave advice during my MSc thesis. I had received excellent service provision from both the University of Edinburgh Library and the National Library of Scotland.

I would like to thank Historic Scotland, in particular my contacts Richard Strachan and Rod McCullough, for funding this investigation and the associated biochemical and radio-carbon dating analyses, and for their overall interest in the study. I gained invaluable experience from visiting and excavating at the Late Neolithic site of Links of Noltland, Westray, Orkney, the source of my mammal bone for this investigation. I am especially grateful to the excavation directors Hazel Moore and Graeme Wilson (EASE Archaeology) who managed the site on behalf of Historic Scotland, for their encouragement and instruction on both Orkney prehistory and on the challenges associated with excavation, recording and reporting a complex Late Neolithic and Bronze Age site. I was also fortunate that professional archaeologists excavating on this site shared valuable insights with me based on their field observations. Additionally, I would like to thank EASE Archaeology and Historic Scotland for commissioning me to investigate the mammal bone from the Iron Age site of Brest Ness, Westray, Orkney, referred to in this report, and to Maeve McCormick who worked with me during this identification work.

I could not have carried out this study without access to the comparative material held at the National Museums of Scotland. My mammal bone analysis was undertaken at the National Collections Centre, Granton. I was also given permission to examine Neolithic Orkney material held in the Natural Sciences collection, predominately from mid-20th century excavations referred to in this report. I would particularly like to thank Dr Jerry Herman, Senior Curator, Mammals, Zena Timmons, Assistant Curator and Dr Andrew Kitchener, Principal Curator, Vertebrate Biology, but all staff at the site were generous and supportive. In addition, I was

fortunate to be included in discussions with other NCC staff and visiting specialists. From NMS Scottish History and Archaeology, I would like to thank Dr David Clarke and Alan Saville for meeting me and to Dr Alison Sheridan for allowing me to view the articulated red deer skeletons from the previous excavation at Links of Noltland. I would also like to pay tribute to a previous Natural History Curator, James Ritchie, who wrote an inspirational publication “The Influence of Man on Animal Life in Scotland: A Study of Faunal Evolution” almost a century ago.

I am very grateful to Catherine Smith, the animal bone specialist at the Iron Age site of Howe, Mainland, in Orkney for allowing me to transfer her accurate written measurements of animal bones to spreadsheets in order to compare results from other pre-historic periods in Orkney.

In terms of the analyses carried out to support this study I would like to give extended thanks to Prof Angela Schlumbaun, Dr Julia Elsner and Dr José Granado, Integrative Prehistory and Archaeological Science, Basel University for producing mtDNA results for cattle bone from Links of Noltland.  I would also like to thank the staff at SUERC, East Kilbride for their radiocarbon dating and isotope results and for showing me around their facilities. Finally, I am grateful to Dr Mike Buckley, Manchester University for carrying out collagen analysis on some mammal bone specimens from the site as part of a protocol test and journal publication.

In addition, I would like to thank my many friends for their interest and support for this study, which helped me gain greater clarity through discussions with them. In particular I would like to thank Glenys McLaren for offering a second opinion on more challenging identifications, to Dr Arthur Robinson and Jill Morgan for discussing PhD report-writing, Ishbel McLaren for translating journal articles from French to English and Nicole Jamieson for assisting with the document format.

Finally, I would like to thank my husband, Duncan Fraser and my sons, Andrew and Cameron, who have all given this study excellent support, and to my wider family who showed great interest in this study, including Bjorn Hulman who produced the templates for the animal skull diagrams.

I am grateful to EASE Archaeology for the use of their photographs and diagrams for this thesis, which are individually acknowledged.

# *Declaration*

I hereby declare that this thesis has been composed by me and (save where acknowledgement is made) is based on my own work.

Signature

Date

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(NEOLITHIC, AVERAGE FROM NO 19) *SOURCES JONES ET AL., 2012*, *SCHULTING AND RICHARDS 2009* ........................................................................................................................ 280

# 1 Introduction

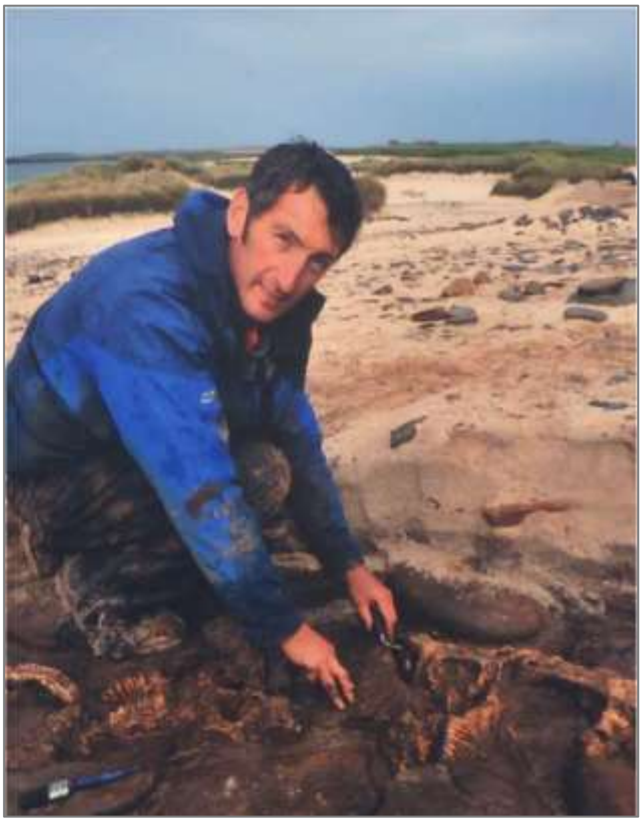
## 1.1 Aim

The aim of this thesis is to investigate the economic and socio-political role of mammals in Late Neolithic Orkney, with particular reference to skull deposits and articulated red deer skeletons excavated from Links of Noltland (LON) settlement, Westray, Orkney. See *Photographs 1 and 2*. This will increase understanding of subsistence strategies in Neolithic Orkney; explore the cultural role of mammals in this society; and consider modes of arrival for medium and larger mammals to Orkney during the Holocene. The words “animal” or “mammal” are used to describe non-human animals, although it is recognised that this is an artificial boundary (Russell, 2012, p2).

Current understanding of Neolithic societies is often based on the study of architectural features, pottery or other artefacts (Barclay, 2003, p132, Higham, 1969, p145, ScARF Neolithic Panel Report) but examination of Orkney society’s engagement with mammals and their products is also essential to gaining insight into Neolithic lifeways (Marciniak, 2005, p1, Russell, 2012, p9).

Domestic mammals and cereals were central to the initial establishment of Early/Mid Neolithic communities in Orkney and their subsequent progression over the next millennium to complex societies. These societies were sufficiently well provisioned to devote time and energy to accrual of architectural skills and procurement of building materials. Prior to the arrival of farming, the number of Mesolithic people supported by non-domestic resources in Orkney may have comprised one, or a few families, but by the end of the Late Neolithic farming supported an estimated population of six thousand people, perhaps more (Basler, 2014, p23, Renfrew, 1979, p217, Ritchie, 1995, p20, Saville, 2000, p98, 2004, p5, ScARF Neolithic Panel Report, Wickham-Jones, 2006, p27).

Evidence that cattle and sheep were important to social/belief driven interactions is demonstrated at LON by the deposition of twenty-eight cattle skulls and two sheep skulls in the foundation course of Structure 9 and a second deposition of cattle and sheep skulls used as blocking material in a passageway in Structure 18. The LON site had already produced the remains of fifteen articulated red deer skeletons during a previous excavation (1979-81) (Armour-Chelu, 1992, Sharples, 2000) and the current excavation uncovered additional red deer skeletons, allowing a review of three unusual deposits for both domestic and wild (or managed) species at the site.



**Photograph 1: Initial excavation of cattle skulls from LON, Structure 9 (Moore and Wilson, 2013)**

**Photograph 2: Cattle and sheep skull deposit, Passageway, Structure 18, LON (Moore and Wilson, 2013)**

In order to explore the relationship between these three bone deposits and remains of mammals consumed and/or processed adjacent to the settlement, eight LON midden or infill areas were selected for analysis. It is noted that the LON mammal bone collection is already a sub-sample of the mammal population that lived and died in Westray, or were transported to Westray as dead stock. For example, a calculation from the Bronze Age site of Godin Tepe, Iran, which supported a population of approximately three thousand people between 2400 and 1300 BC, indicated that the archaeological animal bone from excavated areas of the site only represented 0.015% of the death assemblage of animals potentially consumed (Gilbert and Singer, 1982, p30).

## 1.2 Previous Orkney Neolithic mammal bone investigations

Accounts of 19th and early 20th century excavations of Orkney pre-historic sites included observations on mammal bones, for example at Skara Brae "horns of the ox and deer were well represented" (Petrie, 1867, p212). No detailed quantitative or metrical analysis was undertaken but zoogeographical observations, such as the presence of red deer bones despite the species no longer being resident in Orkney, were highlighted. Mammal bone finds from early investigations of cairns are published in "The Chambered Cairns of Orkney". The present location of animal bone material from cairns such as Cuween (apart from dog skulls), Maeshowe, Unstan and Windford Hill is unknown (Davidson and Henshall, 1979).

From the late 1920s to the late 1950s excavation reports of Orkney Neolithic sites, published in the Proceedings of the Society of Antiquaries of Scotland by archaeologists V.G. Childe, J.G. Callander, W.G. Grant, A. Low, C.S.T. Calder, W. Traill and W. Kirkness included appendices on animal bones by M. Platt, Natural History, Royal Scottish Museum, Edinburgh (a forerunner to the National Museums of Scotland) (Calder, 1937, Callander and Grant, 1935, 1936, Callander, Grant and Low, 1934, Childe, 1930, 1952, Childe and Grant, 1939, 1947, Traill and Kirkness, 1937). In addition, V.G. Childe's book on the Skara Brae excavation included an appendix "The animal bones from Skara Brae" by D.M.S. Watson, Professor of Zoology and Comparative Anatomy, University College, London (Childe, 1931, Watson, 1931) and his second paper on Quoyness cairn a report on a sheep skull by F.E. Zeuner, Professor of Environmental Archaeology, University of London (Childe, 1952, Zeuner, 1952).

These reports by M. Platt, D.M.S. Watson and F.E. Zeuner investigated samples of mammal bones selected by excavators for further examination, and although they provided little quantitative data, did include descriptive morphology, ageing, details of butchery and measurements. The contexts from which bones were recovered were generally not reported, although the distribution of red deer bones (*Cervus elaphus*) in Knowe of Yarso cairn was listed separately for the entrance passage and chambers (Platt, 1935). Some of the mammal bones samples examined by M. Platt are curated at the National Museums of Scotland (NMS) Collection Centre, and were re-examined for this thesis to enhance published information and, in particular, to produce comparative measurements for the LON material.

By the late 20th century excavation reports from Neolithic Orkney sites either had more comprehensive animal bone appendices written by zooarchaeologists, for example, Point of Cott, Pierowall Quarry, Knap of Howar and Isbister (Barker, 1983, Halpin, 1997, MacCormick, 1984, Noddle, 1983) or mammal bone chapters within site monographs, for example the cairn sites of Quanterness and Holm of Papa Westray North (Clutton-Brock, 1979, Corbet, 1979, Harman, 2009). These reports reflected greater emphasis on the systematic study of all mammal bone fragments from identified contexts and were associated with the adoption of a “processual” archaeology and influenced by (i) an upsurge of publications on animal bone examination and interpretation (e.g. Boessneck and von den Driesch, 1978, Bökönyi, 1969, Chaplin, 1971, von den Driesch, 1976, Ducos, 1978, Grayson, 1973, Higham, 1967, Klein and Cruz-Uribe, 1984, Payne, 1973, Silver, 1969, Uerpmann,1973) (ii) international zooarchaeological conferences leading to the establishment of the International Council for Archaeozoology (ICAZ) which promoted international nomenclature and working practices (Davis, 1987, p21). By comparing results with modern and historic analogies it was considered that pre-historic subsistence strategies could be reconstructed. Later research emphasised that interpretation of faunal assemblages must also consider taphonomic effects such as gnawing, weathering, burning, fracturing and dispersal/re-dispersal (Binford, 1981, Gifford-Gonzalez, 1989, Higgs, 1972, Lyman, 1994, Reitz and Wing, 1999, Schiffer, 1983, Shipman, 1981).

Late 20th century Orkney Neolithic animal bone reports did not review the roles of mammals in wider subsistence or belief systems, although differing explanations for the presence of mammals in cairns (natural or human action) were debated (Barker, 1983, Clutton-Brock, 1979, p113, Halpin, 1997, Henshall, 1985, p116, MacCormick, 1984, p109, Renfrew, 1979, p160, Ritchie, 2004, p98). However, in the early 21st century two substantive mammal bone reports, included within publications for Pool and Tofts Ness in Sanday, Orkney considered not only details of species composition, age of death, sex, health and butchering, but also the role of mammals within a wider subsistence strategy (Bond, 2007, Dockrill, 2007, Hunter, 2007, Nicholson and Davies, 2007). These sites both contained Neolithic and later animal bone material. For a full list of sites, excavators and authors of animal bone report authors *see Appendix 1*.

Two excavations at Orkney Neolithic settlements at Skara Brae and Links of Noltland (Grobust) undertaken in the late 20th century by D. Clarke are still awaiting publication, but it is anticipated that interpretation of human relationships with animals will be included in these monographs along with discussion on subsistence. For this thesis, comparative mammal bone information from LON 1979/81 (Grobust) excavation was obtained from a PhD thesis "Vertebrate Resource Exploitation, Ecology, and Taphonomy in Neolithic Britain, with Special Reference to the Sites of Links of Noltland, Etton and Maiden Castle" (Armour-Chelu, 1992) and, for Skara Brae, general publications that included a few mammal bone results or quoted unpublished data.

Culture and human agency in decisions relating to mammals (Hodder and Hutson, 2003, p208) was considered for sheep (*Ovis aries*) from Pierowall Quarry cairn, with the excavator suggesting a ritual explanation for the Group 2 assemblage, a view not endorsed by the zooarchaeologist (MacCormick, 1984, Sharples, 1984). A publication by the same excavator also deliberated on the non-economic role of red deer in Neolithic Orkney "Antlers and Orcadian rituals: an ambiguous role for red deer in the Neolithic" (Sharples, 2000). Three years later A. Jones and C. Richards reviewed cultural lives of animals in Neolithic Orkney and although some of their discussion regarding deposition of dog skulls and eagles in cairns may need revision, based on more recent radiocarbon dates, the paper also redresses the emphasis of mammals' role as only providers of food and secondary products (Jones and Richards, 2003).

Publications on Neolithic Orkney give little consideration of how mammals arrived in Orkney. There is an assumption that domestic stock was introduced by Neolithic settlers and red deer introduced simultaneously, or possibly earlier by Mesolithic hunter-gathers (Clarke and Sharples, 1985, p77, Clutton-Brock, 1979, p113, Jones and Richards, 2003, p47). The exception is a publication by P. Buckland and F. McCormick which suggests that "it is evident that parts of the Orcadian fauna could have crossed the Pentland Firth before it was inundated" (Buckland and McCormick, 2003, p87), based on evidence from a publication on sea levels in the Late Devensian/Early Holocene (Lambeck, 1995). More interest has been devoted to the possible sources and arrival of the Orkney vole (*Microtus arvalis orcadensis*), both from a morphological and genetic perspective (Berry, 1986, p17-18, Corbet, 1979, p136, Cucchi et al, 2009, 2014, Martínková et al, 2013).

Recent radiocarbon dates for Orkney Neolithic mammal bones are listed in the Archaeology Scotland annual publications "Discovery and Excavation in Scotland" and older radiocarbon dates, some from multiple mammals bone samples, reviewed by P. Ashmore (Ashmore, 2004, 2009). Some isotope analysis has been undertaken on mammal bones at Holm of Papa Westray North cairn (Balasse and Tresset, 2004) and from a selection of mammal bones from Orkney Neolithic sites stored at the NMS Collection Centre (Jones et al, 2012).

## 1.3 Objectives

### 1.3.1 General

In order to investigate the economic and socio-political role of mammals in Late Neolithic Orkney, the following research objectives were established.

### 1.3.2 Cattle and sheep skull deposits

- Identify location, orientation and condition of sheep and cattle skulls in Structure 9 and 18 to improve understanding of deposition
- Examine skulls to gain insight into selection criteria
    - By zooarchaeological observation
        - Species representation
        - Sex
        - Age at death
        - Anomalies/pathology
        - Modification
        - Measurements
        - Post-cranial bones associated with the skull deposits
    - By supporting specialised analyses
        - Radiocarbon dates
        - Isotope analysis
        - mtDNA analysis
- Review literature to place LON skull depositions within similar practices in the wider Near East and European Neolithic communities
- Explore other symbolic representations of cattle and sheep in Neolithic Orkney

- Consider possible parallels with the treatment of human and domestic mammal skulls in Neolithic Orkney

### 1.3.3 Red deer articulated skeleton deposits

- Investigate location and orientation of articulated red deer skeletons to investigate possible methods of deposition
- Consider similarities and differences to LON cattle and sheep skull deposits
- Compare articulated red deer skeletons with red deer bones recovered from Orkney midden and cairn deposits
- Review use and deposition of red deer antler, currently considered to be of little importance to Orkney Neolithic communities

### 1.3.4 LON mammal bone deposits

- Identify mammals exploited during the Late Neolithic period in Orkney, mammals that arrived during the post-Neolithic and those now extinct
- Consider taphonomic factors that may have influenced survival of the mammal bones
- Determine if cattle and sheep skull deposits were representative of herds living in Neolithic Orkney
- Review representation of species/elements in midden material recovered from wall core, Structure 9 and other midden areas to determine if this material was associated with cattle skull depositions
- Examine floor/hearth deposits in Structure 9 to explore possible functions for the building
- Generate information of LON mammal bone deposits to determine herd structure, possible subsistence strategies and stature. Compare this information with selected Orkney Iron Age sites

    - By zooarchaeological observation
        - Species representation
        - Pathology
        - Age
        - Size

    - By supporting specialist analysis

### 1.3.5 Analysis

- Review possible sources for the cattle and sheep skull deposits and reasons for depositions
- Explore exploitation of domestic and non-domestic mammals in Late Neolithic Orkney
- Consider evidence for modes of arrival for domestic and non-domestic mammals in Orkney

## 1.4 Outline

The remainder of *Chapter1* records past and present environmental influences on Orkney in order to consider impacts on stock-keeping during the Neolithic and whether natural colonisation was viable in the immediate post-glacial period. Following this are details of the LON excavations. *Chapter 2* describes methods used during this investigation and additional analysis carried out by specialist laboratories. *Chapter 3* provides an overview of mammals previously recorded from Neolithic sites in Orkney, those species that may have arrived at a later date and those now absent. This chapter continues with a review of current literature on initial domestication of mammals, their transmission through Europe and eventual arrival in Britain and Ireland (including Orkney). Domesticated cattle and sheep offered the opportunity to convert inedible food (grassland and browse) into food such as milk, fat and meat for human consumption and could be culled as required, “The Walking Larder” (Clutton-Brock, 1989, title). Finally, special mammal deposits in pre-historic Continental Europe and Britain are reviewed.

Following these introductory chapters, *Chapter 4* provides details of cattle and sheep skull deposits from LON Structures 9 and 18. These are compared with other cattle skulls or articulated cattle skeleton deposits in Orkney. Consideration is given to any parallels with treatment of human skulls in Neolithic Orkney and lack of any other symbolic representation of cattle. *Chapter 5* reviews red deer remains from LON, both butchered bone fragments and articulated deposits, and from other Neolithic sites in Orkney and outlines possible management and procurement strategies for red deer and the possible importance of antler.

*Chapter 6* reports on the analysis of mammal remains from eight areas of LON. This chapter includes a more detailed review of mammal bone recovered from the wall core in Structure 9 and the floor/hearth deposits in Structure 9. *Chapters 7 to 9* consider the pathological evidence, age at death profiles and the stature of LON cattle, sheep, pig and red deer.

*Chapter 10* reports on results from the supporting analysis of cattle mtDNA and cattle and sheep stable isotopes.

*Chapter 11* discusses LON mammal remains and highlights new insights on the role of cattle, sheep and red deer in lifeways of Late Neolithic people in Orkney and *Chapter12* conclusions and recommendations for further study.

## 1.5 Definition of Neolithic period in Orkney

This thesis applies the ScARF definition for periodisation of the Neolithic in Orkney (ScARF Neolithic Panel Report, p34, p43). These are:

- Early Neolithic (from early beginnings to 3500 BC)
- Middle Neolithic (3500 to 3000 BC) (Mid)
- Late Neolithic (3000 to 2500 BC)
- Chalcolithic (2500 to 2200 BC)

Other organisations and researchers may use different terms. For example, English Heritage define Early Neolithic as 4000 to 3700 BC, Early/Middle Neolithic as 3800 to 3300 BC, Middle Neolithic 3300 to 2900 BC, Late Neolithic 3000 to 2000 BC, Late Neolithic/Early Bronze Age as 2400 to 1800 BC (Serjeantson, 2011, p2, table 1.1). Another definition is Earlier Neolithic (4000 to 3000 BC), Later Neolithic (3000 to 2000 BC) and Early Bronze Age 2200 to 1500 BC (Pollard, 2008, p9).

## 1.6 Use of ethnographic material

Historic ethnographic sources were selected for this thesis predominately from Orkney or other Scottish islands. These references are used with caution since warnings have long been issued against unguarded use of ethnographic parallels (e.g. Higgs and Jarman, 1972). A robust argument produced against adoption of ethnographic records for pre-historic Orkney material, states “these exercises in western colonialism are disrespectful, and more importantly, inherently improbable” (Barber, 1997, p68). In addition, Scottish island social and economic behaviour reported by 18th and 19th century visitors and published in a series of “Tours, Visits” or “Descriptions” was almost certainly different from those of the prehistoric period (Hunter, 1991, pp178-179). It is therefore the general technical/functional parallels in material culture that may be of some use in this thesis.

## 1.7 Radiocarbon dates

Radiocarbon dates listed as cal BC at 95.4% probability unless otherwise stated. Palaeogeographic material is quoted as “BP”, following the conventions used by authors of this research. Radiocarbon dates are listed in *Appendix 2*

## 1.8 Orkney Description

### 1.8.1 Location

Orkney has a submerged topography with marine transgressions creating a mosaic of islands firths and straits. Approximately 70 islands and islets cover a total land area of 970 km$^2$ (Berry, 2000, p5, Davidson and Henshall, 1989, p9, Wickham-Jones, 2006, p2) with an estimated coastline is 800 km, considerably longer than the 150 km coastline of the adjacent Caithness coast (Mather et al., 1975, p10). Orkney is located off the north-east of Scotland and separated from mainland Scotland by the Pentland Firth, a high energy channel, in terms of both wave action and currents (7-12 knots), linking the Atlantic Ocean and North Sea (Bates et al., 2013, p26, Sturt, 2005, p71). In recent times approximately half of the land surface of the Orkney Islands has been used for agriculture (Berry, 2000, p200, Bullard, 1975, p22).

Links of Noltland (LON) the Late Neolithic site, the source of mammal bones examined in this thesis, is located in Westray (HY 428 493), the most north-westerly island of the Orkney Islands.  See *Figures 1* and *2*.

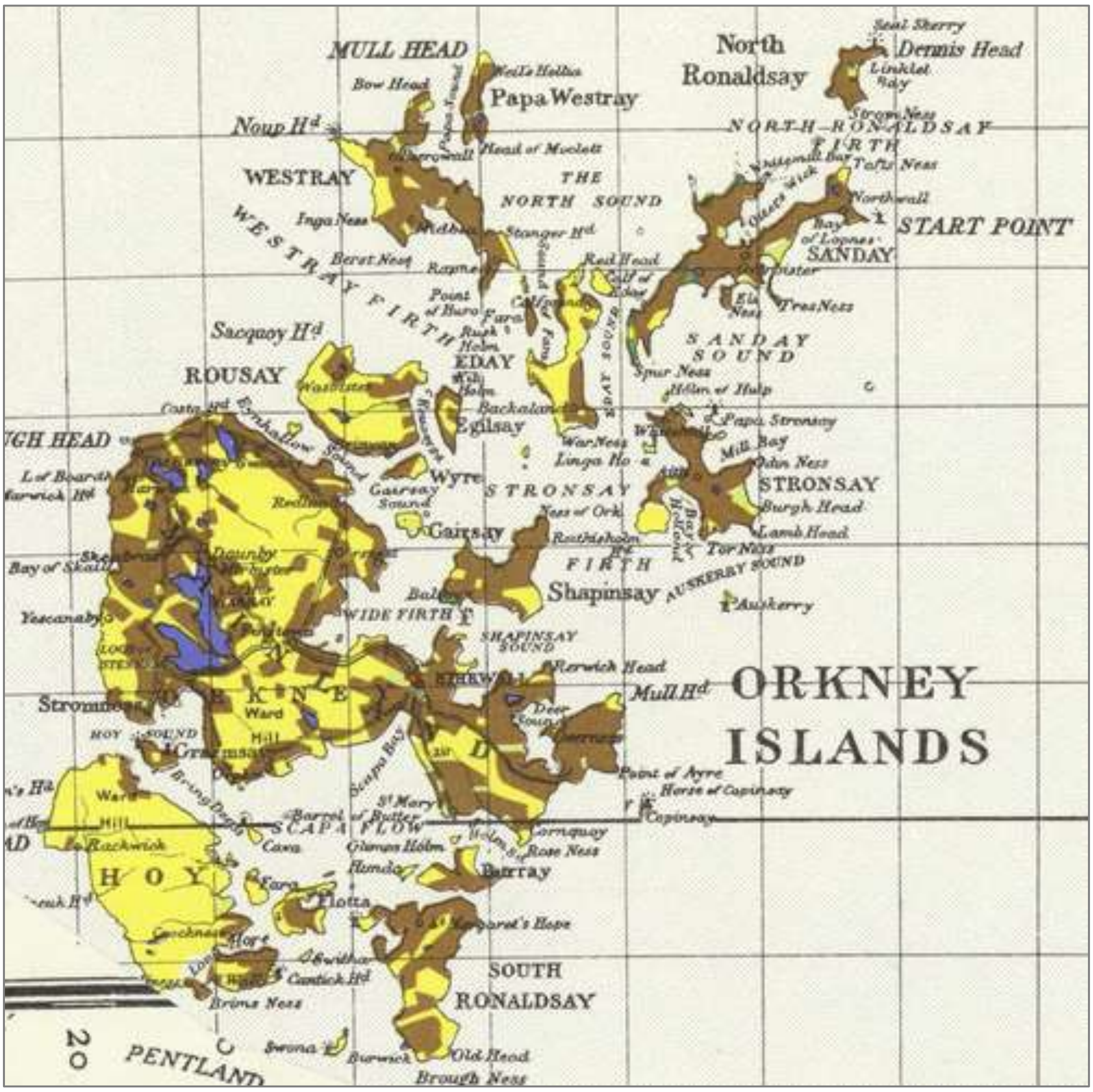


**Figure 1: OS 10 mile Land Classification 1945 reproduced with permission of the National Library of Scotland maps.nls.uk. Key: brown-good quality, ploughable; light brown hatched-medium quality, pasture; yellow-mountain or rough pasture**

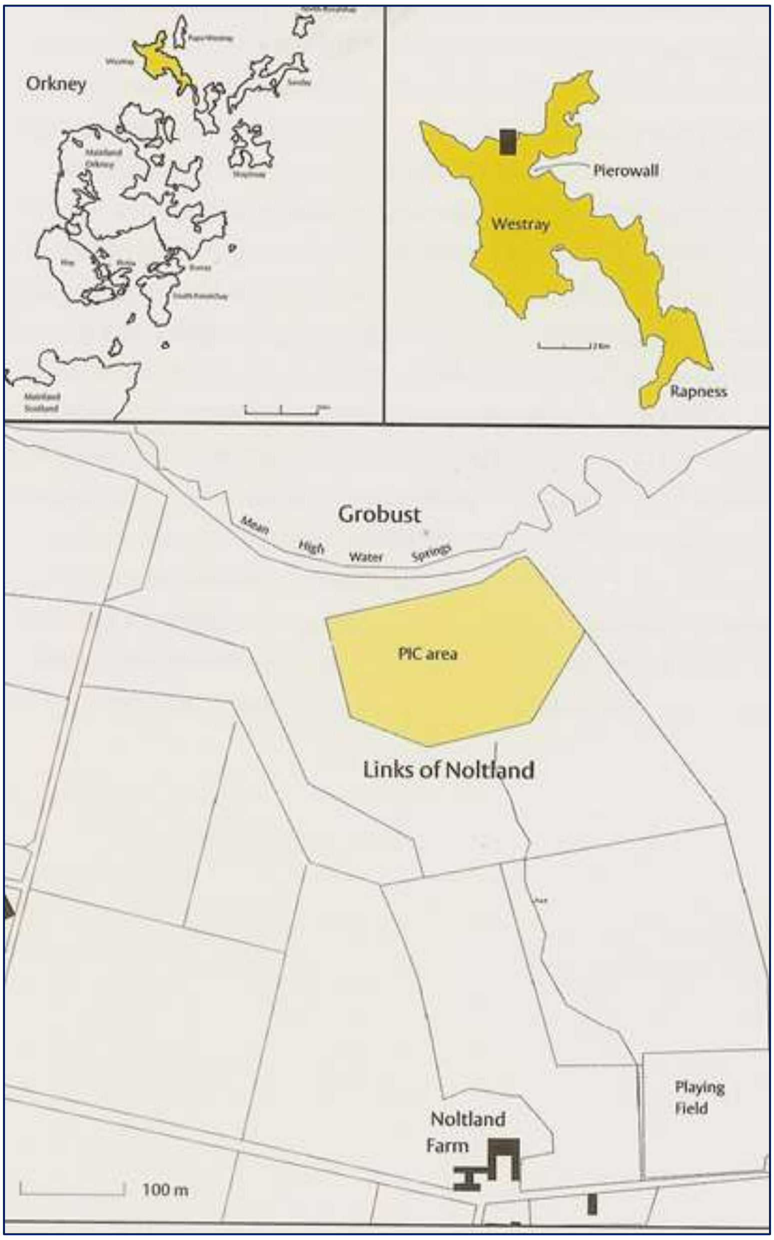


**Figure 2: Location of Links of Noltland (Moore and Wilson, 2011)**

## 1.8.2 Geology

The underlying geology of the Orkney Islands is the Old Red Sandstone (ORS) series laid down in the Devonian period approximately 400 million years ago. The only exception to this is the island of Hoy where sandstone rocks are underlain by lavas and tuffs. The underlying sandstone is covered with till in lower lying areas created by the forces of glaciation (Booth and Booth 2005, McKirdy, 2010, Mykura, 1975).The ORS is an excellent source of flagstones for buildings, readily splitting into flat, even slabs with straight edges (Ritchie, 1995, p16).

### 1.8.3 Last Glaciation

The Last Glacial Maximum (LGM), the time when the ice sheets reached their maximum integrated volume in northern Europe, was approximately 26000 to 19000 BP and Orkney was covered in ice for at least part of this period (Clark et al., 2009, Clark et al., 2012, p123, pp134-136, fig 18-19).

A warm Late Glacial Interstadial followed the LGM when temperatures were similar to present day, although perhaps more continental, with some residual ice (Ballantyne, 2004, p29, p30, fig 2.2, Golledge, 2010, p550). Then the colder Younger Dryas (labeled the Loch Lomond Stadial in Scotland) of approximately 11000 to 10000 BP, part of a wider global event, followed this Interstadial and ice re-advanced, predominately in the west of Scotland (Golledge, 2010, pp552-553). During the LGM the North Atlantic polar front lay at the latitude of northern Spain, whereas during the Loch Lomond Stadial the front did not move so far south and lay at the latitude of south-west Ireland. Today the polar front lies between Iceland and Greenland (Ballantyne, 2004, p30).

Orkney was not covered with ice during the Loch Lomond Stadial but temperatures would have been low, with non-glaciated areas experiencing cold and dry conditions (Ballantyne 2004, p28, fig 2.1, Golledge, 2010, p552). Some researchers suggest that the North Atlantic thermocline circulation (North Atlantic Drift) was restricted during this period, with less warm water being drawn northwards from tropical areas, which, in turn, reduced air temperatures above oceans transversed by the prevailing westerly or south-westerly Scottish winds (Golledge, 2010, p552); others consider that the North Atlantic thermocline continued (arguments detailed in Lowe and Walker, 1997, p364). During the Loch Lomond Stadial the mean ocean temperatures in Scotland would have been cool, with mean July sea-level temperatures of the order 5.5-7°C (Ballantyne, 2004, p30) but if the North Atlantic thermocline continued operating this may have had a moderating impact on air temperature in Orkney.The end of the Loch Lomond Stadial was more abrupt than its onset. Temperatures comparable with present day were reached by c 9800 to 9500 BP (Ballantyne, 2004, p30, Lowe and Walker 1997, p346, Whittingham and Edwards, 2003, p16). On present evidence it appears unlikely that warm-adapted ungulate populations survived in Orkney or northern Scotland during the Loch Lomond Stadial. Reindeer were present in Scotland after the Loch Lomond Stadial but the latest recorded date is 7480 to 7100 cal BC (Murray et al., 1993).

### 1.8.4 Sea levels

A model of sea level change around Britain demonstrates that shoreline retreat was relatively rapid after 10000 BP with the landbridge between Orkney and Scotland disappearing between 10000 BP and 8000 BP (Lambeck, 1995, Van de Noort, 2011, p51, p128). Another model, using sediment cores from the North Sea, ice-sheet reconstructions and present day bathymetric information, based on 1000 year intervals, indicates that Orkney may already have been a single discrete island earlier, by 10000 BP, although with a much greater land area than present (Shennan et al., 2000, p310, fig 5). The Glacial Isostatic Model at 500 year intervals, in addition to measurements used in previous models, predicts that Orkney was already separate from the mainland by 11000 BP, although the channel was narrower than the present Pentland Firth configuration (Sturt et al., 2013, p3970, fig 6). It is noted that all three models review the position from mainland Britain and not Orkney itself, and most data for these models is not derived from sites on or adjacent to Orkney.

After the retreat of the Loch Lomond Stadial the sea level in Orkney may have been 45m lower than at present. Of considerable relevance is that initially Orkney split into only two islands, with Westray part of the northern group of Sanday, Eday, Stromsay and Papa Westray. Only between 6000 and 4000 BP did relative sea level reach minus 6m (Dawson and Wickham-Jones, 2007) and the islands of Orkney start to resemble their present-day configuration, although land area would still be greater than at present. There may therefore have been a reduction of grazing area available in Westray over the Neolithic period. These possible changes in sea level are contradicted by the ScARF Neolithic Panel Report which states that relative sea level rises in Scotland were either very slow or had effectively ceased by the Neolithic period.

### 1.8.5 Climate

Climate of the Orkney Islands is influenced by prevailing westerly or south-westerly winds crossing warm surface currents of the North Atlantic thermohaline circulation. This produces an equitable maritime climate with a small annual range of temperature (hyperoceanic). So, for example, the average temperature in Kirkwall, Mainland in March is 4.7$^{o}$C, that of August 12.7$^{o}$C (Berry, 2000, p10, table 1.1). One consequence of the small temperature range is that growing seasons are ill-defined and prolonged (Davidson, 1979, p10). On average the growth season (temperature average greater than 6$^{o}$C) lasts five/six months per year, shorter than more southerly lowland areas of Britain (Berry, 2000, p9). Strong winds are an important feature of Orkney’s climate (Berry, 2000, p12, Bullard, 1975, p19, Davidson, 1979, p10). These winds can have a desiccating effect on vegetation and require animals to exert additional energy to maintain body temperature. However, they also create long frost-free periods with little snow-fall, allowing access to grazing, so, if stocking rates were below capacity, cattle may have been able to graze “winter-hay on root” as recorded in mediaeval Ireland (Lucas, 1989, p35).

The annual rainfall in the Orkney Islands ranges from 890 to 1020mm/year, low compared with many regions of Scotland, but with a high frequency of rain days (241days/year) (Berry, 2000, p11, Davidson and Jones, 1985, p17). The relatively high latitude of Orkney means summer days are long, winter days short. The benefit of long summer days during the growing season is offset, however, by the high latitude of Orkney reducing the sun’s ray angle, so land is not heated as much as at lower latitudes. Additionally the present-day high frequency of cloud and rain reduces the potential advantage of long daylight hours. A considerable proportion of rain falls in autumn and winter and can cause difficulties with harvesting cereals. The high relative humidity, which rarely falls below 70%, retards the drying, ripening and storage of crops and hay (Amorosi et al., 1998, Booth and Booth, 2005, Davidson, 1979, p10).

The Holocene climatic optimum, during the Atlantic period, when summer temperatures were considered to be 2-3$^{o}$C higher than at present, was 6000 to 5000 BP (Burroughs, 2005, p47, Bell and Walker, 2005, p90) or 7500 to 5000 BP (Elhers, 1996, p310, Whittington and Edwards, 2003 p13) possibly before the arrival of Neolithic farmers in Orkney. Later deterioration during the sub-Boreal period, was gradual, and timing varied between localities, with some researchers suggesting that climatic decline, characterised by lower temperatures and increased cloudiness, started at approximately 4000 BP, the end of the Late Neolithic period in Orkney with the most pronounced deterioration from 2800 to 2500 BP (Bell and Walker, 2005, p92) or between 5000 to 2500 BP (Whittington and Edwards, 2003, p13). It is possible that a combination of oceanic, solar and volcanic factors were responsible (Anderson et al., 1998).

### 1.8.6 Land Cover and Vegetation

Currently land not used for agriculture in Orkney has three main groupings (i) grass heath, and tall herbs and wetland communities within agricultural zones (ii) coastal plant communities (iii) upland vegetation (Bullard and Goode, 1975). Palaeoecological evidence of pollen and macrofossils demonstrates that the first post-glacial Orcadian vegetation comprised open grassland and heath from 12000 to 8000 BP. During the next two thousand years the heath developed further with Juniper (*Juniperus sp*) then crowberry (*Empetrum sp*) dominating. This was replaced during the Atlantic period by a birch/hazel (*Betula sp/Corylus sp)* complex. Pollen has been recovered from oak (*Quercus sp*), elm (*Ulmus sp)* and alder (*Alnus sp*) (all assumed not to be native to Orkney) and pine (*Pinus sp*) (may have been native). This earlier birch/hazel complex was "scrub" woodland (Davidson and Jones, 1985, p23, Tipping, 1994, p13). Other researchers consider oak was present in Orkney during this period and in less exposed areas there may have been dense-canopied woodland (Bunting, 1994, 19996, Farrell et al., 2014, de la Vega-Leinert et al., 2000, 2012).

Open grassland began replacing the open woodland around 3500 BC, or perhaps slightly earlier, approximately when the first Neolithic settlers arrived in Orkney (Bunting, 1994, Davidson and Jones, 1985, p25) and Orkney may have been effectively treeless by 3000 BC (Tipping, 1994, p24), although recent research suggests some woodland resources would still have been available (Farrell et al., 2013). It is difficult to state whether woodland decline was caused by the arrival of farmers or other factors such as increased storminess, changes in precipitation, sea-level change and associated machair formation, natural soil acidification or blanket bog formation, all of which would have had an impact on woodlands (Edwards and Ralston, 1984, p30, Tipping, 1994, p23). Data from Hobbister, Whaness Burn, Blows Moss and Keith's Peat Bank, suggests that there was almost no woodland or scrub cover in Orkney by 4700 cal BP (*3378-3520 cal BC*) and low values prior to this date. There was a decrease in heath cover between 6200 and 4200 cal BP and then a gradual recovery to dominance by 2700 cal BP (Fyfe et al., 2013, p136).

Nine Orcadian Neolithic sites were examined to determine the importance of wild and domestic plants in human diet (Barnhouse, Crossiecrown, Isbister, Knap of Howar, Knowes of Trotty, Ness of Brodgar, Skara Brae, Stonehall and The Howe). In contrast to some other areas of Scotland, plant assemblages were almost entirely cereal-based with little evidence of wild species of fruit or seeds. Naked barley grain predominated, with hulled barley probably only becoming important in the Bronze Age (Bishop et al., 2009, pp87-88), although this species is recorded from LON (Hastie, 2011).

### 1.8.7 Seaweed

Productivity of seaweed (macro-algae) around the Orkney coastline is substantial, with a mid- 20th century survey calculating potential yield of over 38,774 tons within the littoral zone and up to one million tons offshore, some of which will be driven onto land by storms and wind (Fenton, 1978, p274). This, in effect, increases the primary production of the Orkney Islands. Seaweed was utilised as supplementary food by ruminants in both present and historic periods on Scottish islands. For example, modern red deer were noted as grazing on seaweed during winter on Rum, Inner Hebrides (stags 18.3%, yeld hinds 14.4%, and milk hinds 8.2%) but less so in summer (Clutton-Brock et al., 1982, p240). A late medieval report also records herbivores grazing macro-algae on Scottish islands, for example red deer in the Western Isles of Lewis and Harris, cattle in the Inner Hebridean islands of Lingay, Skye and Tiree and horses in Orkney and Shetland (Martin 1695/1999 p18, p34, p51, p101, p164, p212, p223). In the Orkney historic period cattle might be fed fresh or boiled seaweed to supplement their diets (Fenton, 1978, p428) and a modern feral herd of cattle on Swona, an island located in the Pentland Firth, were recorded as eating small quantities of macro algae, particularly *Laminaria sp* and *Fucus serratus* (Hall and Moore, 1986, p93).

Sheep on the Orkney island of North Ronaldsay today follow a diet of seaweed, particularly *Laminaria sp,* throughout most of the year, being separated from the interior of the island by a dyke constructed in 1832 (Fenton, 1978, pp464-469, Lovick, 2004). See *Photograph 3*. The restriction was an extreme solution to protect grazing and arable areas and does not provide optimal habitat. These sheep crop all patches of grassland adjacent to the seashore heavily. During gestation and lactation ewes are brought on to pasture lands within the walled area and even if twins are born, only one lamb is left with each ewe.

**Photograph 3: North Ronaldsay sheep eating seaweed © Wikimedia.org**

Based on isotope studies, it is proposed that sheep recovered from the cairn of Papa Westray North ate seaweed (Balasse and Tresset, 2009, Balasse et al., 2005, 2006). It seems possible that macro-algae were an important resource in Neolithic Orkney particularly during winter. Traces of seaweed (*Ascophylum nodosum*) were recovered from under the floor of a Neolithic structure in the settlement of Rinyo, Rousay (Clark, 1952, p90).

## 1.9 Links of Noltland (LON) Archaeological Site

### 1.9.1 Location

LON is situated in the island of Westray, the most north-westerly island of the Orkney Islands archipelago. Westray has a surface area of 47km$^2$ with an underlying geology of Middle Old Red Sandstones (ORS) known as Rousay flagstones (Leather 2006, Mykura, 1975). These comprise grey and black thinly bedded sandstones that are overlain by glacial till in most areas. The landscape is low and gently undulating, with the highest point, Fitty Hill, only 169m high. The island’s coastline is 61 km long of which beaches occupy 10 km, high cliffs 17 km and low rocky shores 34 km (Mather et al., 1975, p10, table 1). The dominant seaweed in the sub-littoral waters around Westray and Papa Westray is *Laminaria sp* (Walker, 1950). The largest drainage system, approximately 2.5 km in length, discharges in an easterly direction to the Bay of Toquoy. There are also some standing water bodies, the largest being the Loch of Burness and Loch Saintear. A spring has been identified at LON, north-west of the settlement (H. Moore per comm.). See *Figure 3*.

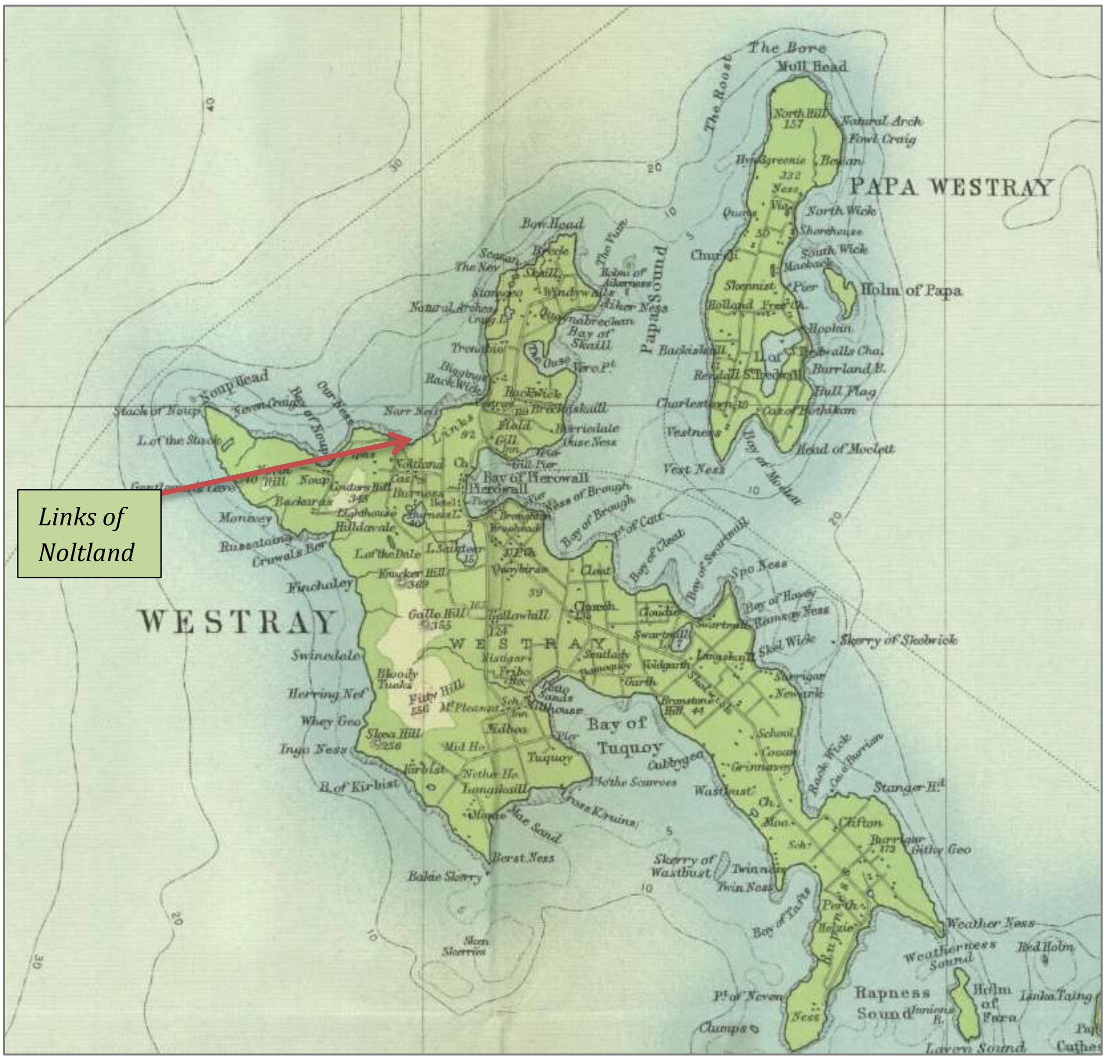


**Figure 3: Half-Inch Bartholomew map 1897-1907 reproduced with permission of the National Library of Scotland maps.nls.uk**

LON archaeological site, covering 2.5 hectares (ha), is located on a machair plain on the north side of Westray (Moore and Wilson, 2011a, b) at an elevation of approximately 10m. The machair vegetation is dominated by *Festuca rubra*, *Carex arenaria* and *Carex flacca* (Bullard, 1975). Machair soils are coarse-textured and porous, heating up more quickly in spring than heavier soils. They have a low organic content, usually less than 10%, and are also poor in phosphorous, nitrates, potassium, copper and manganese (Owen et al., 1996). Calcium from shells ensures that soils are base-rich and one reason for the good preservation of mammal bones from certain locations at LON. For details of present shoreline and marine contours demonstrating the 5m offshore limit see *Figure 4.*

**Figure 4: OS 1 inch 7th series 1955-61 reproduced with the permission of the National Library of Scotland maps.nls.uk**

A sequence for formation of machair in Uist (Ritchie, 1979, 1986) is accepted as relevant for Orkney (de la Vega Leinert et al., 2000). Extensive low altitude machair plains began in the 4th millennium BC in the Outer Hebrides and between 5235 to 3540 cal BC at Skaill, Bay, Mainland, Orkney (de la Vega Leinert et al., 2000, Ritchie, 1979, 1986). The first element of machair formation is when a vast, but relatively finite, deposit of sand swept landwards across on-shore rock platforms to form coastal accumulations. Increasing sea levels assisted this process. This stage was followed by downwind and lateral erosion of these high coastal accumulations, creating an increased deflation area (the flat machair plains) (Ritchie, 1979, 1986). These newly formed plains may have been seen as attractive to Neolithic farmers scouting for new grazing territories for livestock.

Machair is inherently fragile and continues to reconfigure itself, particularly if overlying vegetation is removed (Barber 2011, Gilbertson et al., 1999, Ritchie, 1979). The LON settlement suffered from sand encroachment when in use (Moore and Wilson, 2011a) as did the Late Neolithic settlement at Skara Brae on Mainland, Orkney (Clarke, 1976a, p14, p17).

Movement of sand in this machair plain allowed G. Petrie to identify archaeological remains at LON in the 19th century “in the island of Westray, I discovered the kitchen midden, bone pins and bone scoops” (Petrie, 1867, p214). This evidence was subsequently re-blanketed with sand. Archaeological remains were rediscovered at LON in the mid 1970’s and a portion of the site excavated by D. Clarke between 1979 and 1981 (Clarke and Sharples, 1985, Sharples, 2000).

Much of the LON prehistoric settlement was taken into state care as a Property in Care (PIC) in 1984 and a further portion designated as a Scheduled Ancient Monument (HS index 90337 HY 44 NW33). A loss of vegetation cover had exposed archaeological remains by this date and conservation measures were undertaken. Increased erosion in late 20th century may have been due to the loss of a substantial off-shore sand bar that protected the site and to rabbit activity (Moore and Wilson, 2011a). Conservation interventions did not stabilise the site and some archaeological remains were exposed for the first time since the pre-historic period. So, in 2007, Historic Scotland, after considering expert reports, moved from a policy of preservation to one of rescue archaeology in order to recover information rapidly from the site before it was lost through erosion and weathering (Moore and Wilson, 2011a, b). Structures at LON are considered to be of national and international significance (Moore and Wilson, 2011a) and contemporary with settlements in the Heart of Neolithic Orkney World Heritage Site in Mainland, Orkney (Historic Scotland, 1998). See *Photograph 4.*

**Photograph 4: Kite photograph of LON site © Topofly 2014. Machair grass is the remnant of earlier vegetation cover of site.**

### 1.9.2 Excavation

The current excavation at LON (2007 to 2015) was managed on behalf of Historic Scotland by EASE Archaeological Consultants (directors H. Moore and G. Wilson). The late spring/summer/early autumn programmes included geophysical, augur and topographical surveys, trial trenching and excavation. The author was present for two weeks at the excavations of 2010, 2011, 2013 and 2014, and assisted with excavation of the foundation trench, Structure 9 and the midden deposit below Structure 9.

The previous excavation at LON, 1979 to 1981, managed by D. Clarke, focussed on (i) a stone structure situated adjacent to Grobust Bay, known as the “Grobust” building (ii) anthropogenic soils labelled the “Western midden”. The full report for this excavation is not yet published, but interim reports are available (Clarke, 1976 a and b, Clarke and Sharples, 1985).

The aim of the current excavation at the Historic Scotland PIC and Scheduled Ancient Monument at the LON area is:

*To excavate and record prehistoric buildings and associated finds, soils, middens, field boundaries and landscape features before severe and continuing erosion exposes these archaeological remains to disintegration, contamination and dispersal.*

The area surveyed and excavated was determined by the previous delineation of sections of LON as PIC or Scheduled Ancient Monument sites by Historic Scotland.

The objectives of the excavation were to:

- Undertake a rapid and high-quality excavation to preserve the prehistoric record for future study and analysis
- Prioritise areas under most severe threat from erosion
- Investigate economic and environmental information from an extensive pre-historic landscape, not just from individual buildings
- Provide information on the Late Neolithic/Early Bronze Age transition
- Ensure appropriate post-excavation cleaning and preservation of finds, including animal bones

Areas excavated were determined by the aim/objectives for the project and sampling strategy not prioritised around distribution of mammal bone, although particular consideration was given to special deposits.

The excavation methods employed at LON were:

- Targeted and large-scale open excavation by hand (no mechanical intervention
- Baulks and running sections used to exercise control in open trenching
- Deposits removed stratigraphically
- Production of single and multi-context plans, section and profile drawings
- Creation of visual records using digital, slide and black and white photography
- Allocation of precise location co-ordinates for finds
- Sieving all excavated material through 10mm meshes to ensure consistency with recovery  and sub-samples through 2mm meshes
- Bulk sampling for microscopic and chemical analysis of substrates
- Radiocarbon dating
- Expert support for analysis of cultivated soils, struck lithics, animal bone, pottery, human bone and tools

Details of surveys and each season's excavations are published annually by EASE Archaeological Consultants. The LON site contains not only Late Neolithic and Bronze Age structures but associated features such as middens and cultivated soils and Bronze Age human burials.

# 2 Methods

## 2.1 Collection of material

Mammal bones for this thesis were collected predominately from middens covering Late Neolithic structures. Bones were uncovered by a team of excavators moving across a specified area and depth of midden (spit). Bones were collected by hand, and sieved residue that had passed through a 10mm mesh and, for a sub-sample of excavated material, from retention after water sieving. Hand retrieval is difficult to control (O'Connor, 2000, p31) so sieving brings a degree of uniformity. A mesh size of 10 mm, however, still permits smaller fish, amphibian and rodent bones to pass through the sieve and retention material unavailable when material for this thesis was examined. The excavation was mapped and photographed, including the distribution of partially exposed bone, before the underlying context, or sub-context, was excavated.

Articulated mammal bones were collected together, given a unique find number, photographed and allocated site co-ordinates. Maxilla or mandible portions were also placed in separate bags to facilitate identification. Bone tools were bagged separately and allocated a find number with some of these bones, particularly the metapodial bones, also examined for this thesis.

Skulls from the foundation course, Structure 9 were photographed and planned *"in situ"*. Osteometric measurements were collected in the field when practicable. The six best-preserved cattle skulls were coated in a biodegradable wax (cyclododecane CDD) and lifted by the "call-off" conservation contractor on behalf of Historic Scotland. See *Photograph 5*.

**Photograph 5: Cattle skull F6694 with wax coating © G. Wilson**

The remainder were lifted in September 2010 onto trays with surrounding substrate adhering, with no skulls being removed intact. Skulls from the blocking passage at Structure 18 were lifted in September 2012 and placed in separate boxes. As with the skulls from Structure 9, none was intact. Positions of the articulated red deer skeletons were recorded on site and then excavated with articulated limbs being allocated separate bags.

## 2.2 Cleaning

Retrieved bones were brushed and washed by the excavation team to remove excess soil, sand and debris, and dried at room temperature. The exception to this was the non-conserved cattle skulls which were washed and dried by the author. Washed bones were stored in ventilated plastic self-seal bags with a label written in indelible ink encased within a small plastic bag stating excavation, year, context, find number or general description. The bags were stored in clear plastic containers, with a list of contents, also encased in plastic, placed below the lid of the box. Bones underwent quarantine before accession into the NMS Collection Centre for examination and identification. This procedure kills microfauna and/or eggs/cysts attached to the bones.

## 2.3 Data storage

Edinburgh University Information Services and IT Manager (History, Classics and Archaeology) recommends databases, not spreadsheets, if data entries exceed two thousand (University of Edinburgh IS, 2009, K. Howie, pers. comm.). Data are easier to locate and possibility of errors reduced because analytical procedures are carried out on spreadsheets created from the database, not on the database itself. A complex relational Access database designed by the Environmental Archaeology Unit at York University was adopted (Harland et al., 2003). This database was made available through “Internet Archaeology”.

An attractive feature of the York System is a function that produces a diagram of each bone divided into numbered and labelled sections. The database uses logical text, not codes, and input data are viewed during recording to ensure correct information is entered. The database produces fields for the site, context, collection method, find number, species, element, siding (L/R), age, epiphyseal fusion, butchery marks, standard bone measurements (von den Driesch, 1976), length of fragment, pathologies, preservation, burning, modifications (cut marks, gnawing root etching), completeness, tooth wear, weight, notes and additional information. For the LON data additional species fields for seal and whale were added. Cattle skulls were given an entry into the general database but also allocated an additional spreadsheet. Preservation of bone was given four categories “excellent”, “good”, “fair” and “poor”. Historic Scotland will receive a copy of the data at the end of this study for archiving.

## 2.4 Initial sorting of bone

Contents from each bone bag were placed in a large tray and sorted into identifiable, possibly identifiable and non-identifiable bone. The unidentifiable bone was counted, weighed and entered into the database under the following categories:

- Large mammal (cattle, red deer, horse)
- Medium mammal 1 (sheep, pig or small cervid size)
- Medium mammal 2 (dog, cat or hare size)
- Small mammal (rat, mouse or vole size)
- Unidentified mammal

## 2.5 Bone element identification

Each identifiable bone fragment was allocated to a taxonomic group, either to an order, family or species, based on its own merits and not by association. If some elements from a context were clearly from the same bone or tooth, they were given one database entry with number of fragments noted. Associated epiphysis and diaphysis fragments were also given one entry. Where possible each tooth was allocated to maxilla or mandible and to the correct side.

The primary method for identifying a bone fragment to taxonomic group and element was by comparison with specimens stored at the NMS Collection Centre. Examination was by eye and through a 10x magnification hand lens. Although the NMS collection has an extensive range of mammalian species from Scotland it does not represent all dimorphic, age or habitat variations. Of particular note in the NMS Collection are skeletons from red deer (Rum), Soay sheep (St Kilda), Scottish sea mammals and specimens of prehistoric Scottish aurochs and red deer.

In addition, reference was made to the following texts:

- A Colour Atlas of Bovine Anatomy (Pavaux, 1992)
- Atlas for the identification of foetal skeletal elements of cattle, horse, sheep and pig (Prummel, 1987, 1988)
- Human Osteology (White and Folkens, 2000)
- Atlas of Animal Bones (Schmid, 1972)
- Teeth (Hillson, 2005)
- Textbook of Veterinary Anatomy (Dyce et al., 2002)
- The Anatomy of the Domestic Animals (Getty, 1975)

After examination, bone bags were restored to their boxes with the Access data base number sequences added to the contents list of the box.

## 2.6 Sheep/goat distinction (*Ovis aries/Capra hircus*)

No goat bones have been recorded at Neolithic Orkney or other Neolithic in Northern Scotland and "goat makes its first definite appearance in the north" (*of Scotland*) during the Iron Age (McCormick and Buckland, 2003, p100).

Although goats and sheep have similar skeletons the two species occupy different niches so presence/absence of goat is relevant. The strategy adopted in this study was to examine the most reliable bones for distinction between sheep and goat. Some researchers are not optimistic about the number of bone elements that can be used for discrimination (O'Connor, 2000, p42).

The key literature for post-cranial discrimination is Boessneck et al. (1964) and Boessneck (1969). Although based on a thorough anatomical review of several hundred skeletons the material was modern and may have different characteristics from early breeds of sheep and goat. These published osteomorphological criteria were tested by two research teams who examined (i) modern animals from North American museum collections from several age classes, wild, domesticated or feral, and from different regions of the world (Zeder and Lapham, 2010) (ii) Soay Sheep from St Kilda and Scottish feral goats (Clutton-Brock et al., 1990). Additionally, Prummel and Frisch examined thirteen sheep skeletons and four goat skeletons from collections in the Netherlands and Germany and produced a list of the distinction criteria that they found most useful in a study of medieval material (Prummel and Frisch, 1986).

Examination of the modern American Museum collections established that selected long-bone discriminants identified by J. Boessneck and his colleagues, with some additions from other researchers, were highly reliable, apart from those of the distal tibia. The bones examined were distal humerus, proximal and distal radius, distal tibia, distal metapodials, astragalus, calcaneus, and 1st and 2nd phalanx.

A minimum of sixty skeletons of Soay sheep from Hirta, St Kilda, or relocated from St Kilda, and seven feral goat skeletons from Holy Island, Arran were examined (Clutton-Brock et al., 1990).This examination concluded, "for the discrimination of sheep from goat bones.... there are very few characteristics, used on their own, on which a valid separation can be made" (Clutton-Brock et al., 1990 p40) with only seven traits falling into the category of reliably sheep-like. Unlike M. Zeder and H. Lapham's results, the 1st and 2nd phalanx, astragalus and distal radius were not found to be reliable discriminators in this material (Clutton-Brock et al., 1990).

Based on the results of the two surveys eight features listed by J. Clutton-Brock and her colleagues as sheep-like or predominately sheep-like were adopted for this study. This list includes metapodials as highlighted by O'Connor (2000), metapodials and humerus by Zeder and Lapham (2010) and skull parietal, scapula, distal humerus, metapodials and proximal femur listed as reliable discriminants by Prummel and Frisch (1986). They were as follows:

- Skull: presence of Y-shaped parietal/frontal coronoid suture
- Axis vertebrae: presence of a transverse canal
- Scapula: concave anterior margin
- Humerus: rounded distal epicondyle
- Femur: caput forms a continuum with saddle at proximal end and no synovial pits in the distal end
- Metatarsal: no synovial pit in the proximal end, or if present only one circular hole
- Metapodials: parallel *verticilli* on distal condyles
- Metacarpal: diameter of medial trochlear condyle greater than 62% measured against diameter of the medial *verticillus* for sheep, less than 62% for goats

Note was also made of horn core shapes, although few large sections survived (Clutton-Brock et al., 1990, Schmid, 1972) with sheep's horn core being D-shaped with the anterior edge more rounded than the tapered posterior edge, resulting in a largely triangular cross-section.

Teeth from modern collections have also been examined in order to discriminate between sheep and goat (Balasse and Ambrose, 2005, Halstead et al., 2002, Helmer, 2000, Payne, 1985). However recent examination of 121 mandibles from sheep and goats from museum collections in North America concluded that teeth were "highly unreliable as indicators of species and should not be used for this purpose" (Zeder and Pilaar, 2010, p237). They did concede, however, that the deciduous tooth, $dp_3$ performed better than other teeth and that use of the complete tooth rows was also quite reliable.

R. Gillis and her colleagues at CNRS examined a homogeneous Neolithic Sudanese collection of sheep and goat mandibles from skeletons from Kerma (3rd to 2nd millennia BC) (Gillis et al., 2011). They were able to demonstrate that most, but not all, isolated teeth could be identified to the correct species with less than 10% error, using all individual criteria for one tooth. They noted that in particular that the results for the deciduous tooth ($dp_3$) were one hundred percent reliable and very efficient and that the poorest level of discrimination associated with the fourth premolar and the 1st and 2nd molar ($P_4$, $M_1$ and $M_2$).

The $dp_3$ was therefore the only tooth examined during the present study, seen as a good discriminant not only by Gillis et al., (2011) but also Zeder and Pilaar (2010) and Clutton-Brock et al. (1990).

## 2.7 Tallies

### 2.7.1 NSP/NISP

Extensive discussions on quantifying animal bone remains have continued the importance of producing more than simple species lists for archaeological sites was recognised (e.g. Grayson, 1984, Gilbert and Singer; 1982, Klein and Cruz-Uribe, 1984, Lyman, 1994, 2008, McGovern, 1985, O'Connor, 2001, Reitz and Wing, 1999). The adoption of different measures by different researchers makes inter-site comparisons challenging. It is now acknowledged that there is no single measure that can cover every research question on every site (Amorosi et al.1996, pp135-137, Reitz and Wing, 1999, p143).

The material from LON was tallied as number of specimens, NSP, which includes bones, teeth and fragments thereof (Lyman, 2008, p27). Those identified to taxon and element were referred to as number of *identified* specimens, NISP, a sub-set of NSP. NISP and NSP are observed tallies, and as such, fundamental measurements. The interpretation of "*identified* "specimen for the current analysis is a bone fragment recognised to a skeletal element and attributed to a species.

Most researchers agree that, once defined, NISP is a valid method for recording archaeological samples (e.g. Chaplin, 1971, p64, Grayson, 1984, pp201-202, Lyman, 1994, 2008, O'Connor, 2000, pp54-56, 2001, Reitz and Wing, 1999, pp155-156). However, disagreement arises when NISP is used to describe relative abundance of animal bones and determine details such as age profiles.

Although complete skeletons from some mammals may have been deposited within areas of LON examined for this thesis, it is possible that in some instances only parts were deposited because of use of mammal bones for tools or display or exchange of meat joints or bones between settlements (Gilbert and Singer, 1982, p25). In addition, if birth of lambs, for example, took place out with the settlement, then skeletons from neonatal fatalities may be under-represented.

Each bone fragment should be independent of other fragments, which may not be the case in all excavated faunal collection (Chaplin, 1971, pp64-65, Gilbert and Singer, 1982, p31, Grayson, 1984, p201, p231, O'Connor, 2001, p704, Ringrose, 1993, p126) with potential interdependence of faunal remains claimed by L Lyman to be the most significant problem with this tally method (Lyman, 2008, p36, p69).

In addition, different animals have different numbers of bones and therefore also have different potentials to produce bone fragments (Amorosi et al., 1996, p137, Klein and Cruz, 1984, p25, Lyman, 2008, p29, O'Connor, 2001, p704, Ringrose, 1993, p125). Some animals have more identifiable bones and bone fragments than others (Grayson, 1984, p201, Lyman, 2008, p29, O'Connor, 2000, p57, Reitz and Wing, 1999, pp154-155, Ringrose, 1993, p125). At LON, however, sheep and cattle bones predominate and both species have similar skeletal structures, being from the family *Bovidae*, so this is not a significant issue for this particular site. A more valid argument with regard to LON mammal bone material is that meat joints from sheep and cattle may have been treated differently during butchery, food preparation and cooking, so, for example, a lamb femur may be placed in a pot complete, a cattle femur broken into several pieces (Chaplin, 1971, p65, Noe-Nygaard, 1977).

NISP may also vary with fecundity and fertility of the domestic mammals at LON (Jones and O'Connor, 2001, p420, Vermeij and Herbert, 2004). LON sheep and cattle may have produced offspring annually; however, in the present day twinning in sheep is more common that twinning in cows. If there was differential fecundity between cattle and sheep this could influence the NISP for each species, but will not impact on any changes in the relative proportions either temporally or spatially. Realistically this type of bias would predominately cause problems with multiparous pigs, mammals with relatively high rates of reproduction compared with ruminants.

The problems outlined above have led some researchers to reject NISP as a method of describing the relative abundance of animals in a *death* assemblage, stating that it is only a measure of the relative abundance in the animal *sample* assemblage (Chaplin, 1971, p67, Ringrose, 1993, p134). Others argue that NISP does have a role and can rank samples but not the magnitude of differences (Gilbert and Singer, 1982, p32, Lyman, 2008, pp81-82, McGovern, 1985, O’Connor, 2001, p705) but when working with midden deposits containing heavily processed bones it is probably the best form of quantification (Amorosi et al., 1996, pp135-136) a recommendation followed for the LON material.

In order to maintain some consistency during analysis a clear strategy for NISP counts was required regarding loose teeth and teeth still embedded within mandibular or maxillary fragments, because this can create differences. In this LON study, NISP included loose teeth and fragments from the same bone were cross-matched and allocated to one NISP.

Some LON ribs, particularly those with intact proximal portions, could be assigned to species, but many rib diaphysis fragments only allocated to large, medium or small mammal (contra Armour-Chelu, 1992, p106). For this reason, ribs, and diaphysis fragments with no morphological markers, are excluded from NISP counts and allocated to the general category of large, medium or small mammals. However, proportions of large mammal and medium mammal bones, including shafts and ribs, were calculated to determine if the proportions of cattle: sheep and large mammal: medium mammal (including ribs and shafts) were similar. Red deer antler, which may have been shed, is also excluded from the tally. These restrictions highlight that although the definition for NISP appears straightforward, decisions on whether to allocate a bone to skeletal element and species are subjective and may vary between analysts.

Although NISP used for midden material could rank samples and identify relative increases and decreases in taxa, powerful statistical analysis using NISP was not appropriate, given the issues of concern outlined in earlier paragraphs of this section, particularly the basic requirement that each count should be independent of each other (Grayson, 1984, p202, Lyman, 2008, p9).

### 2.7.2 Weight of bone

This measurement produces weight of skeletal material per taxon and is an ordinal scale measurement. LON bones were washed to remove adhering material, so additional substrates were predominately not included in weights, although some substrates may still have been present within inaccessible cavities (O'Connor, 2001, p704).

Individual taphonomic process bones undergo may affect weight. So, for example a dog skeleton recovered from the Neolithic site of Præstelyngen, Neolithic Denmark had one tibia recovered from organic mud which weighed 18.5g and one from peat which weighed only 11.3g (Noe-Nygaard, 1977 p232). Handling bone fragments during examination may result in losses of small pieces.

Weighing scales were purchased for this study and calibrated once installed at NMS Collection Centre. The results were recorded to the nearest 0.1g.The precision of this measurement was tested using 15 different bone types from the collection in August 2010. The results of 10 and 25 weights per bone had no outliers so a mean and standard deviation were used to examine accuracy (Drennan 2009, p23). The range varied from 0 to 0.1g and the standard deviation varied from 0-0.05g when both 10 and 25 consecutive weights were used.

Animal skeleton weight is related to the size of the animal, with larger animals requiring proportionally larger bones (Alexander, 1994, p181, Currey, 1984, p243, Prange et al., 1979, p103).This can result in larger animals being over-represented if quantified by weighing (O'Connor, 2000, p57). On the positive side, bone weight is not influenced by levels of fragmentation, although fragmentation could indirectly influence the number of bones identifiable to element and species (Lyman, 2008, p43, p95).

Weight of bone recovered from each species was used to rank (i) relative abundances (ii) changes over time (iii) average fragment weights. Additionally, in some analyses the weight of individual elements from each recovered species was used to review the body part distribution (Reichstien, 1994) to investigate whether complete, or only partial skeletons, have been deposited.

Weights of bone were not manipulated to produce estimates of mammal body weights because too many factors influence the relationship between carcass and bone weight to make this a useful analytical tool (Barrett, 1993, Chaplin, 1971, pp67-69, Davis, 1987, p36, Klein and Cruz-Uribe, 1984, pp34-35, Lyman, 2008, pp93-102, Uerpmann, 1973).

### 2.7.3 Other tallies

Minimum number of individuals (MNI) is a derived analytical tool, first introduced by T. White and developed by others (Chaplin, 1971, pp69-75, Grayson, 1984, p203-207, White, 1953, p397). It is defined as "the minimum number of (complete) individual animals necessary to account for (to have contributed) the specimens observed" (Lyman, 1994, p100), a method that avoids the possibility of identifying the same animal twice (Ringrose, 1983, p127).

MNI lends itself to the examination of data from catastrophic kills (Lyman, 1989, Ringrose, 1993, p134) but is unsuitable for midden collections such as LON where element numbers are low and the measurement vulnerable to skewing (Grayson, 1984, p222, Klein and Cruz-Uribe, 1984, Lyman, 2008, p47). Some of the problems with MNI are that:

- Exaggerates importance of rarely represented species
- Represents "minimums" so estimating ratios of taxonomic abundance is impossible
- Is a function of sample size (or NISP)
- Choice of aggregates within a collection (e.g. by context, by trench, by stratigraphic unit, or by structure) influences the value

(Lyman, 2008, pp45-46)

MNI results are minimum estimates, so, for example, "more than twenty" cannot be added to "more than ten" in any sensible way (Grayson, 1984, p221, O'Connor, 2000, p60, 2001, p706).

Since NISP is a fundamental measurement, whereas MNI a derived measurement related to NISP (relationship summarised by Lyman, 2008, pp48-57) with the added overlay of subjective decisions of which bones to count (e.g. whether to define left and right bones or to distinguish between older and younger animal bones), MNI was only used for selected analysis in this thesis. MNI was not used for meat weight calculations, which as well as the derived values required to calculate MNI, involves additional assumptions on meat produced per average animal (despite the fact the collection contains animals of different ages and sex), the health and condition of the animals and the pattern of meat consumption by the society depositing the animal bones (Amorosi et al, 1996, Gilbert and Singer, 1982).

Finally, the Modified General Utility Index (MGUI) is based around the economic decisions of modern hunters (Nunamiut, Alaska) on which parts of culled animals were transported from kill sites to settlements and on cultural decisions regarding butchering and distributing meat (Binford, 1978). The MGUI index was not adopted for this study because of uncertainty surrounding its appropriateness for sedentary populations with little involvement in hunting (Grayson, 1989, p651) or that such a model stands for a description of reality against which other data sets could be tested (Barrett, 2011, p71).

## 2.8 Mammal bone survival

### 2.8.1 General

In order to consider factors that may have impacted on mammal bone survival at LON the natural or cultural bone transformations (Schiffer, 1976, 1983) examination included:

- Butchering/Modifications
- Pathological features
- Root etching
- Gnawing

Awareness of processes that convert living animals to recovered bone fragments is essential in order to perform secondary analysis (Chaplin, 1971, Davis, 1987, Lyman, 1994, Maltby, 1985, Marshall, 1989, Reitz and Wing, 1999). This process is called taphonomy; a term is first introduced by Efremov in 1940 and, literally translated, means “science of the laws of burial” (Lyman 1994, pp30-31, 2008, p7, White and Folkens, 2000, p407).

It was not until 40 years after Efremov’s publication that the term taphonomy was widely adopted by zooarchaeologists promoting theories of “new” or “processual” archaeology (for example, Behrensmeyer and Hill, 1980, Binford, 1978, 1981, Bonnichsen and Sorg, 1989, Schiffer, 1976, 1983). In the early years of processual archaeology, it is assumed that once patterns had been securely identified for a particular study, similar patterns could be safely inferred (Young, 1989, p59).

Binford’s study of the Nunamiut people of Alaska was a landmark ethnographic study (Binford, 1978) illustrating how hunting, butchering and distributing meat created certain cultural patterns in bone deposition. Other ethnographic works in Africa included the study of the !Kung, a northern Botswana San bushmen tribe (Yellen, 1977) and the Dassanetch tribe in Kenya (Gifford-Gonzalez, 1989b).These studies did not look at individual behaviours, but “averaged” behaviours of the community (Bonnichsen, 1989, p518). Detailed ethnographical study of particular groups was labelled low-range theory, its general application to other archaeological situations, middle-range theory (Binford, 1981, Bonnichsen, 1989, pp517-518).

While “post-processual” researchers recognised the value of ethnographic studies in highlighting flaws in earlier interpretations of animal bones (e.g. Maltby, 1985, p34) they were less convinced that “middle range” theories, based on particular and possibly unrepresentative samples, were of value for other archaeological situations (Grayson, 1982, p440, Hodder, 1982, Ringrose, 1993, p151). Although ethnographic studies were a key element in processual archaeology, few have actually been carried out and, those that exist, concentrated on hunter-gatherer or pastoralist societies (Maltby, 1985, pp40-41). Very little observation has been undertaken for sedentary agriculturists (Hill, 1995, Bonnichsen, 1989, p522) the type of community at LON.

### 2.8.2 Modifications

Spiral beaks or stepped spiral breaks and presence of percussion marks on long bones were noted for LON material, as a possible indication of processing for marrow or to create blanks for tools, but were not subjected to the intensive study outlined by some researchers (e.g. Binford, 1978, Outram 2001, 2002, 2004). Tensile strength of long bones has only approximately one-tenth the strength of bone along the long axis which is why a hammer blow in the centre of a long bone will create spiral breaks. Helical/spiral fractures only occur in bones still retaining moisture, marrow and organic components and are influenced by the thickness and diameter of cortical bone (Currey, 1970, p34, Johnson, 1989, p465, Lyman, 1994, p316, Outram, 2001, p403, 2002, p53).

Marrow and fat can make an important contribution to diet and have a higher calorific value than either protein or carbohydrate (Outram, 2001, p401, 2002, p51). Long bones (especially those of the stylopodium: humeri and femora) have high marrow content and are relatively easy to fracture so are often exploited as food. Marrow, or bone grease, can also be obtained by smashing articular ends of bones and boiling them in water and skimming off the fat after cooling (Outram, 2001, p51).

The method of marrow extraction can influence the number of fragments produced per bone. For example, at the Mesolithic site at Star Carr, England, marrow recovery methods would have resulted in a minimum of 124 bone fragments per skeleton, whereas at the contemporary site at Praestelyner, Denmark, a minimum of 229 bone fragments were created (Noe-Nygaard, 1977).

Detailed analysis of techniques used for skinning, dismembering and cooking preparation of LON mammals was also not undertaken for this study. These processes may, or may not, leave marks on the bone, depending on the skill of the butchers (Fisher, 1995, Lyman, 1987, p264, 1994, p302, Reitz and Wing, 1999, p128). Cut marks created by cutting overlying tissue, scrape marks associated with removal of meat from bone and chop marks resulting from sub-dividing the carcass were however noted for the LON mammal bones studied in order to identify bones that may not have been butchered (Gifford Gonzalez, 1989, p200, Lyman, 1994, pp294-299, O'Connor, 2000, pp45-46).

### 2.8.3 Burning

Burning creates continuous modification and colour change on bone. Initially the bone releases water molecules and carbonises collagen, the organic component of the bone, and then, with increased heat, oxidises this carbonised material resulting in bone becoming calcined. Carbonisation peaks at around 330$^{o}$C, with most organic matter being lost 360 to 525$^{o}$C and by 600$^{o}$C virtually all organic matter is absent. At temperatures over 800$^{o}$C there may be fusion or melting of the inorganic hydroxyapatite component (Lyman, 1994, p385, Shipman et al., 1984, p314, table 5) and any subsequent preservation of burnt bone is linked to this heat-altered mineral content (Gilchrist and Mytum, 1986, Pearce and Luff, 1994) which, if buried, absorbs water with the ensuing crystal shapes resistant to dissolution in acidic soils (Mays, 1998).

Bones undergoing burning shrink (e.g. Buikstra and Swegle, 1989, p256, Shipman et al., 1984, pp321-322) but there is no reliable shrinkage factor (Correia, 1997, p277, McKinley and Bond, 2001, p287, Worley, 2005, p64). Bones also fragment leading to many bones becoming "analytically destroyed" (Lymen, 1994, p391). So, for example, after combustion a cattle humerus produced on average almost 182 pieces, mostly shaft fragments (Costamagno et al., 2005, p56). Unerupted teeth and roots protected by bone tissue may survive burning, while exposed crowns fall apart (Correia, 1997, p278).

Examination and description of burning for LON bone fragments was based on the macroscopic study of bone colour, using six categories of burning (slight burn, light (partial) burn, charred, local calcined, dominant calcined and fully calcined) (Stiner and Kuln, 1995, p226, table 3). In reality burning is a continuous modification of bone tissue but using categories assists with the construction of a burning profile (Lyman, 2008, p275). Since many LON bones suffered surface abrasion, it is possible that some charring may have become obscured.

### 2.8.4 Root etching/Gnawing

Presence or absence of root etching was noted on bones studied. Carnivore gnawing was recorded if clear puncture marks were present on bones, rodent gnawing if a series of small tooth grooves noted.

## 2.9 Age

### 2.9.1 General

In this study the eruption and wear of teeth was the main tool used to assess “age of death” with examination of epiphyseal fusion assessed to collaborate results. The analyses did not include high resolution destructive testing of teeth to determine age (e.g. Mitchell 1967, Pike-Tay, 1991).

### 2.9.2 Teeth eruption

Teeth eruption can be utilised to determine age in younger animals. Most archaeological recording systems are based on primary observations of live animals, for example Simonds, (1854), Brown, (1949), Silver (1969) and various mid-20$^{th}$ century German researchers (quoted in Grigson 1982, p13, table 1). The history of these observations, used to allocate ages to animals for market purposes, is summarised by Jones and Sadler (2012). Inconsistencies in published data and small sample sizes have led to some researchers suggesting these tables be treated with caution (e.g. Andrews, 1982, p141, Bull and Payne, 1982, p65, Legge and Rowley-Conwy, 1991, p4, Payne, 1984, p81).

The reference point for eruption in living material when teeth emerge through gums, is not applicable to archaeological material. Eruption of archaeological material is defined as the eruption through the alveolar bone or eruption far enough above the alveolar bone to have reached the occlusal plane of adjacent teeth (O’Connor, 2000, p83, 2006, p2, Hillson, 2005, p212). T. O’Connor suggests that the best method is simply to describe a tooth “in a state of eruption” (O’Connor, 2000, p84) whereas others have produced more detailed categories (e.g. Andrews, 1982, Brown and Chapman, 1991 a+b, Deniz and Payne, 1982, Ewbank et al., 1964, Grant, 1982, Jones, 2006, Jones and Sadler, 2012b).

Teeth eruption is predominately determined by genetic factors, although environmental factors such as poor nutrition may also exert a subtle influence (Legge, 1981, p172). Additionally, castration in sheep may lead to earlier “full mouth” eruption (Clutton-Brock et al., 1990, p6, Hatting, 1983, p119). In this study the definition for eruption of teeth still embedded in maxillary or mandibular bone is based on the protocol first published in 1964

(Ewbank et al., 1964) and adapted by A. Grant in her scheme for mandibular tooth wear for pigs, sheep and cattle (Grant, 1975, 1982), but stages C (perforation in crypt visible) and V (tooth visible in crypt but below head of bone) were merged, as were E (tooth erupting through bone) and ½ (tooth half erupted). This was because most mandibles were incomplete and damaged and it appeared more prudent to follow a simplified pattern, closer to the method advocated by T. O'Connor:

- In crypt (unerupted)
- Erupting with roots starting to form
- Tooth almost full height but unworn, roots not fully formed

Additionally estimates of age are given using illustrations in J. Simonds (1854) It is noted that A. Legge considered that these estimates for tooth development, based on his examination of live animals bore little relation to calendar age, particularly for pig, although preferable to the widely quoted tables from I. Silver (Legge and Moore, 2011, p187, Silver, 1969).

Aging from horn core textures was established for British post-medieval cattle (Armitage, 1982) and used for LON horn cores. However, even when tooth wear indices indicated a mature animal, Armitage's category 6 (smooth compact horn core bone) was never observed.

### 2.9.3 Tooth wear

Mandibular tooth eruption and wear (MWS) patterns were recorded using the Grant system for sheep, cattle and pig (Grant, 1982).

Tooth wear in ruminants occurs when upper and lower jaws grind against each other and rub against cheeks and tongue. Individual variation, mineral composition of individual teeth, characteristics of vegetation ingested and whether or not it contains grit, are important in determining rate of wear (Hillson, 2005, p214, p231, Jones and Sadler, 2012b, Moran and O'Connor, 1994, pp269-270, Stallibrass, 1982, p109). For example, variations in teeth wear for Angora goat herds in Turkey were credited to the different grazing regimes (Deniz and Payne, 1982). A study of modern Shetland sheep indicated faster wear in the permanent teeth of males than those of castrates (Davis, 2000, p378). Other variations include the fact that cattle and sheep only chew on one side of their mouth at any one time and may prefer one side to the other causing differential wearing (Grant, 1975). Tooth wear also occurs in omnivores such as pig but, since by definition, a variety of food is processed through their jaws, wear patterns can be affected by food type as well as level of ingestion of grit.

Notwithstanding these variations, which render tooth wear difficult to interpret accurately (Brothwell and Brothwell, 1998, p34), recording systems, in particular for demi-mandibles, have been widely adopted to link the pattern of dentine exposure on teeth occlusal surfaces to the animal's age.

A series of symbols representing the patterns of dental exposure on mandibular teeth of sheep and goats was produced by S. Payne with observed wear marked directly onto a symbol. The stages are linked directly to age classes derived from modern Middle-Eastern herds. A later addition to this system is a code to allow symbols to be transferred to computer programmes (Payne, 1973, 1987).

Diagrams for wear stages of mandibular deciduous $dp_4$, the 4th premolar, and $1^{st}$, $2^{nd}$ and $3^{rd}$ molars ($dp_4$, $P_4$, $M_1$, $M_2$ and $M_3$) were produced by A. Grant for cattle, pigs, sheep and goats. Unlike Payne's system, the archaeological material is matched to the nearest predetermined category. Each molar tooth is allocated a numeric equivalent for its eruption or wear stage (TWS) and these added together with values allocated to an overall mandible wear stage (MWS) (Grant, 1982) not the absolute age for the animal being studied (Hillson, 2005, p216, O'Connor, 2000, p88). Wear stages are not of equal length, with wear stage "g" being long-lasting (Grant, 1982, p91). Different combinations of individual tooth wear stages can give the same MWS value, perhaps masking subtle differences in age (Moran and O'Connor, 1994, p271). Grant's system is designed for complete demi-mandibles but has been adapted for mandibles with incomplete toothrows (Grant, 1982, p93, p100, fig 2, table 3). The method has been used for single teeth, a common situation encountered in archaeological sites (Haber, 2007, Rolett and Chiu, 1994). Researchers continue to add refinements to Payne and Grant's methods (for example, Jones, 2006, 2012a, Zeder, 2006).

Both tooth-wear systems have their deficiencies, even with recent modifications. No consensus on the best method has emerged, with some researchers favouring the adapted Payne system (e.g. Zeder and Pilaar, 2010, p235), others finding the Grant method more sensitive (e.g. Greenfield and Arnold, 2008, p848). In this study Grant's system was adopted for mandibles because it is intuitive, straightforward to use and can be applied to cattle and sheep, the dominant mammals in the collection. Conversion tables for Grant's system to Payne's system for sheep have been produced (Greenfield and Arnold, 2008, Vigne and Helmer, 2007, p17, table 1) allocation of MWS to age for cattle, sheep and pig (Greenfield and Arnold, 2008, Hambleton, 1999, pp64-65, tables 2-7) allowing comparisons with different sites. It is noted, however, that a study of twenty-three modern feral Soay sheep lodged at the Natural History Museum, London of known age illustrated some discrepancies between converted Grant MWS and known age (Armour-Chelu, 1992, pp135-136, tables 18 and 19, Hambleton, 1999, p65, table 3, 6) for example eight 3 year olds (MWS 30-32) had younger estimated ages ranging from 18-30 months to 30-36 months.

### 2.9.4 Epiphyseal fusion

The state of fusion on all axial, hindquarter, forequarter and foot bones were noted for the eight LON areas under study. No radiographs were produced. If the epiphysis was attached but the fusion line clearly visible bones were classed as “fusing”, otherwise labels “fused” and unfused” were allocated.

The sequence of epiphyseal fusion in ungulates was published in the early 20th century (Todd and Todd, 1938) and these sequences have not been challenged (O’Connor, 2000, p93). So, for example, recent work on a large sample of modern wild caprines from Iran and Iraq confirms that a clear and unchanging sequence for bone fusion exists (Zeder, 2006, p100).

The age at which fusion occurs has, however, been subject to further research and debate. Fusion ages quoted in Silver (1969) using published 18th and 19th century sources are often used in animal bone reports and used as a general guide for LON data. However, data from different sexes from different geographic regions, or different breeds may not be appropriate comparators (Chaplin, 1971, p81, Hatting, 1983, p120, Moran and O’Connor, 1994, p274, Noodle, 1984, p21, Watson, 1978, p97, Zeder, 2006b, p174). It is also possible that fusion may be delayed in castrated sheep (Hatting, 1983, p120, Moran and O’Connor, 1994, p274, Noddle, 1984, p22, Popkin et al., 2010) although a castrate aged 41 months from a modern population of Soay sheep did not display delayed fusion (Clutton-Brock et al., 1990, p9).

In addition to possible variation of quoted ages for epiphyseal fusion, unfused and poorly ossified bone specimens may be less likely to survive in archaeological deposits (Davis, 1987, p39, Grant, 1975, Klein and Cruz-Uribe, 1984, p43, Lyman, 1994, p288, Watson, 1978, p97) so age profiles from epiphyseal fusion methods have more potential than examination of teeth eruption/wear to produce profiles biased towards adults. Finally, fusion ages quoted for modern animals may be derived using radiographs or dissection of dead animals with each method producing slightly different results (Clutton-Brock et al., 1990, p5, Davis, 1987, p39, O’Connor, 2000, pp93-94).

## 2.10 Measurement

Bones complete enough to be identified to species and/or element were measured for greatest fragment length. In addition, all bones with complete features were measured using guidance from von den Driesch (1976) a widely adopted protocol vital for comparison with other published results. Additional measurements were taken for pelvis (Greenfield 2006), carpals, teeth and diaphysis length of selected unfused bones for the purposes of documentation although these are not reported in this thesis.

Bones were measured using the same set of dial callipers. The measurements were recorded to the nearest 0.1mm and calliper's calibration checked regularly. Values to the nearest millimetre were quoted for the Neolithic Orkney settlements at Knap of Howar, Papa Westray (Noddle, 1983) and Skara Brae, Mainland (Watson, 1931). Measurements to the nearest 0.1mm were collected at Pool, Sanday (Bond, 2007a), Tofts Ness, Sanday (Nicholson and Davies, 2007) and the earlier LON excavation (Armour-Chelu, 1992). Some modern specimen measurements report to the nearest 0.01mm using digital callipers (e.g. Clutton-Brock et al., 1990, Davis, 1996). Although such precision may be overshadowed by inter-observer variability, this was assessed during their analysis. The Iron Age site of Howe, Mainland reported measurements to the nearest millimetre.

## 2.11 Size index scale

Individual bone measurements with thirty or more results can be considered normally distributed and suitable for straightforward statistical analysis (Drennan, 2009, p128). At LON these are predominately foot bones. For the remainder of individual measurements, it was possible to combine results together for analysis using the “size index scaling method” (for overview, Meadow, 1999). This scale is calculated by converting each bone measurement into a ratio between observed value and the corresponding measurements taken on the skeleton of a “standard animal” which does not necessarily represent a normal animal, simply a reference against which trends are observed. Since this calculation tends to produce a wide variance, the results are converted into a log ratio to assist with the representation of the data (Albarella, 2002, pp52-55, O'Connor, 2000, p116, Meadow, 1999, Reitz and Wing, 1999, p175).

Problems with the size index scaling method include:

- Some bones, particularly early fusing bones, may increase in depth or width after epiphyseal fusion (Albarella and Payne., 2005, Popkin et al., 2012, Davis, 1996, 2000)
- Bone dimensions influenced by sex ratio, the presence or absence of castrates and plane of nutrition (Albarella, 2002, Clutton-Brock et al., 1990, Moran and O'Connor, 1994, Noddle, 1984, Popkin, 2012 et al., Davis 1996, 2000)
- Loss of resolution on causes of size variation (Albarella, 2002, p54)

For this study the same bone dimensions were selected for all size index-scaling calculations. The calculations were separated into two graphs (i) depth/width (ii) length (different axes of growth) (Albarella, 2002, p54, Popkin et al., 2012). Teeth measurements were not included in the size-scale calculations, since teeth size may respond differently from post-cranial bones to external factors (Albarella, 2002, p54, Viner-Daniels, 2014, p81) but analysed separately. Phalanx measurements were also treated separately because they would otherwise have dominated size index scaling calculations. Only one measurement per bone was included in each calculation, since two measurements from one bone, for example an astragalus “GLl” and “GLm” or femur “DC” and “Bp”, may be highly co-related. Early fusing bone measurements such as scapula “GLP”, humerus “BT”, radius “Bp”, os centrotarsale “GB”, astragalus “Bd”, phalanx “Bp” and metatarsal and metacarpal “Bd” (Popkin et al., 2012) were not excluded because they comprised a large proportion of available measurements.

## 2.12 Pathology

The study of animal diseases is complex (Bartosiewicz and Gál, 2013, O’Connor, 2000, pp98-99) and this study only considers descriptive, macro-morphological changes. NMS Collection Centre does not include a reference collection of pathological specimens. However, zoo animal skeletons comprise part of the collection, including wild boar from the Royal Zoological Society of Edinburgh’s Highland Wildlife Park site, so pathological features could be observed on skeletons from animals which, if roaming free, would have succumbed at an earlier age through natural death or predation. None of the pathological features from LON were as advanced as those observed on zoo specimens.

Examining bone pathology at LON will not reconstruct the complete picture of animal diseases at the site, since many signs of disease are predominately associated with soft tissues (Armour-Chelu, 1992, p225, Baker and Brothwell, 1980, p12, O’Connor, 2000, p98, Siegel, 1976, p355). Also, since a proportion of cattle and sheep from the LON study areas were older adults it is noted that age itself may be a significant background factor to pathological conditions (Bartosiewicz and Gál, 2013, pp42-43, Siegel, 1976, p357).

## 2.13 Additional analysis commissioned to support thesis

### 2.13.1 General

While this dissertation is based on observational and morphometric analysis of LON Neolithic mammal bones, these results were complemented by laboratory work carried out by specialists in various fields. All these methods depend on levels of collagen, the organic component of bone, being preserved in the excavated bone. Collagen, when no longer associated with living bones, hydrolyses to peptides and then breaks down into amino acids, a process known as racemisation. The initial breakdown relates to water present in bone tissue, but later breakdown depends on temperature and availability of water and microbes in the deposition medium. Microbe attack is predominately by fungi and bacteria that utilise collagen as a food source (Child, 1995, Hare, 1980, Henderson, 1987).

### 2.13.2 Radiocarbon Dating

Radiocarbon dates for this thesis were funded by Historic Scotland and produced by the Scottish Universities Environmental Research Centre (SUERC). The $^{14}$C age is quoted in conventional years BP (before 1950 AD). The error, which is expressed at the one sigma level of confidence, includes components from the counting statistics on the sample, modern reference standards and blank and random machine error. The laboratory undertakes this analysis by converting milligram quantities of sample carbon to graphite followed by measurement at the SUERC AMS laboratory using the 5MV and 250Kv National Electrostatic Corporation AMS System. Method details are described in gla.ac.uk/az/suerc/radiocarbondating.

Radiocarbon dating is founded on the principle that natural production of $^{14}$C is a secondary effect of cosmic-ray interactions with atmospheric gas molecules, which results in the production of neutrons. Metabolic processes of living organisms maintain $^{14}$C in equilibrium with atmospheric $^{14}$C until after the metabolic process ceases, when measurable radioactive decay commences (Taylor, 2001). It therefore follows that any sample submitted for radiocarbon dating should be in equilibrium with the atmosphere at time of death; should not be contaminated with other carbon-containing material; and be securely associated with the archaeological activity of interest (Bayliss et al., 2011, p38). For this reason, there is now considerable emphasis on the selection of short-lived, single entity samples (Ashmore, 1999), whereas, for earlier radiocarbon determinations, mixed animal bone samples were often used (e.g. the Neolithic horizon at Northton, Lewis, Western Isles (Gregory, 2006) and Neolithic Orkney cairn samples (Switsur and Harkness in Renfrew, 1979, p72).

In terms of animal bones, the order of preferred samples (Bayliss et al., 2011):

- Bone from articulated sequence visible and recorded during excavation (LON red deer skeletons)
- Bone identified as articulating during faunal analysis
- Unfused bone and an epiphysis retrofitted during faunal analysis

- Bone from group that appear to have been deposited at the same time (LON cattle skulls)
- Well preserved individual disarticulated bones

Radiocarbon dates are estimates of the true radiocarbon content of a sample. Ages therefore scatter around the true value in accordance with the normally distributed quoted error. This effect is often exacerbated by the process of radiocarbon calibration, when calibrated dates can also be spread on to plateaux in the calibration curve adjacent to the true dates of the sample. Bayesian modelling assesses how much variation in the calibrated radiocarbon dates arises from variation in the actual dates of the sample, and how much from the probabilistic scatter inherent in radiocarbon dating and the calibration process. However, since Bayesian calculations are not yet available for the LON radiocarbon dates, it is acknowledged that by informally assessing chronology from calibrated radiocarbon dates, the LON activity will nearly always be interpreted as starting earlier, ending later and thus enduring longer than was actually the case (Bayliss et al., 2011, p18, p19, fig 2.2).

### 2.13.3 Stable isotopes

LON $\delta^{13}C$ and $\delta^{15}N$ stable isotope results on animal diets were obtained from sixteen-bone collagen and eight tooth collagen samples generated from radiocarbon dating (rather than targeted palaeodietary analysis) by SUERC. The isotope determination was made from collagen and results suitable for isotope analysis, although duplicate results are not available. This analysis is discussed in *Chapter 10*.

### 2.13.4 Collagen identification

Collagen preservation in excavated bone allows distinction between closely related genera using a method called “zooarchaeology by mass spectrometry” ZooMS, collagen peptide mass fingerprinting (Buckley et al., 2009, 2010).

Recent research has shown that type 1 collagen can persist in mineralised animal bone tissue for a long period of time and can be sampled directly from the bone, avoiding the risk of contamination during any amplification process. Although previously considered to be a highly conserved protein with slow evolutionary rates, there is now evidence that the COL1α2 chain evolved at a faster rate.

Collagen analysis was carried out on selected LON bones by M. Buckley, Faculty of Life Sciences at Manchester University Interdisciplinary Biocentre. Methods and results have been published (Buckley et al., 2014). The first group of LON bones subject to collagen analysis were whale bones. Often whale bones were only carried to a settlement for use as structural supports, for tool making or for fuel (Mulville 2002, Savelle, 1997) and this appeared to be the case at LON. Some residual whale bone fragments from LON with no distinguishing morphological features were identified using collagen analysis. The second group were a selection of bones identified as sheep using morphological methods in order to confirm initial identification. The third group were deer bones, originating from small individuals with some morphological features similar to reindeer. The aim of these latter tests was to confirm that the bones originated from red deer.

### 2.13.5 mtDNA

Mitochondrial D-loop investigation on sixteen cattle teeth and bones from LON was funded by Historic Scotland and undertaken at the Integrative Prehistory and Archaeological Science Center, Basel University (IPAS). Details of the method is detailed in *Appendix 3* and results discussed in *Chapter 10.*

# 3 Background Information

## 3.1 Mammal records for Orkney

### 3.1.1 LON Neolithic site

Cattle and sheep dominated the mammalian bone assemblages from LON. The mammals present were:

- Cattle (*Bos taurus*)
- Sheep (*Ovis aries*)
- Pig (*Sus scrofa)*
- Dog (*Canis familiaris*)
- Red deer (*Cervus elaphus*)
- Orkney vole (*Microtus arvalis orcadensis*)
- Otter (*Lutra lutra)*
- Fox (*Vulpes vulpes*) (one metatarsal)
- Whales (Cretacea, various species)
- Grey seal (*Halichoerus grypus*)
- Aurochs (*Bos primigenius*)?

### 3.1.2 Other Neolithic sites

Neolithic Orkney sites (settlements, cairns or monuments) published in 20th and 21st century. Mammals present at all, or most, sites:

- Cattle (*Bos taurus*)
- Sheep (*Ovis aries*)
- Pig (*Sus scrofa)*
- Dog (*Canis familiaris*)
- Otter (*Lutra lutra)*
- Red deer (*Cervus elaphus*)
- Orkney vole (*Microtus arvalis orcadensis*)
- Whale (Cretacea, various species)

Mammals with more limited distribution:

- Fox (*Vulpes vulpes*) (Vesta Fiold, Mainland)
- Wood mouse (*Apodemus sylvaticus*) (Neolithic/Early Bronze Age, two bones, Tofts Ness Sanday, three bones, Isbister, Quanterness, Mainland)
- Walrus *(Odobenus rosmarus*) (Skara Brae, Mainland, worked)
- Seal, no species identification provided (Tofts Ness)
- Grey seal (*Halichoerus grypus*) (one bone, previously labelled sheep, Rowiegar, Rousay)
- Roe deer (*Capreolus capreolus*)? (Knap of Howar, Papa Westray)
- Pine marten (*Martes martes)* (Pierowall, Westray, (cf) Vesta Fiold, Mainland)
- Possible wolf (*Canis lupus*) (Stones of Stenness)

### 3.1.3 Aurochs?

The most significant difference in the mammal species list from LON and other Neolithic sites in Orkney was the possible presence of aurochs (wild cattle) at LON. This is discussed in further detail in *Chapter 11*.

Although no aurochs were identified in 20th and 21st century animal bone reports from Neolithic Orkney, their possible presence was reviewed (e.g. Armour-Chelu, 1992, pp166-172, Clutton-Brock, 1979, p120, Platt, 1937c, p818, Chaplin in Switsur and Harkness, 1979, p72). A photograph of a Heck bull, a combination of primitive breeds claimed to resemble aurochs. See *Photograph 6.*

**Photograph 6: Heck cattle (combination of primitive breeds claimed to resemble aurochs) © The Wild Foundation**

### 3.1.4 Domesticated cattle, sheep and pig

Cattle and sheep dominated the LON bone collection and other Mid/Late Orcadian Neolithic settlements and pig rare. These species are discussed in more detail in the following chapters.

### 3.1.5 Red and roe deer

Low numbers of red deer bones and/or antlers were recovered from most Orcadian Neolithic sites. The roe deer identification at Knap of Howar is queried because there are no other records of roe deer from Orkney in either the prehistoric or historic period.

### 3.1.6 Dog

The few LON dog bones and teeth matched those of medium and medium/large-sized dogs held at the NMS Collection Centre. Although bones of large, morphologically generalised dogs can be difficult to distinguish from their wolf ancestors (Morey, 2010, p39) LON dog bones were smaller than any male or female wolf bones examined. A wolf jaw has, however, been recovered from the prehistoric site at Jarlshof, Shetland (Platt, 1933) and a possible wolf bone from Stones of Stenness, Orkney. Dog coprolites were identified at LON (Carrott, 2011) and two dog bones noted during an earlier excavation, a tooth and a scapula fragment

(Armour-Chelu, 1992, p113, table 4, or three bones, with the addition of a pelvis fragment, p114, table 5).

There was no evidence of special deposition of dog bones at LON, a feature at the Neolithic causewayed site of Windmill Hill in southern England (Grigson, 1999, pp230-231, Whittle et al., 1999, p358) and the later Iron Age site at Brest Ness, Westray, Orkney, (Fraser, unpublished).

Only a few dog bones have been recovered from other Orcadian Neolithic settlements. For example at Pool, Sanday no dog bones were recovered in the Neolithic phase (Bond 2007, p,210, table 7.2.1) and at Tofts Ness, Sanday dog was represented by a MNI of 1 (Nicholson and Davies, 2007, p173, Illustration 6.3.1.2). A dog tibia was recovered from Skara Brae, Mainland (Clutton-Brock, 1976, p35). The largest number of dog skulls and associated skeletons was from Cuween cairn, Mainland (Charleston 1901/02) and these have recently been dated to the end of the Late Neolithic or Chalcolithic period (Sheridan, 2005, p177).

### 3.1.7 Sea mammals

Grey seal, or seal bones not identified to species, were rare at Neolithic sites on Orkney, only being identified in low numbers at the settlements of LON, Tofts Ness, Sanday and the cairn at Rowiegar, Rousay. This result aligns with stable isotopic research that indicates Neolithic communities in Britain, unlike preceding Mesolithic communities, consumed few proteins originating from marine animals (Richards and Hedges, 1999, Richards et al., 2003, Schulting, 2004, 2013, p326, Schulting et al., 2004), although there is some contradiction between isotope analysis and archaeological evidence of fish and shellfish remains (Milner et al., 2004). At the cairns of Papa Westray North, and Quanterness, Mainland, a minor marine contribution to the diet was noted, either directly from consumption of marine food or through ingestion of sheep that consumed marine macro-algae (Schulting and Richards 2009, p71, Schulting et al., 2010, p42). A well-designed sequential investigation of human tooth dentine from juveniles and adults buried at the Neolithic site of Sumburgh, Shetland, indicated there was occasional short-term consumption of marine protein, but that inhabitants of this northerly agricultural site (60$^{o}$N) attempted to maintain a terrestrial diet whenever possible (Montgomery et al., 2013).

Today Orkney grey seals haul out and pup on beaches in November (Berry 2000, p98) and, if this behaviour prevailed during the Neolithic, would have represented an accessible source of fur and meat, so it is of interest that so little evidence of their exploitation exists. There were more grey seal bones recovered from the Iron Age site of Brest Ness, Westray, including a large number of new-born pups (Fraser, unpublished).

Whale bones were present at LON, possibly the remains of elements used as building materials or artefacts such as pots. For example, fragments of ribs/possible mandibles with no distinctive features from medium/large whales (fragment lengths 185-450mm and widths 130-135mm) were recovered from Structure 18 and may have been associated with construction. At hut 1, Skara Brae, Mainland, whale jaw bones may have been part of the roof structure, although it has been highlighted that this find was not duplicated in any other known hut (Childe, 1931, p11, Clarke, 1998, p15).

Collagen analysis for three LON whale bone fragments with no distinguishing morphological feature indicated two were humpback whale (*Megaptera novaengliae*) and one from the family *Delphininae*. Humpback whales (12-15m long baleen whales) are described as "very rare" in present-day Orkney (Booth and Booth, 2005, p85).

**Photograph 7: Sperm whale (male) stranded in Westray in 2007, skeleton displayed at Westray Heritage Centre**

A whale bone fragment from Rowiegar cairn, Rousay was also from a humpback whale and a bone from Knap of Howar from a minke whale (*Balaenoptera acutorostrata*) (Buckley et al., 2013, table 2). At the cairn of Point of Cott, Westray, teeth from killer whale (*Orcinus orca*), pilot whale (*Globicephala meles*) and sperm whale (*Physeter macrocephalus*) were recovered (J. Herman in Barber, 1997, p35). The skeleton of a sperm whale beached in Westray in 2007 is shown in *Photograph 7.*

There was therefore a diverse range of whale species represented in Neolithic Orkney, all species recorded in Scottish waters today (Gillham and Baxter, 2009). Although there are strong arguments for whale hunting in Scandinavia from the Mesolithic onwards (Clark, 1947b, 1952, pp63-72) current evidence from prehistoric Orkney is considered insufficient to determine whether whales were stranded or hunted (e.g. Nicholson and Davies, 2007, pp183-184). The variety of whale species perhaps militates against a targeted hunting strategy. Acquisition may have been opportunistic, including scavenging of stranded species and/or driving medium species into shallow water when sighted, as happened with pilot whales in the historic period of Orkney (Berry, 2000, p103 Fenton, 1978, p549). Whale population numbers would probably have been higher during the Neolithic period and standings more frequent.

In contrast, a survey of selected Bronze, Iron Age and Norse Age sites in the Scottish Western Isles identified sperm, minke and bottlenose whale and bottlenose dolphin and concluded that “we can envisage the seafaring islanders setting out to actively capture whale” (Mulville 2002, p45).

### 3.1.8 Fur-bearing animals

No pine martens’ bones were noted at LON despite prior knowledge of their presence in Neolithic Westray (MacCormick, 1984, pp108-109, table 3). The pine martens’ bones at Pierowall Quarry were not intrusive, being dated to 3350 to 2650 cal BC (Fairnell and Barrett, 2007, p479). In the original Pierowall Quarry animal bone report it was stated that pine martens were thriving in Orkney (Fairnell and Barrett, 2007, p479, MacCormick, 1984, p110) but in a later publication their presence was associated to imports for pelts (McCormick and Buckland, 2003, p91) which could be from animals imported alive or dead. Fox bones at Quanterness, Mainland, were considered remains of intrusions by denning foxes (Clutton-Brock, 1979, p113) and an Iron Age radiocarbon date has now been established (180 cal BC to cal AD 230) (canmore.rcahms.com accessed 2/01/15). The only other Neolithic record of fox bones in Neolithic Orkney is at Vesta Fiold, Mainland where twenty fragments of fox bone and teeth, some articulated, were recovered. These fox bones were incorporated into the physical structure of the cairn (Richards et al., 2013). It is possible that the 4th metatarsal bone of fox from LON (recovered approximately 400mm below the surface of midden context 7302, spit 4/8) was imported to the site from mainland Scotland as part of a pelt, but if bones from Vesta Fiold were to be confirmed by radiocarbon dating as Neolithic, this might create a stronger argument for the presence of this mammal in Neolithic Orkney.

Many sites in Orkney, including LON, produced otter bones, some confirmed as Neolithic by radiocarbon dating (Ashmore 2009, p60, table 17, Armour-Chelu, 1992, p78, Harman, 2009, pp57-58, R. Hedges et al., 1987, Noddle, 1983, Sheridan and Higham, 2006). Otter hunting in historic Orkney is recorded in the Norse Orkneyinga Saga and this practice continued into later periods because otter skins appeared in export lists from the 17th century onwards (Berry, 2000, pp108-109, Fenton, 1978, pp525-526).

Otter bones from Neolithic sites in Orkney could therefore have been carcasses discarded after hunting and skinning, otters colonising abandoned structures and dying "*in-situ*" or special deposits. Otter spraint (scented faeces containing fish bones and scales, shell fragments and possibly small terrestrial mammal and amphibian bones) was recovered below midden material and within ruined structures at LON. Since spraints can be located at, or near the entrance to holts (Harland and Parks, 2009, p117, Kruuk, 2006, p74, p79) this evidence perhaps supports the hypothesis that otters colonised abandoned LON structures. In addition, although by the Iron Age, at Pool, Sanday, otter bones displayed clearly identifiable butchery marks (Bond, 2007, p232) but no definite cut marks were noted on LON otter bones, apart from two faint marks on an otter radius diaphysis.

The presence of otter bones at other Neolithic Orkney sites has also been attributed to colonisation after abandonment, for example, at the cairns of Pierowall Quarry, Westray, Point of Cott, Westray, and the settlement of Tofts Ness, Sanday (Halpin, 2007, p56, MacCormick, 1984, 2:E3, Nicholson and Davis, 2007). At D. Clarke's previous LON excavation it was also deduced, based on the state of preservation, lack of butchery marks and age and sex profiles, that otters had colonised the building shortly after abandonment and the skeletons reflected mortalities in a natural population (Armour-Chelu, 1992, p269).

However, the excavator himself, while agreeing that “*in-situ*” natural deaths may account for some otter remains at Neolithic sites in Orkney, argued that the presence of three individual skulls at the Late Neolithic site of Skara Brae, Mainland, in a cell off Passage C, did not fit well with this explanation and may be a deliberate deposition (Clarke, 1998, p17). This is supported by the assertion that otters were introduced by humans into the cairns at Isbister, South Ronaldsay (Barker, 1983, p134) and Quanterness, Mainland (Clutton-Brock, 1979, p118). However, as already discussed, radiocarbon dates have reallocated Quanterness fox bones to the Iron Age, perhaps reducing evidence of deliberate introduction of carnivores.

### 3.1.9 Rodents

Orkney voles were the only rodents positively identified at LON but sieved residue is still to be examined. Field voles were noted at the Iron Age Westray site of Brest Ness (Fraser, unpublished). This species resides only in Orkney, Guernsey and continental Europe (Berry, 2000, pp131-135, Corbet and Harris, 1991, pp208-21, Hayes et al., 2002). The possible origins of this vole sub-species have been subject to recent morphological and genetic research but the location of their European continental parent population remains elusive. Within Orkney itself, genetic and morphological variation has been noted between islands, indicating dispersal from Mainland to other islands in the archipelago (Cucchi et al., 2009, 2014, Martínková et al., 2013).

Orkney voles have inhabited Orkney since at least the Neolithic period (Berry, 2000, pp131-135, Booth and Booth, 2005, pp82-83, Corbet, 1979, Corbet and Harris, 1991 pp208-211, R Hedges et al., 1987, Lever, 2009, p40). It is argued that voles found within Neolithic cairns in Orkney were the result of deposition of pellets from owls roosting (Corbet, 1979, p135, Cucchi et al., 2009, p90) and this was also the tentative explanation advanced for the Neolithic/Early Bronze Age settlement of Tofts Ness, Sanday. This is because owls, unlike diurnal raptors, leave little evidence of acid erosion on bones after digestion (Nicholson, 2007, p207). However, voles have been observed in rubble in present-day Westray (H. Moore pers. comm.) and, in view of their wide distribution within LON, including their recovery from within the cranial cavity of LON cattle skulls, the possibility that they colonised abandoned structures should be considered an alternative explanation to deposition by owl pellets.

Some field mice have also been recovered at a Neolithic cairn site and from the Neolithic/Early Bronze age context at the settlement site of Tofts Ness, Sanday.

Future radiocarbon dating will help resolve the arrival date of this species to Orkney, but it is of interest that two rodent species may have been imported into Neolithic Orkney.

Rabbit has been found at several Orcadian Neolithic sites but considered intrusive by all specialists. Rabbit is known to have reached Scotland by 12th century AD and not recorded in Orkney until 16th century (Lever, 2009, p61) or the 17-18th century (Booth and Booth, 2005, p81 Buckley and Harvie Brown, 1891, p88). At LON rabbit bones were rare and only associated with upper spits of middens.

### 3.1.10 Mammals absent from Neolithic Orkney

Cat bones (*Felis catus* and *Felis sylvestris*, domestic or wild) have not been identified from any Orcadian Neolithic sites. Cat bones found at the Neolithic cairn of Quanterness were dismissed as intrusive (Clutton-Brock, 1979, p115). Cat bones of transitional size (large domestic male/female wildcat) have been recovered from the Orcadian Iron Age sites of Brest Ness, Westray (Fraser unpublished), Pool, Sanday (Bond 2007, p210, table 7.2.1) and Howe, Mainland (Smith, 1994, p140, table 12) suggesting they may have been introduced to Orkney after the Neolithic period.

Horse (*Equus sp*) bones were recovered from Quanterness cairn (Clutton-Brock, 1979, pp118-119) and Skara Brae (D. Clarke's 1977 excavation). Radiocarbon dating has determined these bones intrusive (Quanterness 920 +/- 80 BP; Skara Brae 1380+/- 75 BP (Hedges et al., 1995). These results, as well as dates from other sites in Britain, have led researchers to state that "more recent dates support the general supposition that there were no horses in Britain before the Beaker (early Bronze Age) period" (Hedges et al., 1995). Horse bones from the Late Neolithic/Chalcolithic site of Newgrange, Ireland (Wijngaarden-Bakker, 1974) have also been revised to a later date (Bendley, 2012).

It is therefore surprising that horse bones were reported in several 19th and early 20th century Neolithic Orkney site reports, for example Wideford Hill cairn (Wilson MS quoted in Davidson and Henshall, 1989), Skara Brae settlement (Stewart and Boyd, 1914, Petrie 1867, p211) and Loch Stennis (*Stenness*) cairn, (Ritchie 1920, p71). Since horse bones, particularly teeth, are morphologically distinct from those of cattle it is possible that the first excavators of Orcadian Neolithic sites encountered intrusive horse burials, evidence perhaps of later use of these structures. Interestingly, horse bones have also been recorded from cairns in Caithness (Davidson and Henshall, 1991).

Large and medium sized mammals present in Mainland Scotland during the Neolithic period, but apparently absent from Orkney include elk (*Alces alces*), lynx (*Lynx lynx*), brown bear (*Ursus arctos*), beaver (*Castor fiber*), weasel (*Mustela nivalis*), mountain hare (*Lepus timidus*) and hedgehog (*Erinaceus europaeus)* (Kitchener, 1998, Yalden, 1999).

### 3.1.11 Mammals currently resident in Orkney

The current terrestrial non-domestic mammal population of the Orkney Islands (excluding bats) are listed below. Post-Neolithic introductions are in italics (Berry, 2000, Booth and Booth, 2005):

- *Hedgehog* (*Erinaceus europaeus)*
- Pygmy shrew (*Sorex minutus*)
- Water shrew (possible) (*Neomys fadiens*)
- *Rabbit (Oryctolagus cuniculus)*
- *Brown hare (Lepus europaeus)*
- Mountain hare (*Lepus timidus*)
- Orkney vole (*Microtus arvalis orcadensis*)
- Wood mouse (*Apodemus sylvaticus*)
- House mouse (*Mus domesticus*)
- *Common rat (Rattus norvegicus)*
- *Black rat (Rattus rattus)(possibly now extinct)*
- Otter (*Lutra lutra)*

House mice were probably an Iron Age introduction (Kitchener, 1998, p79, table 4) and mountain hare introduced in the 19th century (Corbet and Harris, 1991, p162). It is of interest that hedgehogs were introduced to Gotland, Scandinavia, during the Mid Neolithic period and some hedgehog remains associated with burials at Ajvide (Rainbird, 2007, p124), but these mammals have not been identified in Neolithic Orkney to date.

There was a short-lived introduction of red deer to Orkney in the 19th century (Buckley and Harvey-Brown, 1891, pp81-82) and a re-introduction of red deer in the 20th century, which was abandoned for commercial reasons, not because the herd did not thrive (H. Moore pers. comm.). A reindeer antler from Rousay, Orkney, considered a possible pre-historic relic, has now been dated to the 18th century (Kitchener, 1998, pp68-69).

### 3.1.12 Overview

Comparing simple lists of mammalian species present at LON, other Orcadian Neolithic sites and modern-day Orkney produces valuable information. It demonstrates, for example, that red deer were present and widely distributed throughout Orkney during the Neolithic period, whereas the only large herbivores present today are domestic stock.

The range of mammals recovered from Neolithic Orkney is smaller than that of mainland Scotland, with all larger carnivores such as wolf, lynx and brown bear absent, either because there was (i) no route for them to colonise the Orkney Islands after glaciation (ii) they arrived but were eliminated by man or demised because ranges in Orkney were too small to support them.

Hedgehog, brown hare, mountain hare, and commensal species such as house mouse and common rat are present in modern Orkney, demonstrating that, at least for these species, introduction post-dated the Neolithic period. This establishes that humans introduced mammals to Orkney, either deliberately or accidently, since arguments for refugee populations or post-glaciation land/ice bridges can be ruled out in these later examples of “facilitated immigration” (Vigne, 1999, p313). Current genetic research also indicates a human facilitated arrival of Orkney vole during the Neolithic period (Martínková et al., 2013).

Bones from smaller carnivores such as pine marten and fox present in Orkney during the Neolithic may have been introduced by humans as live or dead stock. There is evidence for exploitation of foxes and pine martens going back into the late Palaeolithic/early Mesolithic period in Europe, including pine marten remains at the British Mesolithic site of Star Carr (Charles, 1997). In the case of fox they may also have played a role in rodent control if this was perceived a problem in Neolithic Orkney (Clutton-Brock, 1979, Vigne et al., 2011, p261).

The otter is the best represented small carnivore in Neolithic Orkney, and it has been assumed, that in a similar manner to seals, this mammal would have been able to swim to Orkney after inundation of the Pentland Firth which separated Orkney from Mainland Scotland (Armour-Chelu, 1992, p78, citing Macintyre 1950). There is evidence of long-distance grey seal dispersal (Berry, 2000, p98) but data for Eurasian otter concentrate on home ranges, dispersal using terrestrial routes and time spent out of water (Berry, 2000, p110, Corbet and Harris 1999, pp427-428, Kruuk, 2006, p42, pp177-178). Otters can swim at a maximum rate of 1m-1.2m/second (Corbet and Harris, 1999, p428, Kruuk, 2006, p156), so may have required island stepping stones to facilitate colonisation.

## 3.2 Domestication

### 3.2.1 First evidence of domestication in Near-East

Mammal bones from LON were dominated by sheep and cattle bones. These mammals, and probably dogs, originated from the Near East, one of several regions where domestication occurred during the Early Neolithic (Burroughs, 2005, p192, Russell, 2012, p208, table 6.1, Zeder and Smith, 2009) many millennia before their first arrival in Orkney. The term “domestication” is widely used and understood at a general level but precise definitions are elusive. Domesticated strains cannot be considered separate species from their wild progenitors because they can still, in most cases, interbreed.

Two early examples of descriptions for domestic animals are ”the capture and taming by man of animals of a species with particular behavioural characteristics, their removal from their natural living area and breeding community, and their maintenance under controlled breeding conditions for mutual benefits”(Bökönyi, 1969, p219) and “one that has been bred in captivity for purposes of economic profit to a human community that maintains complete mastery over its breeding, organization of territory, and food supply” (Clutton-Brock, 1987, p21). These definitions exclude tamed wild animals not bred in captivity under human control.

These definitions do not cover all aspects of cattle, sheep and pig presence in Neolithic Orkney. Cattle may have been kept for economic benefit for the community, but deposition of cattle skulls also indicates a social/belief role. Maternal genetic material associated with aurochs may indicate non-controlled breeding at some point in their journey to Orkney, or on Orkney itself. As highlighted by D. Orton, another definition with a different emphasis towards domestication is perhaps helpful: domesticates are “integrated as objects into the socio-economic organization of the human group” (Ducos, 1978, p54, Orton, 2010, p190).

The LON sheep, originating from south-west Asia, with no native equivalent in Holocene Europe (Rowley-Conwy, 2003, p99, 2011a, pS433) are far removed from their natural breeding areas. In Westray their territory may have been organised, but alternatively, they may have roamed freely over the island, particularly since there is evidence of consumption of fresh seaweed through isotopic analysis of dentine from sheep’s teeth recovered from the

Mid Neolithic cairn of Holm of Papa Westray (Balasse et al., 2005, 2006, Balasse and Tresset, 2009, p81).

The red deer on Westray cannot be considered domesticated if the above quotations are evoked, but their population numbers and age/sex structure may have been managed by judicious culling as suggested for other European societies, prior to, and during the early stages of the Neolithic (Jarman, 1972, Higgs and Jarman, 1969), although others have highlighted that no direct evidence supports this (Simmons et al., 1981, p123).

All the definitions quoted are anthropocentric but some researchers argue that this does not encompass the complexity of the relationship and that domesticated animals are in partnership with humans to the mutual benefit to all parties (e.g. Barrett, 2011, p77, Budiansky, 1992, O’Connor, 1997, p149, p152, Morey, 2010, p68, Ray and Thomas, 2003, Zeder in Leach, 2003, p363).

Over the last 10,000 years it is not only the human population that has undergone rapid demographic and territorial expansion. Domesticated plants and mammals, which started from relatively few ranges, now comprise approximately one-fifth of the world biomass (Budiansky, 1992, p125). So, for example, at the beginning of the 21st century there were four hundred million dogs in the world, far more abundant than their ancestors, wolves, which now inhabit only a small proportion of their original range (Morey, 2010, p66). Aurochs, ancestor of domestic cattle became extinct in 1627 at Jaktorow, Poland (Kyselý, 2008, p9). Another change associated with farming was population growth of commensal mammals, such as mice and rats that feed on stored foods (Crosby, 2004, Russell, 2012, p216).

Domesticating animals was one of the ten strands of the “Neolithic Revolution” a concept initially envisaged by V.G. Childe during his consideration of the development of civilisations (Childe 1925, 1936, pp66-104, 1958, pp34-43). Research since these seminal publications has clearly shown that these ten Neolithic stands were incorporated in humans’ lifeways at different times and in different areas approximately 20,000 to 10,000 years ago (Barker, 1985, p8, Barrett, 2011, p66, Belfer-Cohen and Goring-Morris, 2009, Thomas, 2013, p103, Zeder, 2009, Zeder and Smith, 2009). The process was not rapid, but the label “Neolithic Revolution” is still prescient because humans were hunter-gatherers for millions of years prior to these changes, but, once initiated, the process of domestication and sedentism was irreversible (Crosby, 2004, Dobney et al., 2013, Larson et al., 2014, p6140, Robb, 2013, p657, Simmons, 1993. p10), apart from a few well-documented reversals (e.g. Rowley-Conwy and Layton, 2011, p858).

The move from hunter-gatherer to farmer relocated the boundary of energy transfer from immediate energy procurement and consumption to the storage of crops and management of livestock, including timing of culls, procured from pastures, browse and cultivated soils (Barrett, 2011, p76, Russell, 2012, p217, Winterhalder and Kennet, 2009, p646), although it is noted that hunter-gatherers may have already used some deferred return strategies (Rowley-Conwy, 2001, pp40-44, Zeder and Smith, 2009, p684). Farming may have been more arduous than gathering and hunting, resulting in more work, lower adult stature, heavier disease burdens and poorer nutrition (Crosby, 2004, pp29-30, Davis, 1997, p152, Diamond, 2002, p700, Mithen, 1996, p251, Price 2000a, p20) but was up to one hundred times more productive per km$^2$ (Burroughs, 2005, p189, Budiansky, 1992, p115) and associated with increased populations (Bocquet-Appel et al., 2012, Shennan, 2009). In addition, the possession of wealth by farmers, such as crops, stored food and domesticated animals which could be unambiguously demarcated and defended, may have led to the spread of property rights which was advantageous to those groups that adopted this lifeway (Bowles and Choi, 2013).

The term “revolution” was also used by A. Sherratt to describe the use of domestic animals for milk, traction and fibre in the “Secondary Products Revolution”, (Sherratt, 1981, 1983), although earlier researchers had already considered this concept (e.g. Bökönyi, 1974, cited in Greenfield, 2010, p45). Secondary products are renewable since no livestock are killed during exploitation. These products may have been more valuable to farmers or herders than meat (e.g. Ingold, 1980, p100). It was proposed that these changes in animal exploitation occurred around four to five thousand years ago (Sherratt, 1981, p159) but more recent research indicates that some, if not all, were adopted earlier (Greenfield, 2010, Vigne and Helmer, 2007). So, for example, milk residues have been recovered from pottery shards from the 9th millennia BP (Evershed et al., 2008). However, there may have been change of scale in the uptake of secondary products during the Chalcolithic and Early Bronze Age, if not first adoption (Bogucki, 1993, p492, 2011, p114, Greenfield, 2010, p41). Pig, unlike cattle, sheep or goats, do not provide secondary products and are kept exclusively for meat and fat (Albarella et al., 2007, introduction).

Prior to domestication, taming and management of a variety of mammals was undertaken (Vigne, 2011, pS256). Identifying the first domesticated animals from archaeological sites is a complex, if not impossible, task because a number of traits associated with domestication, such as lack of aggression or changes in coat colour cannot be identified from bone fragments. The traits that can be noted include reduction in size, shortening of facial features, reduction in cranial capacity, loss of horns and crowding of dentition (Albarella et al., 2007, introduction, Cohen, 2009, Clutton-Brock, 1969, 1989, Dobney et al., 2013, Ingold, 1980, p82, Leach, 2003, p349, Shipman, 2010, Vigne, 2010, p173, Zeder, 2006). However, all these skeletal indicators can be altered by factors other than domestication (Jarman and Higgs, 1972, p96, Vigne et al., 2011). So, for example, cave hyena (*Crocuta crocuta*) a species never tamed or domesticated underwent size reduction in the post-glacial period (Higgs and Jarman, 1972, p6). Recent examples of aurochs of small stature, considered to be domesticated cattle, are discussed in more detail in *Chapter 11*. Changed demographic profiles (age and sex of culled animals as reconstructed from archaeological assemblages) are also often considered proxy evidence for domestication.

Much scholarship has been expended over the last fifty years in pursuit of the identification of sites associated with the early appearance of domesticated mammals (e.g. Albarella et al., 2007, Arbuckle and Makarewicz, 2009, Barker, 1985, Conolly et al., 2011, Dobney et al., 2013, Martin and Edwards, 2013, Rowley-Conwy, 2003, Uerpmann, 1996, Vigne, 2010, Vigne et al., 2011, Zeder, 2006) including genetics studies (e.g. Bradley and Magee, 2006, Bollongino, 2006, 2007, 2012, Larson et al., 2014, Troy, 2001) but from the perspective of the Late Neolithic site of LON, Westray, the most important evidence is that cattle and sheep were domesticated in localised areas of the Near East at least five or six millennia before their arrival in Orkney (Zeder and Smith, 2009). Not only would breeding lines had been known and valued by the time of their arrival in Orkney, but also experience of how to manage these animals successfully (Case 1969a).

Dogs, non-stock mammals, were domesticated earlier than other mammals, from at least 14000 BC with the oldest known secure specimen from Bonn-Oberkassel, Germany. Earlier dates for dog domestication are disputed (Germonpré et al., 2012, 2015, Larson et al., 2014, p6140, Morey, 2010, p25, Shipman, 2010, p526). Despite this early date for domestication, dog remains are sparse at Neolithic sites in Orkney. Pigs have a more complex domestication history and it is possible that there may have been multiple sites of domestication, and some interbreeding between domestic and wild strains (Albarella et al., 2007, Ervynck et al., 2001, Graves, 2007, p33, Larson et al., 2005, 2007, Rowley-Conwy et al., 2012, pp34-35).

Reasons proposed for the advent of domestication are wide-ranging. V.G. Childe suggested the effect of climatic change, with increasing aridity forcing populations to gather together in areas where water was still available, and that this restricted environment and greater population density gave rise to Neolithic lifeways (Childe, 1936). Although climatic fluctuations were certainly a constraint to agriculture prior to the Holocene, after this adoption of new social innovations may have been dictated by the rate of uptake not by climate (Bettinger et al., 2009, Binford, 1983, pp214-232). Specific “push” mechanisms proposed for the onset of mammal domestication include an increase in sedentism in areas of abundant gathering and hunting with consequential larger populations creating a need for greater food productivity as surrounding wild game numbers are reduced (e.g. Anthony, 1990, Bellwood, 2009, Cohen, 2009, Davis, 1997, p154, Makarewicz and Tuross, 2012, Price, 2000, p5, Rowley-Conwy and Layton, 2011, pp857-858, Tchernov, 1993, p204). It has also been conjectured that obtaining milk, with its higher percentage of conversion of pasture to food than simply culling herbivores for meat, might not have been part of the secondary revolution, but one of the possible drivers for initial domestication (Vigne and Helmer, 2007, Vigne, 2011, pS267).

In contrast, “pull” mechanisms include the suggestion that the human belief systems changed prior to the uptake of agriculture, incorporating a hierarchical (or vertical) view of relationships with animals, which legitimised exploitation (Cauvin, 2000, Goring-Morris and Belfer-Cohen, 2010, Lewis-Williams and Pearce, 2005). Another proposed mid-set change is the “domus” characterised by sedentism, food storage and hierarchical societies provided a new conceptual framework about the wild (Hodder, 1990). A third suggestion centres around a need for ceremonial feasting led to a requirement for easily secure and accessible food sources (Hayden, 2001, 2009, 2011).

Another possible trigger, neither “push” nor “pull”, is based on natural selection theory of “survival of the fittest” first propounded by C. Darwin (1859), and more recently by DNA forensic evolution researchers (e.g., Carroll, 2008, Dawkins, 1989). Certain mammals co-evolved with humans creating practices that led to niche agro-pastoral conditions in which domesticates were isolated and outcompeted other animal species. These species could be introduced into an evolving system of land management/agriculture (Barrett, 2011, p70, Budiansky, 1992, Rindos, 1984). This relationship may have emerged from pre-existing economic relationships with selected mammals prior to the post-glacial period (Higgs and Jarman, 1972, p12). However, this proposal can be challenged because only one species, (human) entered into a spate of new symbiotic relationships in a short time scale, implying human agency based on multi-generational memory and flexible response to changes (Zeder, 2009).

In conclusion, it is probable that more than one factor was responsible for the domestication of selected mammals in the Near East. Climatic, economic, ecological and natural selection pressures, or human derived social and symbolic factors, or a mix of both that led to the selection of cattle, sheep, pigs and goats to inhabit human agro-economic niches (Banks et al., 2013, Barrett, 2011, p70, Larson et al., 2014, p6140, Zeder 2009). Once adopted, the management of domesticated mammals, the storage and planting of seeds, the possible storage of animal products such as milk, requirement to maintain soil fertility and many other associated activities not associated with hunting and gathering, would have been part of an increasingly complex and entangled lifestyle (Hodder, 2012).

### 3.2.2 Domestic stock transmission throughout Europe

After the initial uptake of agricultural lifeways, the descendants of domesticated cattle and sheep embarked on a series of rapid advances, punctuated by lengthy pauses from areas of first domestication through Europe to Orkney, possibly by the 38th or 37th century BC (Barrett, 2011, p78, de la Vega Leinert et al., 2012, Fiedel and Anthony, 2003, p144, Robb, 2013, Rowley-Conwy, 2011, Rowley-Conwy and Layton, 2011, Thomas, 2013, Whittle, 1996).

This expansion had a greater impact on human society than the original development of cereals and domesticated stock (Price 2000b, p316). The early spread of farming was into temperate climate zones of south-east Europe, similar to those of the primary sites of domestication (Crosby, 2004, p18, Rowley-Conwy, 2011, pS443).

Orkney, Shetland, and Scandinavia are at the northernmost limits of this spread, both geographically and climatically. Limitations to managing domestic mammals might have included low temperatures/wind chill causing metabolic energy loss in stock mammals and inhibition of winter grass growth creating a requirement for complementary winter feed. However, the ameliorating impact of the North Atlantic Drift must have been a factor in facilitating the transmission of domesticated stock to these areas (Tipping, 2010, Tipping and

Tisdall, 2004, Tipping et al., 2012). Attempts to establish farming at even more northerly sites during the historic Norse period resulted in abandonment in Greenland, and farming supplemented by fishing in Iceland and the Faroes Islands, although these changes were also related to a complex interplay between political, social and environmental factors (Amorosi, 1992, Amorosi et al., 1994, Barlow et al., 1997, Church et al., 2005, Dugmore et al., 2005, 2007, 2012, McGovern, 2000).

A key publication indicated that Neolithic lifeways took over the rest of Europe as a “wave of advance” which spread out through time in ever increasing arcs from the Near East (Ammerman and Cavalli-Sforza, 1984). The model examined local population growth, site relocation and markers for the adoption of farming in a quantitative framework and concluded that these lifeway changes had been the result of demic (migratory) diffusion. The model is explicitly based on the assumption that migrations will be over short distances, based on the wave front having locally high birth rates among pioneer farmers resulting in random movement to less settled locations at an average rate of 1km per year (Anthony, 1990, p901, Fiedel and Anthony, 2003, p144).

This model is challenged by more recent data from Europe. For example, the LBK culture is associated with rapid expansion in loess areas of central Europe, but slower entry to France and Denmark (Davis, 1997, p153, Lowe Kooijmans in Rowley-Conwy, 2004, p102. Whittle et al., 2011). It is probable that early agricultural sites were not spatially continuous but restricted to patches with favourable conditions (Shennan, 2009, p342). However, the “wave of advance” model was important for stimulating further discussion on whether changes in Europe were predominately the result of Mesolithic populations adopting agriculture (indigenous) or migrants colonising areas (demic diffusion) (e.g. individual papers in Ammerman and Biagi, 2003, Colledge et al., 2013 and Price, 2000) plus Barrett, 2011, Fort, 2012, Robb, 2013, Robb and Miracle, 2007, Shennan, 2009, Thomas, 2013, Whittle, 1996).

Recent genetic work suggests that approximately 15% of people in European Neolithic settlements were migrants from the Near East and so perhaps the people carrying domesticated mammals to the rest of Europe arrived not in a wave, but as a “trickle” (Rowley-Conwy, 2011, pS434). However, farming could have also been introduced by migration of European based peoples, so these genetic studies do not provide a complete solution to the on-going debate. A model based on physical transport equations suggests that although there was significant regional variation, demic diffusion was the most important process responsible for Neolithic transmission in Europe (Fort, 2012, p18671). There is evidence that long distance networks of Mesolithic communities pre-dated the Neolithic (Thomas, 2013, p128) and areas for potential migration would have already been known to these travellers.

From the perspective of investigating mammals in Neolithic Orkney, it is significant to note that domesticated mammals were transported to Mediterranean islands from adjacent mainland sites at an early stage of adoption of Neolithic lifeways (Brookbank, 2000, p45, Brookbank and Strasser, 1991, Cherry, 1981, 2004, Dawson, 2011, Masseti, 2008, Peltenburg et al., 2000, Phoca-Cosmetatou, 2011, Vigne, 1999, Rainbird, 2007, pp68-89). Of particular interest is the introduction of both domestic and non-domestic stock to Cyprus from the 11th and 10th millennia cal BP onwards, easily identified because the island only supported an impoverished late Pleistocene endemic fauna, none of which were related to the introduced animals (Conolly et al., 2011, p543, Schule, 1993, Vigne, 2011, Vigne et al., 2011). It is probable that Cyprus was considered part of the eastern Mediterranean landscape, not as an isolated unit (White, 2004).

These results from Early Neolithic Cyprus illustrate three points. Firstly, although there is no surviving evidence of actual sea crafts in the Mediterranean during the pre-Neolithic and Neolithic (McGrail, 2010, pp98-101), these migrations present clear evidence of maritime competence with craft large and stable enough to carry animals to new locations. Recent evidence indicates that sea voyaging in the Mediterranean can be dated to the pre-Neolithic period (Ammerman, 2010, Farr, 2010, pp179-180, Brookbank, 2006, pp115-116). Possible sea crafts used in the Mesolithic/Neolithic may have been complex log rafts, multiple hide-float rafts, bundle rafts, multiple hide boats, basket boats, pot-float rafts, stabilised log boats, paired log boats and extended log boats propelled and steered by paddles (McGrail, 2010, p105, table 8.1).

Secondly it demonstrates a desire and impetus to introduce wild mammals such as fallow deer and wild boar as well as domesticated stock by Early Neolithic people exploiting the Cyprus environment. It was not simply a farm “starter pack”.

Thirdly the introduction of Neolithic lifeways to Cyprus and other Mediterranean islands suggests a “scouts and settlers” pattern of migration, not a random movement of people (Fiedel and Anthony, 2003, p153).

### 3.2.3 Arrival of domesticated mammals to Britain and Ireland

Arrival of domesticated stock into Britain and Ireland was late within the European Neolithic sequence, at approximately the 41st to 37th centuries BC, but uptake was relatively rapid (Ashmore, 2004, Rowley-Conwy, 2004, Piggott, 1954, p15, Richards and Hedges, 1999, Schulting and Richards, 2003, Whittle et al., 2011) perhaps suggesting a high degree of population influx and mobility (Cunliffe, 2012, p135). Other researchers advocate that transmission may have initially involved only pioneer settlements leaving the majority of landscapes unmodified (Milner, 2010, Noble, 2010, p129) or that transmission of domestic stock was phased (Woodman, 2000, p249). A recent find of charred grain perhaps indicates domesticated crops being imported into the south of Britain at an earlier date (Larson et al., 2015) but the first example of the presence of domesticated stock in Britain and Ireland, at Ferriter's Cove, Ireland requires further investigation. See *Appendix 4*. The Ertebølle culture of southern Scandinavia adopted domesticated stock in approximately the same period as Britain (Bonsall et al., 2002, p9, Price, 2000, Rowley-Conwy, 2011).

Resonating with the demic diffusion versus indigenous debate on adoption of Neolithic lifeways in continental Europe, arguments continue as to whether domesticated stock arrived in Britain and Ireland by (i) importation with incoming farmers (ii) acquisition from continental Europe by indigenous peoples (immigrants after the last glaciation) who embraced Neolithic lifeways (iii) combination of both. For a summary of the arguments by the main protagonists (V.G. Childe, S. Piggott, J. Hawkes, G. Clark, H. Case, A, Whittle, R, Dennell, I. Kinnes, I. Hodder, J. Thomas, G, Cooney, A. Sheridan and P. Rowley-Conwy), see "The Neolithic Transition in Britain: a critical historiography" (Thomas, 2013, pp129-187). In the 1944 Rhind lectures, for example, V.G. Childe suggested that cultivated plants and domestic animals were brought to Scotland by incoming settlers although indigenous people may have joined them or copied their way of life (Childe, 1946, p24).

Some researchers have suggested that the impetus for transmission of cereal cultivation and domesticated stock to Britain and Ireland was the result of a "pull" mechanism associated with climatic instability which disrupted Mesolithic acquisition of food (Tipping, 2010, Tipping and Tindall, 2004, Tipping et al., 2012). Alternatively, relative drought may have led to an expansion of grassland, inviting to Neolithic pastoralists (Bonsall et al., 2002). Another factor may have been a reduction in storminess, with an associated perception that sea voyages were less climatically hazardous (Tipping, 2010, p71). Transporting domesticated stock by boat would have been a complicated undertaking, probably requiring reconnaissance trips prior to departure (Anthony, 1990, Case, 1969, 1969b, Fiedel and Anthony, 2003, p163). The argument that climatic factors were too local to be linked to widespread changes in lifestyles is disputed on the basis of the widespread nature of some climatic changes (Thomas, 2013, p386, Tipping 2010, Tipping et al., 2012, p9). Some "push" factors may have been social regulation, population numbers, search for prestige by either indigenous people or immigrants (Anthony, 1990, Piggott, 1954).

By the Neolithic period the landbridge linking Britain with continental Europe submerged (Coles, 1998), so transportation of domestic mammals to Britain and Ireland must have been by boat. In the colder waters of the North Sea, the Channel and the Atlantic Ocean, it is unlikely that "wash-through" boats such as floats and rafts would be used because they would not offer protection against ingress from cold sea water (Crumlin-Pedersen, 2000, p46). It is probable that a displacement vessels such as skin/hide boats were utilised (Clark, 1952, p283, Crumlin-Petersen, 2000, p46, Noble, 2006, p26, Van de Noort, 2011, pp149-151), although stabilised log boats, extended log boats or paired log boats might also have been viable (McGrail, 2010, p105, table 8.1). The ocean-going capabilities of hide boats were demonstrated by the recent Ireland to Newfoundland crossing of the hide-skin boat, the "Brendan" (Severin, 2005). This craft used downwind sails as well as paddles, methods of propulsion available to early seafarers. These boat types would have predated the transmission of domestic mammals into Britain and Ireland and so, for example, there is evidence of Mesolithic occupation in Orkney, the Inner Hebrides and the Isle of Man (Garrow and Sturt, 2011, p66), which must have included use of boats.

An example of a hide boat model (probably with a sail for downwind passage) is the gold boat from a hoard at Broighter, County Derry, Ireland (Cooney, 2004, p147), which, although from Bronze Age, may also represent sailing craft available during the Neolithic. See *Photograph 8.*

Seafaring would have been a difficult and complicated activity, requiring specialist skills (McGrail, 1998 pp275-285, Noble, 2006, p26). Changes in sea levels during this period may have precipitated continental European coastal foragers and inland, dry-land farmers into closer relationships (Coles, 1998, p77) perhaps introducing greater opportunities for sea voyaging to these communities.

**Photograph 8: Broighter gold boat showing oars and structure for sail © National Museum of Ireland**

The “Western Seaways” route along the Atlantic/Irish Sea would have been familiar to seafarers in northern Europe, Britain and Ireland, whereas the changing configurations of the Channel and North Sea would have made these areas more difficult to navigate (Callaghan and Scarre, 2002, Garrow and Sturt, 2011, p65), perhaps making this a less favoured route for the introduction of domestic mammals. It is assumed that animals would be “thrown” or trussed up during passage (Case 1969a) which may have limited time at sea, since these mammals would require water and fodder more easily administered on dry-land.

The source of domesticated stock to Britain is unresolved, with the suggestion that the initial stock imported to southern England was from the Paris Basin, based on close morphological similarity (Tresset, 2000, 2003,) being challenged by recent studies (Viner-Daniels, 2014). Stature of domesticated mammals can alter in relatively short time scales, making comparisons challenging. So, for example, recently the weight and hindlimb length of Soay sheep on Hirta, St Kilda has fluctuated around a declining trend over a twenty year period (Ozgul et al., 2009) well within the resolution of archaeological radiocarbon dating.

If domesticated stock was initially introduced to only a few geographic locations in Britain and Ireland it is probable that the most suitable territories for raising domesticated stock and cereals were colonised first (Shennan 2009, p345). This would include off-shore islands, because when viewed from the sea these areas would not appear isolated and mainland areas with dense forests or mountains may have been more of a barrier to settlement than being an island (Dugmore et al., 2010, Rainbird, 2007, pp217-220, Van de Noort, 2011, p125). Orkney, with its sparse woodland, equitable maritime climate, machair plains and shallow bays, may have been an attractive area for farming and, although based on present radiocarbon evidence, was not one of the first areas of Britain to be occupied by farmers (Garrow and Sturt, 2011, Whittle et al., 2011), might have been an area of successful uptake. Cattle Depositions in Neolithic Europe

The archaeological concept of "island laboratories" (Evans, 1973) or the ecological concept of "island geography" which considers changes to biota without human intervention are not appropriate frameworks for considering mammal interactions and development in Orkney since it would not have been isolated from human contact (Gorman, 1979, Losos and Ricklefs, 2010, MacArthur and Wilson, 1967, Whittaker and Fernández-Palacios, 2007).

## 3.3 Review of special depositions of Neolithic cattle

### 3.3.1 General

A large body of literature highlights the special deposition of cattle skeletons and skulls in Near-East, continental European and British Neolithic and is selectively reviewed to demonstrate the depth and breadth of cattle/human relationships since the earliest Neolithic period. Examples of cattle deposition from categories (i) invisible building deposits (ii) visible building deposits (iii) cattle and human co-internment (iv) cattle burials, highlights the diverse records from the earliest pre-Pottery Neolithic period through to the Iron Age, providing evidence that cattle were far more than simply a means of substance. It is possible that the importance of cattle may have preceded their domestication, and may, indeed, have promoted it (Hayden, 2001, p143, 2011, p33, Hodder, 2012, p172, Mithen, 2003, p64, Russell, 2012, p18).

### 3.3.2 Invisible cattle skull building deposits

An early foundation deposit, a bovine skull at the base of a building wall, was recorded from the PPN to Early Ceramic Neolithic period in Ginning, northern Iraq, an area associated with early domestication of cattle (Campbell and Baird, 1990, p 68). Other early examples of cattle skeletal portions incorporated into buildings are cattle skulls, or frontlets, and scapulae, placed below floors or invisibly built into walls or benches at the PPN sites of Mureybet, Tell'Abr and Tell Halula in northern Syria, and Çayönü in south-eastern Turkey (Cauvin, 2000, p28, Russell 2012, p85). Also at Cafer Höyük cattle scapulae were found in the interior of a house which had no connection to food preparation waste (Cauvin, 2000, p89).

The well-documented Early Neolithic site of Çatalhöyük, Turkey, had cattle horns and scapulae built into walls or blocked crawl holes. Feasting remains are recovered from under floors, often at hearths or internal thresholds and associated with obsidian and human neonatal burials (Russell, 2012, p80, p85).

Another foundation deposit, a long distance from Orkney, both in time and distance, was the Early Neolithic Tripolye culture located in the South Bug/Dniester river valley, Ukraine. In these villages preconstruction foundation deposits of cattle horns and skulls, and occasionally human skulls, have been recovered. For example, under every house in the Early Tripolye village of Bernasheva, dated between 5620 to 5300 cal BCE there was the skull of a domesticated cow or bull. Like LON, the cattle skull deposit was not focused on male animals. One house also had wild animal deposits, those of an aurochs and antlers of red deer (Anthony, 2007, p172).

Closer to Orkney, in northern Europe during the 5th and 4th millennium BC domestic cattle and aurochs skulls were laid under houses in Dachstein, Alsace (Chaix, 1985, quoted in Anati and Gomes, 2013, p144).

### 3.3.3 Visible incorporation of cattle skulls into buildings

At Jerf el Ahmar, Syria, 120 km north of the contemporary PPN site of Mureybet, four large skulls of aurochs may have originally hung on walls (Mithen, 2003, p64), although gazelles and equids were the most commonly hunted animals (Cauvin, 2000, p214). Also at the PPN site of Hallan Çemi, Anatolia, a bull skull with horns, probably hung on the wall, and three sheep crania with horns were uncovered in the central activity area (Verhoeven, 2004, p246).

One of the best documented examples of cattle skulls, or bucrania, visible, decorated and incorporated into building is from Neolithic Çatalhöyük, Turkey. Often bull heads on walls were modelled in clay and finished off with real bull horns/frontals (Cauvin, 2000, p31, Russell and Meece, 2006). The animals appeared to emerge from the walls (Lewis-Williams and Pearce, 2005, p110). Cattle horns were also incorporated into benches and on short clay pillars at the edge of platforms (Russell, 2012, p84). It is possible that these remains from bulls were associated with male symbolism (Hodder and Meskell, 2011).

At the Neolithic site of Vinča, Serbia, bucrania, characterised by plastering and frequent painting of actual cattle skulls, were attached to the gable end of houses or on internal walls (Chapman, 2000, p217). Similarly, aurochs and oxen heads with horns attached were fixed to exterior walls of the Arbon/Bleiche 3 long houses, Switzerland (Anati and Gomes, 2013, p144).

### 3.3.4 Cattle and human co-internment

#### 3.3.4.1 Continental Europe

During the PPNB period at Kfar HaHoresh, northern Israel a minimum of eight aurochs joints, some still articulated, were recovered from a mortuary pit. Seven of the aurochs were adults, one a sub-adult. Still in the PPNB period, at Çayönü, south-eastern Turkey, cattle horns and skulls occur with human remains in a pit from the 1st phase of Skull Building (Russell, 2012, p102).

At a later period, around 3500 BC at Alsónémedi, Hungary cattle/human graves were recovered, one containing a man, women, a mature female cow and a juvenile bullock, the other a man, six year old cow and calf. Other contemporary Hungarian sites produced similar evidence. The formality of burial extended to the cattle, this was not a case of meat joints being deposited in the grave. It is possible that this change mirrored the arrival of new economic practices of traction and transport by cattle (Whittle, 1996, pp122-124).

#### 3.3.4.2 Britain

Neolithic/early Bronze Age co-depositions of cattle and human remains have become known as “head and hoof” burials with the suggestion that human bodies were wrapped or covered in a hide which still retained skull and foot bones (Piggott, 1962). The practice was considered widespread over a large geographical area of central and east Europe and Russia, perhaps the earliest example being from Alaca Hüyük, Anatolia (Piggott, 1962, p112).

Some Late Neolithic long barrows from Wiltshire, containing cattle skulls and articulated foot bones in association with human skeletons, have also been designated possible “head and hoofs” burials, for example Fussell’s Lodge (Ashbee, 1966) and Hemp Knoll (Robertson-Mackay, 1980). However, the evidence is ambiguous, since the Hemp Knoll deposition was out-with the grave and the Fussell’s Lodge articulated foot bones recovered from above a collapsed masonry wall with the cattle skull at the entrance enclosure (Grigson in Ashbee, 1966, p63). J. Pollard’s observation that at Fussell’s Lodge “the draping of hides over mortuary deposits almost bespeaks of containment, melding together of ancestral bone and cattle” may be only one of various interpretations (Pollard, 2006, p141).

In the same area of southern England several other barrows produced evidence of cattle deposits:

- Knook 2 Barrow: cattle skull and horn cores resting on top of the Late Neolithic cairn
- Sherrington 1 Barrow: cattle skull excavated from pit at the base of the barrow
- Boles Barrow: seven cattle skulls and horns in pit, separated from the human skeletons (Field 2006, pp4-5, Piggott, 1954, pp60-61)
- Beckhampton Road Barrow: three cattle skulls at intervals along mound, incorporated into rock rubble. No human bones, leading to speculation that cattle skulls were substitutes for human bone (Ashbee et al., 1979, p247, Bishop, 2013, p78, Thomas, 1991, p28)
- South Street Barrow: four cattle scapulae incorporated into the mound (Ashbee et al., 1979, p247)
- Ascott-under-Wychwood: cattle skulls within the architecture of the burial mound (Thomas, 2013, p407, Thomas and McFadyen, 2010, p111)

A much larger cattle bone deposition was recorded at the Late Neolithic Beaker Culture site at Irthlingborough, Northamptonshire. A collection of 185 cattle skulls, including one or two aurochs, 38 cattle mandibles, 33 cattle scapulae and 15 pelves were overlying, and mixed with, construction material slumping into a large central grave in the barrow. This deposit was considered to be not just the remains of a funeral feast, but heads and other significant bones curated as trophies from previous feasts/sacrifices (Davis and Payne, 1993, p14, p20). Close to this site, during the same period, another Early Bronze Age barrow grave, Gayhurst, Buckinghamshire, produced remains of at least three hundred cattle. There was a wide range of ages and female cattle outnumbered males by four to one. It was again suggested that most of these cattle were slaughtered away from the barrow and then flesh left to rot from the skulls prior to deposition (Towers et al., 2010).

### 3.3.5 Cattle burials, including skulls

#### 3.3.5.1 Continental Europe

Burials of intact cattle skeletons, including skulls, appeared in central Europe from 3500 BC onwards, often not in association with human bones, and sometimes in pairs. The age and size distribution of the pairs suggests these were not traction teams. This contradicts the suggestion made by A. Whittle for the cattle/human graves in Hungary (Whittle, 1996, p124). Both male and female cattle from a variety of ages were involved. These animals had not been consumed but it cannot be determined if they were sacrifices, grave gifts or simple burials (Pollex, 1999, Whittle, 1988, p171, p190, 1996, p211, p255, p263).

In Neolithic Scandinavian cultures there was also an emphasis of the burial of cattle skulls and long bones, either separately or together. In Denmark fourteen Mid Neolithic TRB bog finds were associated with complete cattle skeletons, many of which were bullocks or old animals, thought to be possible sacrifices (Sjögren and Price, 2013, p702).

#### 3.3.5.2 Britain/Ireland

Cattle bones, often in bundles, or articulated portions, have been recovered from the Early Neolithic causwayed sites in southern England (Edmunds, 1999, p92, Grigson, 1999, p206, Legge, 1981, p173, Ray and Thomas, 2003, p39, Whittle et al., 1999, p360). There was also purposeful deposition of cattle skulls at causwayed sites such as Whitesheet Hill, Maiden Castle and Hambleton Hill (Thomas 1991, p28) and these may have been afforded special treatment, similar to those of human skulls (Edmonds, 1999, p117).

At the Early Neolithic site of Windmill Hill, for example, substantial portions cattle skeletons or articulating bones were deliberately deposited in ditches, along with a goat, a pig and two fox skeletons (Grigson, 1999, p236). A large number of complete or nearly complete cattle skulls and horn cores were recovered from contexts containing particular concentrations (Grigson, 1999, p204). Some cattle bones recovered were from aurochs, but their remains did not seem to be the result of different deposition practices (Grigson, 1999, pp231-232).

At the Late Neolithic site of Stonehenge a cattle skull and two mandibles plus a red deer tibia were recovered at the putative blocked southern entrance within a primary ditch. The dates from these bones show that may have been curated for substantial periods of time before deposition (Cleal et al., 1995, pp529-31, Serjeantson, 1995, p442).

In addition to the causwayed enclosures of southern England, an Irish Mid Neolithic enclosure at Kilshane, Co Meath, revealed structural deposition of articulated and disarticulated bones from a minimum of fifty-eight cattle. Certain bones such as vertebrae and long bones were deposited, predating a large Middle Neolithic Broad-Rimmed vessel dated to 3645 to 3390 cal BC (Smyth, 2014, p138).

As well as domestic cattle, two aurochs skulls were recovered from a Late Neolithic pit at Etton (Pryor, 2006, p45). A structural deposition of an aurochs in a pit from a gravel quarry, Hillingdon, London was thought to be from the Late Neolithic/Early Bronze Age (Cotton et al., 2006). During the Iron Age, in the immediate vicinity of a spring at Bourbonne-les-Bains, Haute Marne, France, eighteen aurochs horns were recovered (Grant and Sauer, 2006), perhaps indicating a remaining interest in these wild animals many millennia after the domestication of cattle.

## 3.4 Cattle Artistic representations

### 3.4.1 Pre-Neolithic

Depictions of animals in Europe originate from the Upper Palaeolithic as (i) cave paintings at locations such as Lascaux and Chauvet Cave, France (ii) rock carvings at Côa Valley, Portugal (iii) portable art such as the bison carving from Abri de la Medeleine, Dordogne, France (Bahn 2010, Cleyet-Merie, 2007, pp84-85 Scarre, 1998). Some rock carvings of animals have also been recovered from the Upper Palaeolithic in Britain, for example Creswell Crags, Derbyshire (Bahn, 2010, p29, Hutton, 2013, p10).

Animal representation continues during the transitional period between hunter-gathers and agricultural societies (Anati and Gomes, 2013, p125). For example, in the pre-Pottery Neolithic A/B in the early ninth millennium BC, at Göbekli Tepe, a site still dependant on wild animals for meat, there are remarkable T-shaped carved pillars and carved stones depicting a wide range of animals such as aurochs bulls, foxes, snakes and cranes, all of which were also present in the animal bone assemblages from the site (Schmidt, 2007, fig 45, p113, p115, fig 46, Verhoeven, 2002). At ‘Ain Ghazel, Jordon, in the Early/Mid Pre-Pottery Neolithic B, zoomorphic figurines found within special deposits represented cattle

(Twiss 2008, p429). In this period, although domesticated caprines were introduced, wild animals such as aurochs still dominated special deposits (Twiss, 2008, p430).

### 3.4.2 Late Neolithic/Chalcolithic

At the Early Neolithic site of Çatalhöyük, as well as bucrania of aurochs and wild ram already discussed, there were as series of narrative paintings featuring mainly wild animals (Hodder and Meskell, 2011, p241). At the pre-Pottery Neolithic site of ‘Ain Ghazal, Syria, there were twenty-four cattle figurines (Schmidt, 2007, p36). Sheep, goats, cattle and sheep figurines were also present at Çayönü (Özdoğan, 2011, comments in Hodder and Meskell, 2011).

By the 4th and early 3rd millennium BC, an extensive range of cattle figures, or cattle bucrania depicted on rock art (paint, engraving or relief carving) have been recorded from European tomb sites covering a wide geographic area including Eastern/Central Europe, French and Italian Alps, Mediterranean islands, Iberian Peninsula, northern France and Scandinavia. These representations may symbolise the importance of cattle, not only to the agriculture of these communities, but also to their social and religious lives (Anati and Gomes, 2013, p125).

For example, in Eastern/Central Europe, at Maikop in the North Caucacus Piedmont, Russia, a site where copper-working had been adopted, the grave of a chieftain, dated between 3700 and 3400 BC included four long-horned bulls statuettes, two silver and two gold, approximately 100mm in length (Anthony, 2007, p289, Piggott, 1965, p82).

In Magoura Cave, north-eastern Bulgaria, two bucrania harnessed to a cart were part of a painted repertoire of images from cave walls dated to the late 4th or first half of the 3rd millennium BC, along with anthropomorphic figures, serpents, idol figures, solar symbols and weapons (Anati and Gomes, 2013, p126). At the megalithic tomb of Züschen I, Kassel, Hessen, Germany, cattle bucrania were illustrated with semi-circular, lyre, rectilinear and serpent shaped horns, and in one instance, circular horns, on structural elements of the tomb. At this site there are also depictions of yokes, ploughs, sledges or tribula, two-wheeled carts and wagons with two or four wheels, some with cattle harnessed to them (Anati and Gomes 2013, pp89-97, figs 44-51, p120).

In the European Alps, Camonica Valley, Italy, rock art depictions comprising schematic anthropomorphic figures linked to bucrania and some representations of ploughs (these are not present in the earlier 6-5th millennium BC rock art). In the following period further carvings were carried out using metal tools (Anati and Gomes, 2013, pp126-129). One of the largest collections of engraved bucrania, from 4th and 3rd millennium BC, was from Mont Bego, in the Meridional, Ligurian or Maritime Alps. There were 571 representations of bucrania, both alone and in pairs accompanied by ploughs. In the oldest phase of this collection, bucrania are associated with circles and meander figures (Anati and Gomes, 2013, pp120-121, Clark, 1952, p101, fig 47).

On the Mediterranean island of Sardinia orthogonal, U-shaped and nested cattle horn motifs, painted, engraved or in relief, have been recorded in 116 rock-cut rock tombs, These encompass both curved and rectangular representations, the oldest examples being associated with the curved representations (Anati and Gomes, 2013, p132, Robin, 2014, Tanda, 1985). Some motifs reflect the horns and dorsal aspect of the bovine head, some reduced representations of the full head, others only horns (Tanda, 1985, p23, fig 4, Tanda, 2008 pp129-143, figs 3-28). Since horns are always represented, this may indicate that they are the defining symbol for cattle.

In the Iberian Peninsula, at El Martinete, Toledo, Spain, although the oldest rock carvings were of semi-naturalistic deer, in the Late Neolithic images of bucrania, wagons and carts appear. The cattle horns are represented by semi-circular, rectilinear or vertical horns (Anati and Gomes, 2013, pp135-137, figs 91-93). At Escoural, southern Portugal in both a cave and adjacent open-air stones, before settlement in the Chalcolithic village, there were carvings of bucrania with lyre and semi-circular horns, followed by rectilinear horns one with wagon, one with plough (Anati and Gomes, 2013, pp138-140). In contrast, however, in over 10,000 engravings from the Tagus Valley, Spain/Portugal, only a few engravings were associated with cattle during the Late Neolithic/Chalcolithic period (Anati and Gomes, 2013, pp136-137).

Examples of cattle representation from Neolithic Atlantic Europe include a capstone of a megalithic tomb on the island of Gavrinis, Carnac, Brittany, France, dated to around 3500BC, where, there are three separate carvings, including a two- meter statue of a bull or cow with long curving horns, another pair of curving horns that occurred at the break in the stone and could be matched with a body on another stone, and an “axe-plough” motif, either representing a polished axe head within a wooden shaft or a primitive plough. The capstone had originally been a *menhir*, or standing stone (Scarre, 1998, pp62-64). The U-shaped motifs identified in the Mané Lub passage tomb, Locmariaquer, Morbihan, may have also been horns signifying a cattle cult (Cassen, 2007, p224). In addition, some Neolithic Breton pottery appears to illustrate cattle horns or bucrania (Bradley, 2005, p94).

On the other side of the North Sea from Orkney, Swedish rock art, dating from around 3500 to 2000 BC has carved or pecked representations of people, boats, whales, elks, cattle and ploughs (Clark, 1952, p69, fig 32, Clark, 1977, p150, Cochrane and Jones, 2012, p2, Tilley, 1991).

# *4 Cattle and sheep skull deposits*

## 4.1 Introduction

Mammal skull deposits were excavated from LON Structure 9 and Structure 18. It is unusual to recover partially complete skulls from prehistoric sites because they are frequently broken during butchery or fragmented by taphonomic processes such as pressure of overlying material on thin flat bones (Bartosiewicz and Gál, 2013, p30).The unusual treatment of LON skulls, either by deposition in the foundation course, Structure 9, or in the passageway in Structure 18, preserved these skulls for further analysis.

Cattle skulls, which dominate these skull deposits, offered an opportunity to expand beyond a simple discussion of food-webs and subsistence to symbolic interpretations (Twiss, 2012, p357). "Symbolic" is used in this report as "something that is used to represent a quality or idea" (dictionary.cambridege.org).

## 4.2 Structure 9 skull deposit

### 4.2.1 Introduction

A minimum of twenty-eight cattle skulls were recovered between the inner and outer foundation layer of Structure 9, an oval building lying directly north, and seawards, of a series of cellular buildings enclosed by a boundary wall in Area 5. Two sheep skulls, six cattle pelves and three red deer antlers were integral to the deposit. There was also a cattle maxilla fragment associated with skull F4253 from an animal of approximately 12-15 months old, which, based on estimated age, could not have been detached from any adjacent deposited skulls. Structure 9 had an angular or cruciform interior enclosed by a thick wall in which at least two facings are apparent (Moore and Wilson, 2011, p20). Only the west and east elevation foundations remained, so it is possible that there had been further skull depositions. A central hearth was present within the building.

The location of deposited skulls is given in *Figure 5* (Moore and Wilson, 2013), a simplified sequence of skulls, pelves and red deer antler in *Appendix 5* and an example of the deposition in *Photograph 9.*

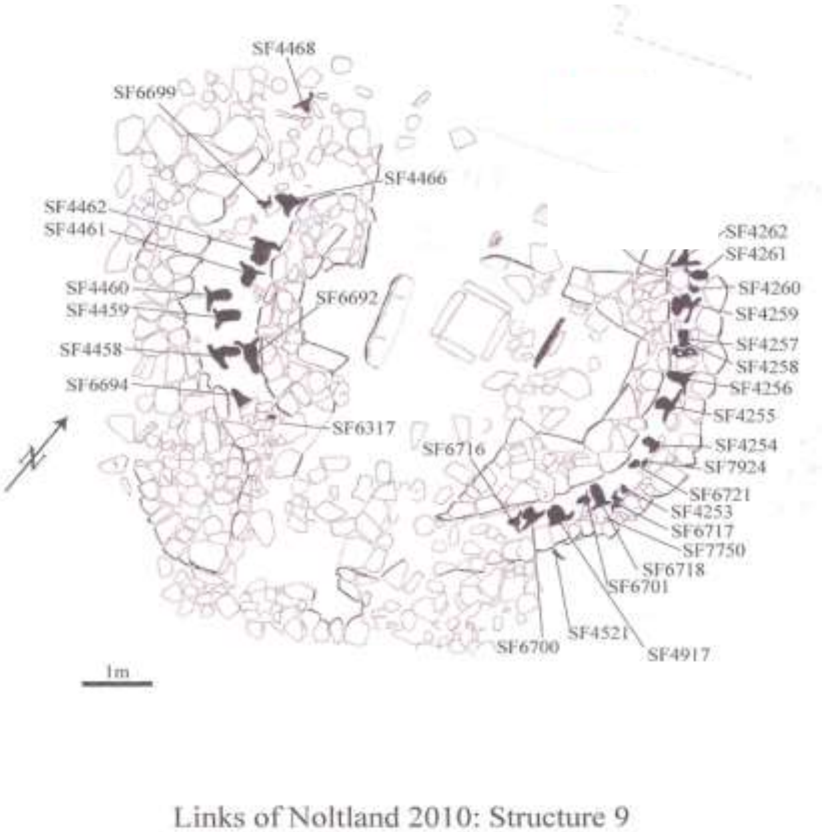


**Figure 5: Positions of cattle and sheep skulls in LON Structure 9 (Moore and Wilson, 2011)**

Cattle skulls were first identified during a trial excavation above the east wall of Structure 9 in 2009. The skulls were exposed because building stone and wall-core had been removed down to foundation level in the prehistoric period and subsequently covered by midden. For an illustrative plan of Structure 9 see *Figure 6*. The skulls had been placed on underlying midden and although a few shells were present, including oyster shells below a horn core of skull F6701 and the frontal bone of skull F6718, there was little evidence of blown sand being integral to these deposits.

**Photograph 9: Cattle skulls in east foundation, Structure 9, LON © G. Wilson**

So, although it is possible that the skulls were visible from deposition in the foundation course until the construction of Structure 9 walls, the lack of wind-blown sand may indicate this was not an extended period.

Ten skulls had evidence of root etching, all but one from the east foundation, indicating at some point in the skulls' history plants growing on the overlying midden produced roots deep enough to reach the cattle skull deposit.

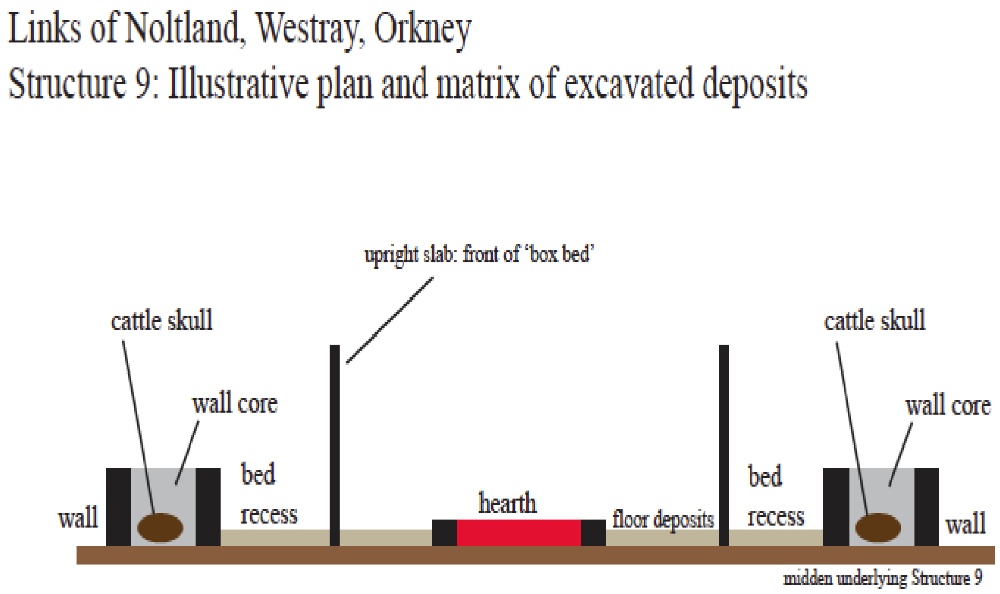


**Figure 6: Illustrative plan of excavated deposits in Structure 9 © EASE Archaeology 2015, please do not reproduce or use without permission.**

### 4.2.2 Position of skulls

The skulls were consistently placed with their frontal bones/ horn cores lying on underlying midden and occipital condyles/maxilla uppermost. The only exception was F4262. The horn cores connected with underlying midden, or in the case of sheep skull F6852, with clay.

Most skulls were placed with horn cores facing outwards from LON Structure 9. The skulls had been placed in position after the main foundation stones were laid, although some smaller loose stones did cover the skulls, for example the right occipital bone of F4253 and the internal frontal bone of F4260. The density of the skull deposit varied, with the south/south-east portion of the foundation containing more tightly packed skulls. This was the foundation section which retained stone courses higher than the cattle skull deposit.

Some of the skulls were overlapping, for example:

- Left F4255 and right F4256 horn core
- Left and right F4257and F4258 horn cores
- Left F4459 horn core interlocked with F4460 orbit
- F4462 horn cores and maxilla F4461
- Right F4261 horn core beneath pelvis bone F4260

These observations indicate a sequence of cattle skull/pelvis deposition, but not a timescale for this activity.

### 4.2.3 Condition of skulls

The skulls were in “poor” or “fair” when first exposed by excavation. Eleven skulls were recorded as disintegrating when inspected in the field; the rest had cracking and flaking bones. One skull, F4459, also had green algal growth on the horn core, perhaps associated with exposure in the year prior to excavation. It was recognised, based on EASE Archaeology’s experience and previous work on a Neolithic dugong skull mound in UAE (Méry et al., 2009) that field observations, photographs and measurements taken prior to full excavation would be a important source for further analysis.

Many of the cattle skulls were flattened and distorted, for example:

- F4255 horn cores distorted
- F4459 frontal and horn cores bent
- F4462 horn cores and frontals flattened
- F6694 maxilla tooth rows bent

This may indicate skull bones retained some flexibility at deposition and when wall-core and rubble was placed above them.

It is probable that the cattle skulls have been subjected to the destructive impact of drying/wetting/freezing/thawing/wind when protection of building stones and wall-core was removed in antiquity and before a layer of protective upper midden was deposited (Lyman and Fox, 1989, Reitz and Wing, 1999, p116). In addition, all twenty-eight cattle skulls were exposed, or re-exposed, in 2010 for photographs, site drawings, on-site measurements and a

Historic Scotland survey. These activities were essential to gain information before the deposit was removed from the site. Although care was taken to re-cover the skulls after each activity, this did expose them to risk of desiccation and further deterioration. Bone density varies throughout a cattle skull, with neurocranium bones having greatest bone density. The horn cores, while still in the earlier phases of growth are less dense, with open, porous structure, presenting a large surface area for taphonomic destruction but become smoother with age (Armitage, 1982).

It was noted that when "*in situ*" some skulls (F4253, F4254 and F6701) displayed no apparent difference in bone condition between the inner and outer bones surrounding the foramen magnum. However, later examination at NMS Collection Centre demonstrated that the outer bone did, in fact, display more evidence of weathering than the interior. Skull bones fragmented during excavation and cleaning, such as horn cores and frontal bones, revealed internal diviculatum and sinus channels in excellent condition, perhaps indicating that deterioration of the skulls occurred sub-aerially, not after the bones were covered with midden/wall core substrate.

### 4.2.4 Excavation of skulls

Six cattle skulls, thought by field examination to be in best condition (F4256, F4458, F4461, F6716, F6692, F6694), were removed by Historic Scotland's on-call conservator. Even with wax coating no skull remains were removed intact because they were fragile and brittle. See *Photographs 10 and 11*. The remainder of the skulls and pelves were lifted into trays on site then cleaned and examined at the NMS Collection Centre. Diagrams with shaded areas indicating bones present and a photograph for each skull recovered is presented in *Cattle Skull Data Records* at the end of this thesis, including those removed by the conservator.

As the conservator excavated below F4256 into underlying midden some red clay deposits were exposed. These deposits were not identified with any other skulls and, after on-site discussion the red clay was allocated to disintegrating pottery, not clay covering for the skull.

Skulls were fragmented, with the number of fragments recovered varying from 10 (F6701) to 365 (F4462). The smaller number of fragments recovered from F6701 is reflected by an average weight per fragment of 35g, far heavier than the average fragment weight from other skulls. The greatest length of fragment recovered from each skull varied from 44.4mm (F7687) to 220mm (F4259).

**Photograph 10: example of a cattle skull from foundation course, Structure 9, after excavation**

**Photograph 11: example of a cattle skull from foundation course, Structure 9, LON "in situ" conservation**

The weights of skulls recovered ranged from 2877g (F4253), an almost complete skull, through to 110g (F4255). Eight skulls weighed more than 1kg (F4259, F4468, F6693, F6718, F4462, F4917, F4254 and F4253). Full lists of fragment numbers, maximum fragment length and weight for the non-conserved cattle skulls see *Appendix 6.*

Some variation in skull weights may be associated with the sex and age of the animal, but predominately reflect the amount of skull material recovered. There are two possible explanations for the variation; either the skulls were in different states of completeness prior to deposition, or some skulls were subject to greater taphonomic loss prior to final recovery.

Maxillary teeth were present in twelve of twenty-eight skulls and apart from the maxilla adjacent to F4253 mentioned above as a possible extra skull, there were only two loose unworn $M^1/M^2$ maxillary molars (not a sequence and adjacent to F4462/4468) and three loose maxillary molars in sequence $M^1$, $M^2$, $M^3$, with no associated bone (F4306). If all skulls had been placed with maxilla/premaxilla still attached, then it is probable that more loose maxillary teeth would have been recovered from the substrate surrounding the skulls. Additionally, the positioning of some of the skulls are so close or intertwined that it seems improbable that more complete skulls were present at deposition. See *Photograph 12.*

Some skulls (F4253, F4917, F6718 and F6728) had maxilla fragments with alveoli but no teeth, perhaps indicating that there had been sufficient time for teeth to fall from the skull prior to deposition. In the cattle skull deposit of the Bronze Age barrow at Irthlingborough, Northamptonshire, lack of premolars was attributed to a delay between death and incorporation into the barrow (Davis and Payne, 1993, p17).

Although the actual number of bones from each skull and weight of skulls from the foundation deposit in Structure 9 varied considerably, the horn core bases and frontals were always represented.

**Photograph 12: Cattle skulls in close juxtaposition in foundation course, Structure 9 © G. Wilson**

### 4.2.5 Cattle skulls

#### 4.2.5.1 Sex

Most of the skull horn cores attached to skulls in the Structure 9 deposition were damaged but a few could be allocated to a particular sex. Three adult/older adult skulls had horn core basal circumferences as follows:

- F4256 (164mm)
- F4261 (160mm)
- F4468 (170mm)

These horn core basal circumferences are within the published range for female Neolithic cattle (cows), for continental Europe and British Neolithic cows. These published ranges for Neolithic cow horn cores basal circumferences are given in *Table 1*.

**Table 1: Published female domesticated Neolithic cattle (cow) skull horn core basal circumference dimensions (mm)**

| No | Range (mm) | Published Source |
|---|---|---|
| 106 | 122-190 | Backmann in Degerbøl and Fredskild, 1970 |
| 11 | 150-176 | Nobis in Degerbøl and Fredskild, 1970 |
| 7 | 145-175 | Degerbøl and Fredskild, 1970, p81, table 7 |
| 26 | 130-190 | Grigson, 1982a, p28, fig 2 |

Another five horn core basal circumferences from adult/old adults had basal horn core circumferences greater than the published range for Neolithic cows in *Table 1*, so may have originated from domesticated males (bulls), domesticated male castrates or aurochs. These were:

- F4917 (221mm)
- F6718 (222mm)
- F4461 (230mm)
- F4253 (253mm)
- F4458 (270mm)

In addition, the single horn core at the outer edge of Structure 9 foundation stones F4251 had a basal circumference of 264mm and may also be a domesticated bull, a domesticated male castrate or an aurochs. See *Photograph 13.*

**Photograph 13: Cattle horn core F4251© G. Wilson**

The mtDNA results (details in *Chapter 10*) have demonstrated that F4917 was a domestic animal, so in this case, the possibility of the skull being from an aurochs can be discounted. Neolithic aurochs have much longer horn core outer curvatures than domesticated male cattle, greater than 350mm. (Grigson, 1999, p217). The only LON cattle skull with an intact horncore greater than 350mm was F4461. However, all the LON bull/castrate horn cores have outer curvatures greater than 200mm, defining them as “long-horned” (Armitage and Clutton-Brock, 1976).

No cattle horn core measurements were published for V.G. Childe’s excavation of the Late Neolithic site of Skara Brae, Mainland, but in 1867 G. Petrie reported a cattle horn core with a circumference of 254mm and a straight length (not outer curvature) of 330mm (converted from inches) (Petrie, 1867, p212, Watson, 1931) within the same range as LON bulls/castrates.

Bulls are considered to have the shortest and most conical shaped horn cores; castrates the longest horns, which gradually decrease towards the tip; and cows an intermediate shape (Armitage and Clutton-Brock, 1976, p332, Degerbøl and Fredskild, 1970, p153). When D.M.S. Watson examined material from Skara Brae excavation he defined the three categories slightly differently (i) bulls had conical horn cores that were not long in proportion to their width and nearly straight, projecting at almost right angles from the skulls’ principal plane (ii) cows had horn cores that were long, slender and tapering slowly, projecting forwards from their base (iii) castrates had a similar shape of horn core to cows but wider at the base, shorter and narrowed rapidly. He based these comments on comparison with modern cattle (Watson, 1931, pp198-199). There is, however, variation in horn core circumference and shape of modern castrates, depending on the timing of the castration (Armitage and Clutton-Brock, 1976, p332, Degerbøl and Fredskild, 1970, p153).

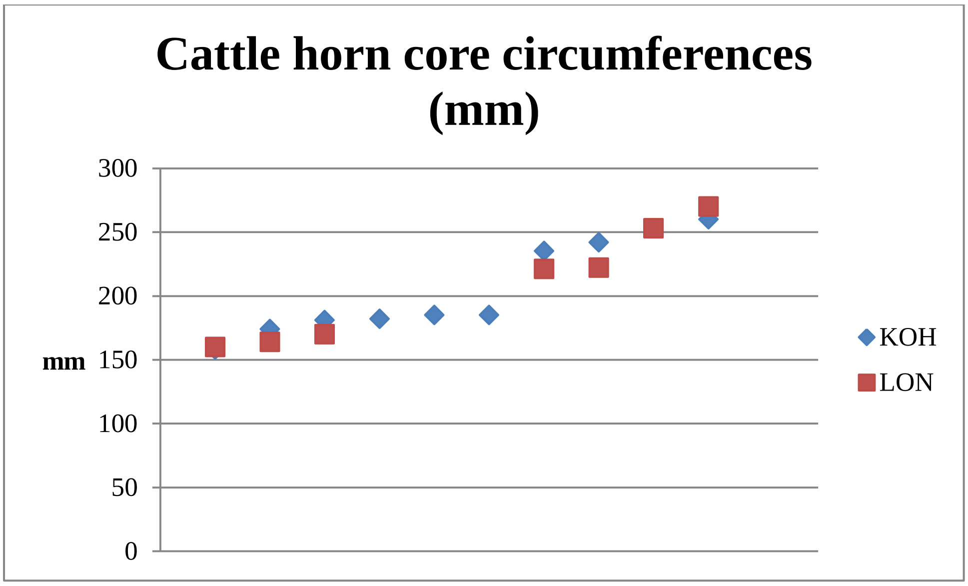
In marked contrast to M. Degerbøl’s and D.M.S. Watson’s descriptions, C. Grigson states that domesticated Neolithic bulls had longer horn cores than cows and only later, perhaps in the Middle or Late Bronze Age, did bull horn cores become shorter than cows or castrates. She notes that even if Neolithic domestic males show some degree of portioning when basal circumference is plotted against length of outer curvature it is not known which group would represent castrates, if indeed they were present (Grigson, 1982a, pp27-28, fig 2, 1982b, p9, 1999, p216).

Examination of Neolithic cattle horn cores at Windmill Hill produced a continuous variation of length and thickness, leading P. Jewell to suggest it would be “hazardous to attempt to distinguish bullock horns from cow horns” (Jewell, 1963, p85).

To add to the complexity of interpreting cattle horn cores it is difficult to distinguish the skull/horn cores allocated to a young bull at Skara Brae, Plates LV11 and LVIII (1) from Degerbøl's Ogaarde III female sub-adult, Plate X (Childe, 1931, Degerbøl and Fredskild, 1970).

Despite the reservations detailed above, some researchers have attempted to distinguish castrates from bulls based on basal horn core circumference. Nobis allocated Neolithic domesticated cattle basal circumferences of 199-210mm to bulls and 218-268mm to castrates, which would place the five LON cattle skulls with horn core basal circumferences greater than 220mm as castrates. Backmann allocated two basal circumferences from Neolithic cattle of 245 and 268mm to castrates, measurements less than this, but greater than 190mm, to bulls or castrates, which would place two LON skulls and the loose horn core as castrates (Bachmann, 1962 and Nobis, 1954, quoted in Degerbøl and Fredskild, 1970, p154).

When LON Structure 9 cattle horn core basal circumferences are plotted and it appears they may separate into two different groups. Nine horn core measurements from the Mid Neolithic site of Knap of Howar, Papa Westray, Orkney measured at NMS Collection Centre, also show the same range of measurements and two different groups, one group with horn core basal circumferences from 158-185mm, the other from 235-260mm. *See Graph 1.*



**Graph 1: Cattle horn core circumferences (mm) (Y-axis) from two Orkney Neolithic sites: LON (Structure 9, Links of Noltland, Late Neolithic) skull deposit, Structure 9 and KOH (Knap of Howar, Mid Neolithic)**

On the basis of the LON eight sexable skulls with horn cores, there is no evidence of partitioning into different areas of the foundation course, Structure 9 for deposition of female and bull/castrate skulls.

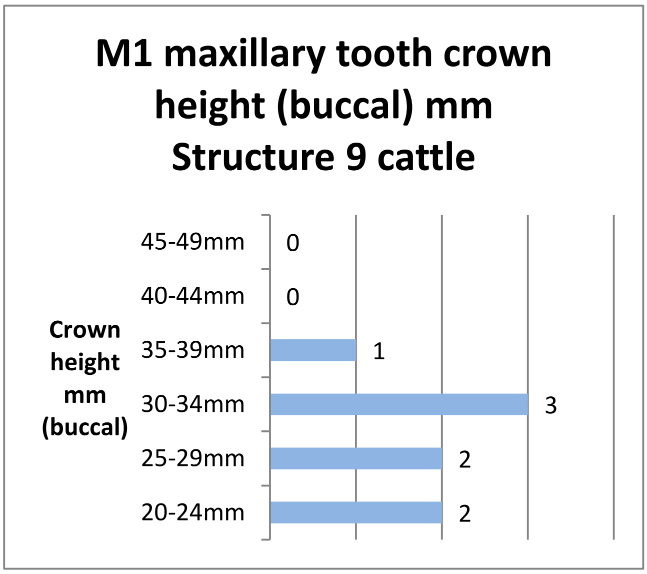
### 4.2.5.2 Age at death

Ages at death of cattle skulls were examined, using published criteria for maxillary teeth, horn core texture and perlen growth, and skull suture closure. Published categories for cattle age vary but for this study the main question was whether the animals had been bred to maximise meat production (e.g. for ceremonial feasts) or whether they had multiple functions. Consequently the code used was as follows:

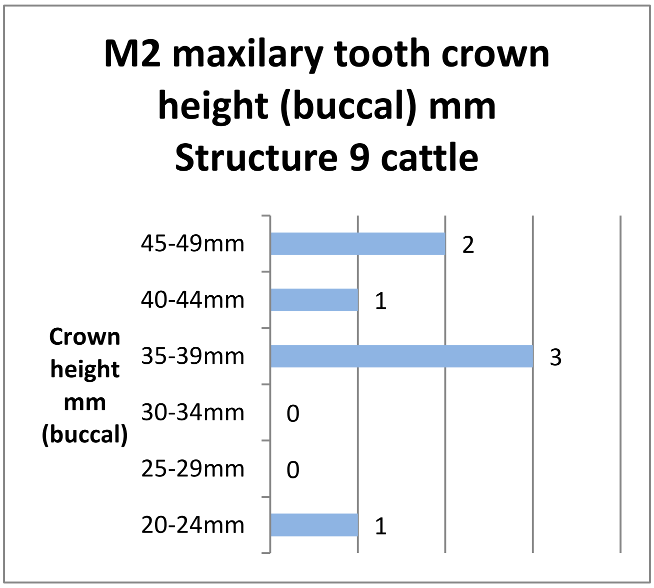
- Calf: <12months
- Juvenile: 12-24m
- Sub-adult: 24-36m
- Young adult: 36m-48m
- Adult/older adult: 48m+

Most eruption and wear pattern ageing schemes for cattle teeth are associated with mandibular teeth (e.g., Ewbank et al., 1964, Grant, 1975, 1982, Higham, 1967, Legge, 1992), the exception being an extensive survey of modern young cattle, when maxillary molars $M^1$ and $M^2$ eruption patterns were recorded (Andrews 1982). Maxillary teeth erupt later than their mandibular counterparts (Andrews, 1982), but since maxillary and mandibular teeth occlude, their wear patterns are necessarily linked. In general, age estimates up to 36 months old, are reasonably precise, but information above this age is limited (Jones and Sadler, 2012a and b).

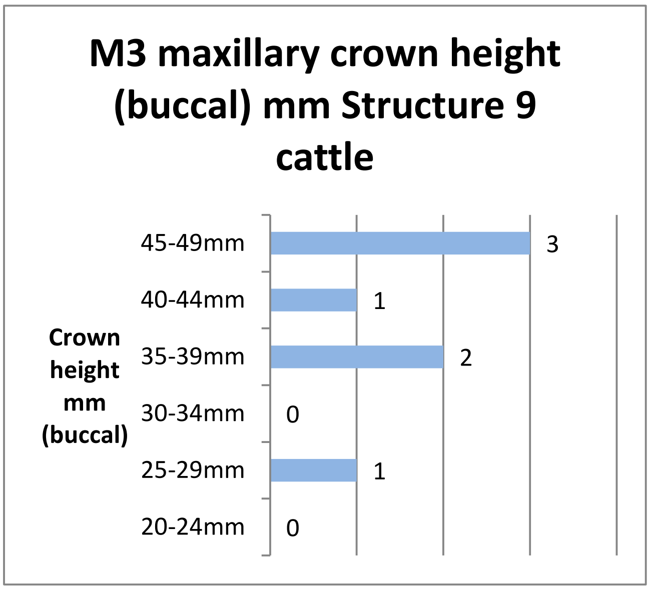
Based on thirteen skull maxillae, one of which contained only alveoli, it is calculated that there were seven adults/older adults, two young adults, two sub-adults and two juveniles of approximately 15-18 months. Only two of the adult/old adult skulls had maxillary $M^3$ pillar engaged (F4254 and F4458). See *Appendix 7*. Age calculations based on teeth are listed in *Appendix 8*. Maxillary $M^1$, $M^2$ and $M^3$ teeth crown height (buccal), left side if available, confirm that F4254 and F4458 are probably the oldest cattle skulls containing maxillary teeth. The buccal crown height results indicate variation of cattle age at death and no cattle of extreme age. See *Graphs 2-4.*



Graph 2: Maxillary molar crown heights M1 (buccal, mm) from LON (Links of Noltland) Structure 9 cattle



Graph 3: Maxillary molar crown heights M2 (buccal, mm) from LON (Links of Noltland) Structure 9 cattle

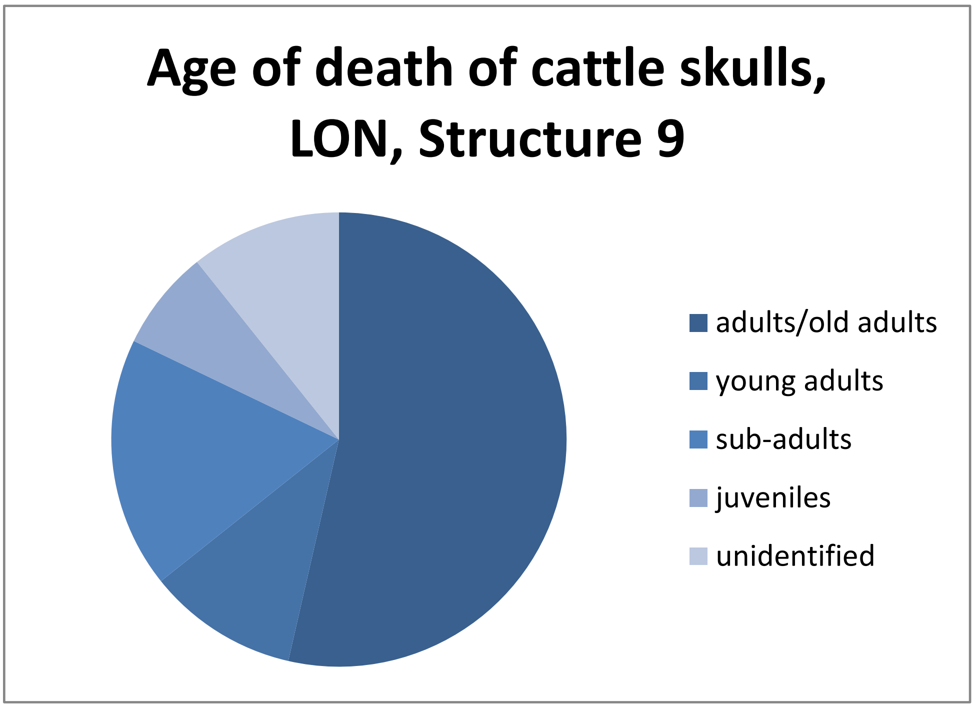


**Graph 4: Maxillary molar crown heights M3 (buccal, mm) from LON (Links of Noltland) Structure 9 cattle**

Four cattle skulls had perlen at the base of horn cores, two of which F4256 and F4458, were classed as adult/older adult based on tooth eruption/wear stages. The other two cattle skulls with perlen growth were F4253 and F4468, a male and female respectively based on horn core basal circumference, indicating that F4253 is older than 3-5 years and F4468 older than 5-10 years (Grigson, 1976, p122).

Using criteria for ageing by horn core texture, based on late medieval horn cores from England (Armitage 1982) was not straightforward because different areas of horn cores display different textures and porosity and it has been suggested that the methods are highly subjective (Sykes and Symmons, 2007, p517). Only one set of Structure 9 horn cores (F4458) appeared to be clearly in the "over 10 years" category. However, the method supported the age categories allocated to the thirteen skulls by tooth eruption/wear analysis and gave an approximate indication of age for eight cattle skulls with no maxillary teeth present as (i) four adult/older adult (ii) one young adult (iii) three sub-adults. Another two skulls F6716 and F6692 were probably adult, based on the skull suture closures. The final three skulls had no data to contribute to age assessment.

Overall, there were fifteen adults/old adults, of which one or two may have been over 10 years old, three young adults, five sub-adults, two juveniles and three of non-identifiable ages. There were no calf skulls present. See *Appendix 9.* For age distribution see *Graph 5.*



**Graph 5: Estimated distribution of cattle skull age of death, LON (Links of Noltland) Structure 9 (No 28). (No calf skulls were present)**

It could be argued that a number of calf skulls had also been deposited in the foundation course, Structure 9, but, due to lower levels of bone mineralisation, rendered undetectable by taphonomic processes. In this scenario, however, some fragments of the more resilient maxillary deciduous teeth or unerupted molars might be expected and none were recovered. Two calf mandibles with associated deciduous $dp_2$, $dp_3$ and $dp_4$ and newly erupted $M_1$ teeth were recovered from the deposit.

Using “age of death profiles” from cattle mandibles recovered from eight areas of midden and infill areas investigated at LON, when adult cattle comprise only a third of all aged mandibles (see *Chapter 8*) then under-representation of calves and juveniles appears even greater in the cattle skull deposit. If the cattle skull deposit at Structure 9 reflected cattle culled or dying over a period of time at LON this would have resulted in calves’ skulls dominating the deposit, which is clearly not the case.

The presence of two juveniles, aged approximately 15-18m, may disclose a potential late summer/autumn culling in the second year of the animals’ life. This statement must be treated with caution since it not certain that cattle only bred in spring in Neolithic Orkney because today feral herd of Chillingham cattle also give birth to calves at other seasons of the year (Corbet and Harris, 1991, p540). However cows in an existing feral population in

Swona, an island on the Pentland Firth between mainland Scotland and Orkney, do calve only in spring (Hall and Moore, 1986).

In conclusion the cattle skulls did not reflect the expected age profile of the LON cattle herd, but predominately represent sub-adult or adult cattle. Two juveniles were present, and at least one animal may have been over 10 years of age, so, although it could be argued that some of the cattle had been culled to maximise meat production, it does not appear that a single cohort of animals had been bred for this purpose and the pattern may, to a certain extent, be expedient.

#### 4.2.5.3 Anomalies/pathology

Very few pathological lesions were observed on Structure 9 cattle skulls. F4917 has some additional bone growth at the proximal edges of the occipital condyles, F4253 and F4255 small pores on the frontal bones. There was also some minor pathology associated with maxillary teeth, but not at a level to inhibit feeding. Most permanent teeth had cementum cover, with a few having the layered configuration highlighted for the Orcadian Neolithic site of Pool (Bond 2007, p233 Illustration 7.2.16). No anomalies were noted with the skulls apart from skull F4458, which had horns with asymmetrical orientation. See *Photograph 14*. This trait was illustrated in an aurochs shot by Mesolithic hunters at Prejlerup, Zealand, Denmark (Whittle, 1996, p14, fig 2.3).The asymmetric horns do not appear to be due to manipulation or binding of the horns, a feature of some of the cattle deposited at Kerma, Sudan (Chaix, 2004). No damage to horn cores potentially caused by tethering was noted.

**Photograph 14: Cattle skull F4458 with asymmetric horns © G. Wilson**

### 4.2.5.4 Modification

Condition of Structure 9 cattle skulls makes it difficult to determine if pole-axing occurred. The one skull which had frontal bones facing upwards (F4262) was not pole-axed. However, a few skulls did have cracks on frontals/parietals that did not follow sutures and appeared to have occurred when the bones were fresh (F4253, F4255 and F4917) which may be from pole-axing, although such symptoms need to be treated cautiously.

One cut mark was identified on the skull bone fragments examined, on the frontal bone of F6718. The general absence of cuts may be due, at least in part, to the poor preservation of the outer surfaces of the skulls, but such a low number is of note. Adjoining mandibles were missing from the skulls, possible evidence of primary butchery.

Three skulls may have had some hack/chop damage to the occipital condyles, F4254, F6701 and F4917, perhaps associated with removal of the skull from the vertebral column. The articulated post-cranial cattle skeleton from the Orcadian Neolithic site of Tofts Ness had cuts on the ventral and dorsal surface of the atlas, considered to be associated with severing the animal’s head (Bond, 2007b, p197).

Based on the presence of ultrafine, dark greasy sediment around the contours of many skulls, it has been suggested that a Neolithic cattle skull ring from Wadi Sana, Yemen was deposited with the skulls still fleshed (McCorriston et al., 2012, p51). This type of sediment was not observed in the LON soil, however taphonomic conditions under such radically different climates are difficult to compare, especially in terms of preservation of soft tissue.

### 4.2.5.5 Measurements

As a result of the condition of the Structure 9 cattle skulls only a limited number of measurements could be taken, some “*in situ*”. Nine field measurements, which were recorded to the nearest mm, could be compared with measurements taken later at NMS Collection Centre, Granton. Eight field measurements were within +/- 3% of the subsequent measurement, but one; the foramen magnum height (F4917) was recorded at 41mm in the field and 43.8mm at Granton, a difference of 6%. Therefore any subsequent discussion based on field measurements acknowledges the limitations on achieving accurate metric information when skull remains cannot be manipulated into favourable positions for measurement.

Two field measurements obtained for condylobasal lengths for adult skulls. One skull (F4256) was within the range for Neolithic domestic cattle as outlined by M. Degerbøl, but the other skull (F6718) had an estimated length of 550mm, which would place it within the size range for a male aurochs (Degerbøl and Fredskild, 1970). The cheekteeth row estimate of 170mm for this skull is also in the range for male aurochs (Degerbøl and Fredskild, 1970, Grigson, 1978). Five mainland Scottish aurochs had cheektooth measurements of 152-178mm (Smith, 1872). The photograph of F6718 with a scale in position appears to confirm these estimates.

**Photograph 15: Cattle skull F6718 © G. Wilson**

Two cattle skull mastoid lengths (F4253 and F4254) 258mm and 240mm respectively are within the size range of either male domesticated cattle or female aurochs. Horn core evidence suggested that F4253 is male, so possibly domesticated. The greatest breadth of occipital condyle from these two skulls, 102 and 105mm respectively, are also in the same category (i.e. domestic male or female aurochs). See *Photograph 15.*

In conclusion, the small number of cattle skull measurements from Structure 9 indicated that their size falls within the range of large domestic cattle and some domesticated male/female aurochs, except cattle skull F6718 that is within the male aurochs range.

### 4.2.6 Sheep skulls

The two sheep skulls (F6721 and F6852) in Structure 9 were represented by neurocranium bones, weighing 142.1 and 159g respectively. Both were in “good condition”. It is not possible to estimate age because no maxilla or maxillary teeth are present, but F6852 has an unfused basisphenoid/ basioccipital and F6721 visible frontal sutures, indicating neither were old individuals. Skull F6721 has a frontal bone partially broken at the suture line and partially through the bone.

The basal circumference of both horn cores from F6721 was 140mm. In Soay sheep the range of horn core basal circumferences for male sheep (age known) ranges from 102 to 160mm, females (age known) 68-82mm, and castrates (age known) 60-106mm (Clutton-Brock et al 1990, p47) so if the LON sheep follow the same pattern of sexual dimorphism in horn core size horn then F6721 may be male. No horn cores were recovered from F6852.

Two right sheep maxillae, associated with cattle skulls F6718 and F4255, were aged approximately “just over 24 months old” based on eruption/wear (Simonds, 1854).

### 4.2.7 Additional post-cranial bones associated with skulls deposition

#### 4.2.7.1 Cattle pelves

Twenty-one cattle pelvis fragments were recovered from the foundation course, Structure 9. At least six bones were clearly integral to the deposit. Two demi-pelves (F4260), a left and right pair, were the most complete bones, with only the iliac crest of the left bone missing. To deposit these bones intact must have required careful butchery and handling. Another set of pelves, F7924, both approximately half complete were from the left side of two cattle, one assessed as being a younger individual because the pubis bones was unfused. A right pelvis comprising an acetabulum and adjacent bone was associated with skull F6721 and another partial right pelvis recovered from the west foundation deposit. *See Photograph 16.*

**Photograph 16: Pelvis F4260 in foundation course, Structure 9, LON © G. Wilson**

Three pelves could be sexed:

- F7924 older animal- male
- F7924 younger animal-female
- Associated with F6721-female

Cut marks were noted on two pelves (i) F7924 on the ilium adjacent to acetabulum (ii) pubis arch from the pelvis associated with skull F7924, indicating removal of meat prior to deposition. Five length of acetabulum including lip ("LA" according to von den Driesch, 1976, p83) ranged from 69mm (younger female F7924) to 81mm (older male F7924). "LA" measurements are not recorded by M. Degerbøl, so comparisons cannot be made with Danish aurochs and Neolithic/Bronze Age cattle. Additionally no "LA" measurements are published for Orcadian animal bone reports. Four cattle pelvis measurements from LON Context 7302 midden ranged from 66.1 to 73.2mm, just below, and within, the lower range of those from Structure 9 foundation deposit. Additionally, four measurements from the Mid Neolithic settlement of Knap of Howar, Papa Westray ranged from 67mm to 77.2mm. *See Table 2.*

**Table 2: Cattle pelves: "LA" (mm) dimensions from LON (Links of Noltland, Late Neolithic) and KOH (Knap Howar, Mid Neolithic)**

| LON St 9 (mm) | LON 7302 (mm) | KOH (mm) |
|---|---|---|
| 69.0 | 64.1 | 67.0 |
| 70.9 | 67.0 | 71.3 |
| 72.0 | 68.0 | 75.0 |
| 75.0 | 70.7 | 77.2 |
| 81.0 | 73.2 | |

Three of the more complete pelves displayed pathological lesions (i) pelvis associated with skull F6721 porous bone at the perimeter of the acetabulum (ii) pelvis F4260 "pouching" or remodeled bone growth at perimeter of acetabulum (iii) pelvis of the older male (F7942) pouching at perimeter of acetabulum and some deformity and remodeling within the acetabulum.

### 4.2.7.2 Other mammal bones

Other mammal bones, from cattle, sheep, red deer, pig, Orkney vole and otter were identified within the foundation course of Structure 9 adjacent to the cattle and sheep skulls. As discussed, the cattle pelves recovered were an integral part of the deposition but it is not clear whether other cattle bones, such as scapula, long bones or phalanges were associated with a deliberate selection process or general midden deposits. This question is further investigated in *Chapter 6*. Loose 1st phalanges were found lying in the maxilla/palatine of two cattle skulls (F4256 and F4462) but the phalanx on F4462 was unfused, and therefore not from the same animal as the skull. See *Photograph 17.* A list of mammal bones recovered in given in *Table 3*.

**Photograph 17: Cattle skull F4462 in foundation course Structure 9, LON with phalanx located within maxilla**

**Table 3: Mammal bones recovered from LON (Links of Noltland) Foundation Course, Structure 9**

| **Species** | **Element** | **No** | **Comments** |
|---|---|---|---|
| Cattle | Skull | 28 | *No mandibles attached, 18 adults, 5 sub-adults, 2 juveniles, 3 not determined* |
| | Pelvis (demi) | 6 | *2 L&R pairs and two L pelvis, adults* |
| | Mandible | 6 | *1 adult, 2 sub-adults, 1 juvenile, 2 calves* |
| | Articulated post-cranial | 2 | *Neonate 1/2/3 phalanges;*<br>*3 carpals (hamate, lunate, trapezium)* |
| | Additional | | *Foot bones, vertebrae, ribs, scapulae, humeri radii ulnae, femur, tibia and loose teeth plus additional mandible and pelvis fragments* |
| Red deer | Antler | 3 | *1 shed, 1 attached to pedicle, I not determined* |
| | Additional | | *Includes foot bones, vertebrae, pelvis, tibia, loose teeth* |
| Sheep | Skull | 2 | *2 adults, no mandibles attached* |
| | Mandible | 4 | *Partial bones, 3 adults, one juvenile* |
| | Maxilla | 2 | *2 sub-adults* |
| | Articulated post-cranial | 1 | *Articulated cervical vertebrae (V3-V6)* |
| | Additional | | *Foot bones, vertebrae, ribs, scapula, humerus, radius, ulna, pelvis, femur, tibia and loose teeth plus additional mandible fragments* |
| Pig | Skull | 1 | *1 zygomatic skull fragment* |
| Pig | Additional | | *Foot bones* |
| Otter | Skull | 0 | |
| | Additional | | *Foot bones, vertebrae, radius, tibia and loose teeth* |
| Vole | Skull | 1 | |
| Vole | Mandible | 3 | |
| Vole | Additional | | *Humerus, femur and loose teeth* |

Additionally long bone portions, with spiral breaks mid-diaphysis, were recovered adjacent or directly over the skulls:

- F4254, humerus, proximal and femur proximal, fused
- F4261, radius, distal, fused
- F4468, femur, distal, fusing
- F6716, radius, distal, fused
- F6699, humerus, proximal and radius, distal, fused

Six cattle mandibles with complete or partial tooth rows included four which reflected the age range of the skulls (one juvenile, two sub-adults and one adult).
However another two calf mandibles, one left and one right, associated with skulls F6701 and F4256 had estimated ages of 3-4 months old, and did not reflect the ages of the cattle skull deposit. Some cattle neonatal bones such as a calcaneus adjacent to skull F6852; a carpal adjacent to skulls F4257/48 and a longitudinally unfused metapodial fragment adjacent to skull F6718 were also present.

Three cattle mandibles in the foundation course displayed cut or cut/scrape marks (i) below the condyle (ii) posterior to the tooth row (iii) buccal side of the horizontal ramus. Although mandible/skull separation is a trauma listed as fourth of twenty-six forms of natural dislocation of large ungulates (Hill, 1979, p742), in this case there appears to be evidence of *"post-mortem"* manual intervention.

Two sets of articulated bones were recovered and may be primary butchery discard:

- Sequence of adult sheep cervical vertebrae (F9774) V3-V6
- Possible sequence of neonatal cattle phalanges 1st, 2nd and 3rd, adjacent to skull F4255

In addition, four cattle epiphyses could be retrofitted to their diaphyses; (i) two 1st phalanges associated with skulls F4253 and F6852 (ii) a proximal epiphysis and tibia diaphysis, associated with skull 6718 (iii) epiphysis and 1st sacral segment, associated with skull F6707. It is also possible that three left cattle carpal bones (hamate, lunate and trapezium) associated with skull F4462 were in connection. No bone caches were noted.

Evidence of butchery on cattle post-cranial bones with the Structure 9 foundation course included marks left by cutting and chopping. Many factors affect the placement and orientation of cut marks, so it is difficult to be precise on the function of a particular class of marks (Lyman, 1987, p264). Mid-diaphysis spiral breaks were noted on eleven long bones with proximal or distal portions present. In addition, there were six spiral/longitudinal fractures on metapodial bones, perhaps to extract marrow, to produce pot-sized portions and/or blanks for tool working (Marshall, 1989, fig 1, reproduced in Lyman, 1994, p319, fig 8).

Evidence of butchery on post-cranial cattle bones from foundation course, Structure 9, therefore suggests exploitation for meat; spiral breaks in longbones the extraction of marrow. Only 1.4% of cattle bones were burnt (all categories), by weight, perhaps indicating that roasting was not the predominant cooking method, although if there had been extensive charring this would make the meat on the bone inedible.

#### 4.2.7.3 Red deer antlers

Three antler beams were deposited in the foundation course, Structure 9. Antlers F4469 and F6690 were adjacent to skull F4468, west foundation; the third adjacent to skull F4254, east foundation. One of the antler beams, F4469 was lifted by the conservator but, even with careful treatment, disintegrated on removal from the underlying substrate. The other two antlers also lost structure, shape and definition on excavation. See *Photograph 18*. Another antler was recovered from the infill of Structure 9 (F6306).

**Photograph 18: Deposition of red deer antler F4469 in foundation course, Structure 9, LON © G. Wilson**

Antlers F6690 and F6306 was shed; the antler adjacent to skullF4254 attached to a pedicle/frontal bone and the status of F4469 could not be determined. Two antlers measured in the field had maximum medial lengths of 550mm (F4469) and 570mm (F6690). These antlers are discussed further in the red deer section of *Chapter 5.*

### 4.2.8 Overview of Structure 9 foundation course skull deposits

A minimum of twenty-eight cattle skulls and two sheep skulls were deposited in the foundation course, Structure 9 during the Late Neolithic. Cattle pelves and red deer antler were included in the deposit. All these bones were hidden within the building structure after deposition. The skulls had been carefully positioned between foundation stones, all but one lying on the frontal bones with horn cores projecting backwards into underlying midden material. Most skulls faced into the building and distributed at varying distances from each other, the closest ones overlapping. Inconsistent spacing might suggest that more than one person laid the skulls into the foundation. The number of skull bones present, and the condition of these bones, varied.

Maxillary teeth were only present in twelve cattle skulls. Based on the assessment of these teeth, and other age indicators such as suture closure, it was deduced that there were fifteen adult/older adult cattle skulls, three young adults, five sub-adults, two juveniles and three unknown. Male and/or castrates as well as female cattle skulls were present and not deposited in segregated groups. There is no evidence to suggest the cattle were in poor health or debilitated by congenital problems. The age of the sheep skulls was not determined. Six cattle mandibles recovered in the foundation course had similar ages to those of the cattle skulls, but two others did not, being from young calves.

## 4.3 Structure 18 skull deposits

### 4.3.1 Introduction

Structure 18, known as “Grobust” in the earlier excavation by D. Clarke, is a Late Neolithic structure built into sand dunes and has surviving wall courses almost up to original roof level in some sections. This structure is located to the north/north-east of Structure 9, and comprises an entrance passage, two main chambers, Room 1 and Room 3, both which have cells leading from them, and a passageway linking Room 1 and 3, abandoned at a later stage and filled with the remains of cattle and sheep skulls. Clean windblown sand in the passageway was covered with brown sandy silt containing remains of otter spraints. Otter bones were also recovered from the fill and it appears that after abandonment there was an extended sequence of animal activity and gradual silting of this passageway (Moore and Wilson, 2013).

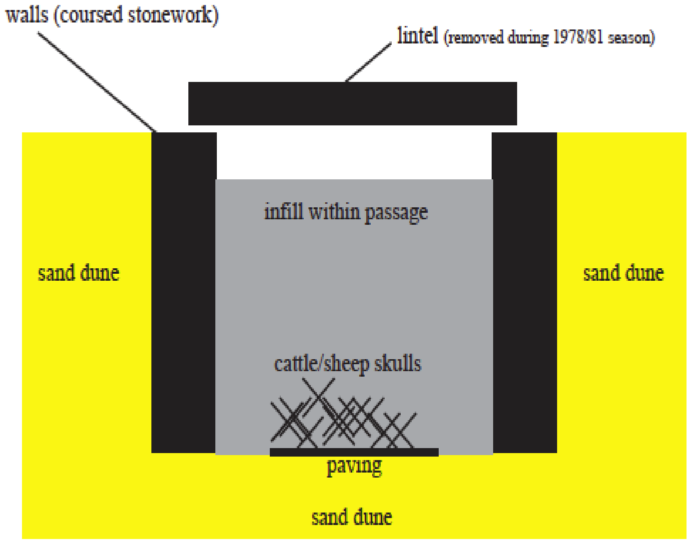
Skulls from Structure 18 were examined in order to highlight similarities and differences between this deposit and that of Structure 9. Only one cattle skull (F19904) has root etching on the bones, indicating that almost all the skulls were protected from overlying plant growth once in final position.

Two cattle skulls from the niche in North Cell, Room 1 (F19946 and F19948), one sheep skull (F19470) from recess Room 1, two sheep skulls from NNE cell, Room 1 (F19598 and F19621) one red deer skull (F19805) from the door-check to the passageway between Room 1 and Room 3 were also examined.

### 4.3.2 Position of skulls

The skulls from the passageway were intertwined, as if used as packing material. There was no obvious orientation, with some skulls basilar side up, others on their frontal surfaces but they may have been more carefully placed initially and then subsequently collapsed. For an illustrative position of skulls see *Figures 7 and 8.*

Links of Noltland, Westray, Orkney
Structure 18: Illustrative section across passageway connecting Room 1 and Room 3.
Shows location of cattle /sheep skulls



(building constructed within pre-existing sand dune)

**Figure 7: Illustrative plan of excavated deposits for Structure 18 © EASE Archaeology 2015, please do not reproduce or use without permission**

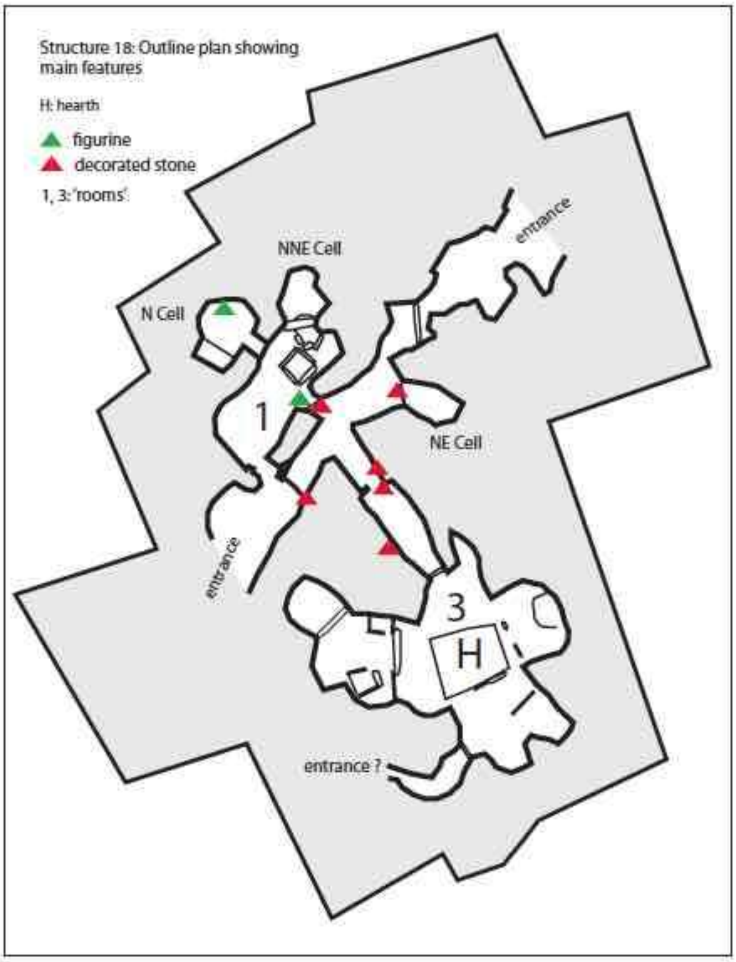


Figure 8: Structure18 outline plan (Moore and Wilson, 2013)

### 4.3.3 Condition of skulls

The skulls recovered from the passageway were not as damaged as the cattle skull deposit, Structure 9, allowing some observations on morphology. For example, fragments from four recovered skulls (F19853, F19854, F19874 and F19876) were sufficiently complete to show that the intercornual ridge was probably a double low arch. At least two skulls F19946 (niche, North Cell) and F19880 appeared to have a single arch (Grigson, 1976, p138).

Structure 18 cattle and sheep skulls were removed directly after exposure during excavation and bone weathering assessed. One cattle skull from the niche, North Cell was in “excellent” condition, another in “good” condition. Both were represented by the neurocranium, retaining neither the maxilla nor premaxilla bones.

Cattle skulls blocking the passageway displayed more variation although none were in “poor” condition. Using skull numbers as defined by find numbers, twelve skulls were in “excellent/good” condition. In addition two skulls (F19851 and F19897b) were in “good” condition apart from the occipital bones, which was beginning to crack and flake. Another three skulls (F18884a/b and F19898b) were in “fair” condition.

Several skulls had frontal/parietal bones beginning to crack and flake (F19895b, F19884a/b, and F19882b). Other skulls had cracking on the maxilla, lacrimal, temporal and zygomatic bones (F19865, F19896 and F19880). It is of noted, however, that internal bones from some of these skulls (e.g. basisphenoid/ sphenoid and/or internal temporal bones) were in “excellent condition”.

Six sheep skulls blocking the passageway were in “good” condition and two (F19898 and F19879) in “fair” condition, with some flaking of bone. The two sheep skulls from NNE Cell Room I and the one from the recess, Room 1 were in “good” condition. The red der skull was also in “good condition”. As with the cattle skulls, most sheep skulls and the red deer skull appeared to have limited exposure to weathering. No burning marks were noted on the skulls apart from blackened condyles on one sheep skull (F19856) from the passageway.

### 4.3.4 Excavation

The skulls were excavated by EASE Archaeology, placed in a separate bag or box and allocated a unique find number. However, since the skulls were interlocked, this resulted in bones from more than one skull being allocated the same find number, leaving various options on how to calculate the number of skulls present. If cattle skulls from the passageway between Room 1 and Room 3 are calculated using Minimum Number of Individuals (MNI) there are 15 cattle skulls (based on sphenoid, 14 if based on right frontal or occipital). If calculated by find numbers, plus additional skull bones associated with each find number, 23 cattle skulls are represented. It is probable that the actual number lies between these 15 and 23. See *Appendix 10.* Most skulls are represented by neurocranium bones, with only five having maxilla bones and associated teeth.

Sheep skulls from the passageway, based on a MNI calculated using left frontal bone is eight; ten if find numbers and associated skull bones are added together. Only one maxilla bone containing teeth was present but three sheep demi-mandibles were recovered. Three additional sheep skulls came from Room 1. As with cattle skulls, the most consistent representation was the aboral neurocranium section of the skull; the occipital, parietal, posterior section of frontals as far as orbits and including horn cores, and in some instances the petrous bones.

The amount of skull bone surviving varied. For cattle skulls recovered from the passageway between Room 1 and Room 3, weights ranged from a minimum of 47.6g (19898b) to 911.2g (F19851). The weight of bone recovered from the two cattle skulls from North Cell, Room 1 were 221.3g (F19946) and 124.0g (F1948). No cattle skull weights approached the maximum weight of skull recovered from Structure 9 (2877g). The greatest fragment length from cattle skulls varied for 75.1 to 268mm. See *Appendix 11*.

For sheep, weight of skulls in the passageway ranged from a minimum of 34.1g (F19865) to a maximum of 133.0g (F19856) and 63.8g from the skull in the recess, Room 1 and 93.3 and 90.7g for skulls in the NNE cell, Room 1. The weight of the red deer skull was 94.7 g.

## 4.3.5 Cattle skulls

### 4.3.5.1 Sex

Eleven cattle skull horn cores from the passageway and one cattle skull from North Cell, Room 1 were sufficiently intact to measure basal circumference. See *Table 4.*

**Table 4: Structure 18, cattle basal horn core dimensions (mm). Key circ.-circumference, dia.-diameter**

| Find | basal circ. (mm) | basal min dia. (mm) | basal max dia. (mm) | basal min/max dia. ratio |
|---|---|---|---|---|
| *19881* | 159 | 41.6 | 58.2 | 0.71 |
| *19882a* | 164 | 42.6 | 55.8 | 0.76 |
| *19875b* | 166 | 41.9 | 59.3 | 0.71 |
| *19854* | 170 | 45.6 | 62.5 | 0.73 |
| *19853* | 171 | 43.6 | 60.4 | 0.72 |
| *19898a* | 172 | 45.8 | 59.3 | 0.77 |
| *19874* | 177 | 44.2 | 66.7 | 0.66 |
| *19897a/b* | 178 | 44.8 | 59.5 | 0.75 |
| *19863* | 182 | 46.7 | 62.2 | 0.75 |
| *19880* | 189 | 49.7 | 66.3 | 0.75 |
| *19875a* | 189 | 50.0 | 65.4 | 0.76 |

Nine horn cores came from adult skulls based on suture closure status, and all appeared to be female, based on the basal circumference measurements (159-189mm) although two cattle skulls (F19880 and F19875a) were at the top of the published range for Neolithic cow horn core basal circumferences.

The horn cores all curved laterally from the frontal, then upwards and forwards, defined as the beginning of a *primigenius* spiral (Grigson, 1976, p133). Minimum to maximum diameter index of these horn core bases varied from 0.66- 0.77 indicating oval basal cross-sections. If the assumption that these nine skulls were female, based on horn core circumferences, is correct, the cross-section indices contradict the classification system which states bulls have oval horn core bases, females round (Armitage and Clutton-Brock, 1976, p345). At The Mid Neolithic site of Knap of Howar, the cattle horn cores with basal circumferences indicating they are female have index ranges from 0.77-0.88, the males from 0.85-0.90, again not conforming to the suggested pattern that females have more rounded horn core bases.

Alternatively, these skulls were from male cattle of diminished structure, but if so, other evidence from the LON site suggests this did not occur during the Neolithic period (See *Chapter 9*).

A more recent examination of thirty-five 19th and 20th century cattle horn cores noted that although the most circular basal cross-sections were female and the most elliptical were male, overall there was no consistency in cross-sectional shape (Sykes and Symmons, 2007, p 518), perhaps giving support to the lack of round horn core bases from Orcadian Neolithic cow specimens.

Two Neolithic horn cores from Woodhenge, Wiltshire, with basal circumferences of 161 and 173mm were allocated to bulls based on basal cross-section shape (Armitage and Clutton-Brock, 1976) and this also informed the sex identification for two horn core fragments with oval basal circumferences of 156 and 164mm, recovered from the Late Neolithic/Chalcolithic site of Newgrange, Ireland (Wijngaarden-Bakker, 1986, p30), but results from LON and KOH may suggest this sex allocation is open to challenge.

Only one set of horn cores were intact (F19880) and these had an outer curvature length of 240mm, defining it as “long-horned” (Armitage and Clutton-Brock, 1976, p 331).

#### 4.3.5.2 Age

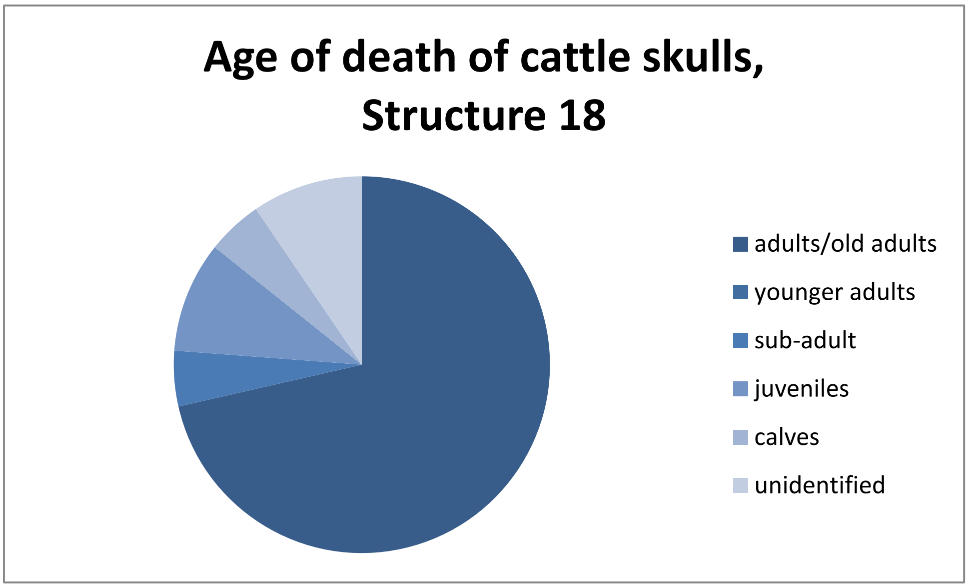
Age estimates of skulls were produced based on examination of maxillary teeth, horn core texture, perlen growth, and skull suture closure. The cattle age codes followed those applied to the Foundation deposit, Structure 9:

| | |
|---|---|
| Calf: | <12months |
| Juvenile: | 12-24m |
| Sub-adult: | 24-36m |
| Young adult: | 36m-48m |
| Adult/older adult: | 48m+ |

Two cattle skulls were calves, having only horn buds, one in North Cell, Room 1 (F19948) and one in the passageway (F19882b). Another skull from the North Cell Room 1 (F19946) had horn core textures associated with a juvenile (category “1”) and a horn core circumference of 110mm. This estimated age was confirmed by suture closure status (Grigson, 1999, p218, fig 172). The other horn core from a young animal was from the passageway (F19882a) and had a basal circumference of 164mm and an outer curvature length of 186mm. These horns were curving outwards with ridges and open pores (category “3”, Armitage 1982), perhaps indicating a male.

Five skulls retained maxillary teeth (F19851, F19864, F19875, F19884a and F19896). All had erupted permanent teeth and were thus considered to be adult. Only one set of maxillary molar $M^3$ had pillars engaged, indicating an older adult (F19875). All these age categories are confirmed by fusion status of skull sutures (Grigson, 1982, Appendix 1). Another ten cattl4e skulls from the passageway are also adults, based on fusion status of the sutures.

Based on ageing criteria, there are at least fifteen adult cattle, ten of which may be older than 7 years, one sub-adult, one juvenile and one calf in the passageway, and one calf and one juvenile in the North Cell, Room 1, see *Graph 6 and Appendix 12.*



**Graph 6: Estimated distribution of cattle skull age at death LON (Links of Noltland) Structure 18 (No 21)**

### 4.3.5.3 Anomalies/pathology

Two bone perforations (greatest lengths of 6.7 and 5.3mm) with smooth edges that penetrated the parietal/frontal margins were noted on skull F19854. Neurocranium perforations have been recorded from other prehistoric north-western European cattle assemblages, the earliest being the Neolithic site of Spiennes, Hainaut, Belgium (Brothwell et al., 1996, p471). Brothwell and his colleagues deduced that these perforations were not caused by parasites, tumours or infection and were either genetic or associated with head-yokes (Brothwell et al., 1996). Subsequent identification of skull perforations from a European bison dated 2000 BC (Manaseryan et al., 1999) and a possible aurochs deposited in a Neolithic ring ditch at Letchworth, Hertfordshire (Baxter, 2002) reduces the link between skull perforations and draft exploitation (Bartosiewicz and Gál, 2013, p167, Fabiŝ and Thomas, 2011). It is therefore probable that LON cattle neurocranium perforations were associated with a hereditary defect.

Other anomalies noted included (i) skull F19898 having two perforations on the frontal bone anterior to the supraoccipital groove (ii) skulls F19896 and F19884 with a double infraorbital foramen on maxilla (iii) skulls F19884 and F19851 with only one foramen in the condyloid fossa of the occipital. If these anomalies are also hereditary this may point to some degree of inbreeding or at least drift within the LON herd, but without large data sets it is difficult to establish the extent of natural variation. There is no record of these anomalies in cattle pathology reports from other Neolithic Orkney settlement sites The only record of a cattle skull perforation in Orkney is from the Pictish and Viking site of Buckquoy, a 17mm diameter perforation midway between the horns (Baker and Brothwell 1980, p37, Noddle in Ritchie, 1976, p207).

No evidence of horn core restructuring to indicate possible habitual tethering or yoking was noted from the Structure 18 LON horn cores, a practice from in 16th-19th century Orkney (Fenton, 1997, p431). A wooden Bronze Age yoke held in the Shetland Museum (ARC 692) indicates that in this period the plough was attached to the neck of two cattle, not horns.

Some pathological features were noted, but none extensive. Ridges of cementum were present on a maxillary molar $M^3$ from skull F19896. In addition two skulls had areas of porous bone, F19884 adjacent to the left frontal orbit, and F19851 adjacent to both frontal orbits and anterior premaxilla. One of these skulls (F19851) also had some additional bone growth on the right zygomatic orbit fragment and adjacent to the occipital condyles. Some remodelling of bone was noted on the occipital bone of skull F19904, the frontal ridge of skull F19853 and the frontal orbit of skull F19898.

Finally, there were some minor pathological lesions expressed on three cattle maxillae, F19864 had bone loss on the lingual side, above the left $M^1$; F19875 had porous bone, located buccally below the right toothrow; and F19851 had the lingual proximal root of $P^2$ exposed.

#### 4.3.5.4 Modifications

Cut and scrape marks were noted on four skulls. These cuts and scrapes may have been associated with skinning and filleting (Binford, 1978, p91, Trolle-Lassen, 1990, p14, fig 9). The cut marks on the zygomatic may be associated with detachment of the mandible by freeing the masseter muscle (Gifford-Gonzalez, 1989b, p205). See *Table 5.*

**Table 5: Modifications on cattle skulls Structure 18**

| Skull | Location of cut/scape marks |
|---|---|
| F19851 | Zygomatic, temporal, frontal, maxilla |
| F19896 | Zygomatic, maxilla |
| F19882 | Frontal |
| F19904 | Frontal |

In addition, two occipital condyles may have been sliced, F19882 and F19884, although this feature was not noted on other skull fragments with intact occipital condyles. This may indicate that some, but not all, skulls were removed from the body at the occipital condyle/atlas connection.

Two skulls (F19853 and F19904) had breaks on the frontal bones located aborally from of the orbits with cracks emanating from them and it is possible that this may be an indication of pole-axing. Skull F19851 had a U-shaped break in the frontal.

#### 4.3.5.5 Measurements

Two skulls (F19851 and F19864) assumed to be females, had molar tooth row measurements of 77.9 and 79.0mm respectively. These measurements were lower than those from the Structure 9 deposit, although close to F4256, 80mm (field measurement), also considered to be a domesticated female based on horn core dimensions. The greatest length of the occipital from skulls F19851 and F19880 were less than measurements from Structure 9 (two male, one not attributed).

Cattle skull F19875 had the most worn teeth from cattle skulls in Structure 18 but the cervical length, buccal, from $M^3$ was also greater than the other cattle skull teeth from this deposit.

### 4.3.6 Sheep and red deer skull

#### 4.3.6.1 Sex

The only measurable sheep horn core circumference (F19904) was 107mm. If it is from the same animal as the maxilla from a 3-4 month old lamb, also given find number F19904, may be male (Clutton-Brock et al., 1990, p 47). The red deer skull, F19805, may be a young female, based on lack of rudimentary antler pedicles on the skull.

#### 4.3.6.2 Age

Four sheep skulls included maxilla. Two (F19884 and F19904) had $M^1$ erupted, but not in wear, indicating an age of approximately 3 to 4 months (Simonds, 1854). The other two skulls with maxillary teeth (F19854 and F19856) had adult dentition. The fusion of skull sutures reveals that F19879 and F19898 were also adults, based on observations from feral goats (Bullock and Rackman, 1982, table 2, p76). Overall there was a minimum of two lambs and four adults deposited in the Structure 18 passageway. The two sheep skulls from the NNE Cell in Room 1 and one from the recess, Room 1, were adults.

The red deer maxilla contained $dp^2$, $dp^3$ and $dp^4$ teeth and a molar $M^1$ tooth erupted but not in wear, giving an age of approximately 4 months (Brown and Chapman, 1991, p94) or approximately 5 months (Mitchell, 1967, fig 3, p285).

#### 4.3.6.3 Anomalies/pathology

One sheep skull (F19879) had horns that were “small inconspicuous knobs” (Clutton-Brock et al., 1999, p16). This skull was from a female or castrate adult sheep. Another skull (F19872) had no horn cores and must be of a female, if the same pattern as Soay sheep is followed. Polled sheep are not mentioned in reports of Neolithic sheep from Pool, Sanday, Tofts Ness, Sanday, Skara Brae, Mainland, or Pierowall Quarry, Westray (Bond, 2007, Nicholson and Davies, 2007, MacCormick, 1984). They are, however, recorded from the Neolithic cairn of Holm of Papa Westray North (Harman, 2009, p51) and settlement of Knap of Howar, (Noddle, 1983, p97). In the modern feral population of Soay sheep on Hirta, St. Kilda regarded as a primitive breed, 15% of rams are scurred, 35% of females are scurred, and 30% polled a far higher incidence than in Neolithic Orkney (Clutton-Brock et al., 1999, p29). No anomalies or pathology were noted on the red deer skull (F19805).

#### 4.3.6.4 Modifications

One sheep skull (F19865) had a hole in the left parietal/temporal bones with cracks emanating from it and may have been associated with dispatch. There was only one series of cut marks noted on sheep skulls, on the temporal bone of F19856. Four skulls from the passageway (F19862, F19865, F19879 and F19885) and two from the NNE Cell, Room 1 (F19598 and F19621) were broken mid-frontal, but it is not possible to state whether these animals had been pole-axed. No modifications were noted on the red deer skull.

#### 4.3.6.5 Measurement

Several measurements from sheep skulls were recorded. The greatest breadth of occipital condyles from two skulls was compared with published results from Soay sheep of known age and sex, as well as a sheep skull recovered from the Neolithic cairn of Quoyness, Rousay The greatest length of occipital condyles for F19865 and F19898 were greater than the range for female Soay sheep, but within the range for males and castrates. The Quoyness sheep skull dimension was greater than Structure 18 and all modern Soay sheep dimensions (Clutton-Brock et al., 1999, p47, Zeuner, 1952, p189).

### 4.3.7 Additional post-cranial bones associated with skull deposits

Few cattle and sheep post-cranial bones were associated with Structure 18 skull deposits. See *Table 6.*

There is a sequence of thoracic vertebrae from a calf, V6 and V7 and other thoracic and cervical vertebrae fragments may be from the same animal, based on state of fusion. Two fragments appeared to have canine gnaw marks on them. In addition, there was a substantial portion of a left mature cattle scapula, with only the distal blade missing and cut marks adjacent to the glenoid cavity. Eight bone fragments were retrofitted to obtain measurements from this scapula (weight 225.3g). This bone has the 3rd largest “GLP” measurement (70.5mm) from this study and slightly larger than the range listed for D. Clarke excavation, (67.5-70.2mm) (Armour-Chelu, 1992, p315). The “LG” and “BG” measurements are within the lower range for female *aurochs* from Danish settlements (Degerbøl and Fredskild, 1970, p192/193), so the bone either came from a large domesticated male or a small female aurochs.

In addition to the red deer fawn skull, a distal portion of a mature red deer radius was recovered, broken with a spiral break mid-diaphysis. Long thin cut marks, and some scrape marks, were noted on the diaphysis, indicating this bone had been butchered.

The sheep bones included a complete atlas from a mature animal and some cervical fragments from a lamb/juvenile. There was also a small fragment of proximal unfused humerus and an unfused acetabulum fragment from a right sheep pelvis. Three sheep mandibles, two right ones from lambs, 3 to 4 months old, that could partner the lamb skulls recovered from the deposit and a left mandible with full adult dentition and cut marks on the buccal ramus were recovered. Finally, there was a mature sheep sacrum, 1st to 3rd segments, associated with F19872.

**Table 6: Mammal bones recovered from LON (Links of Noltland) passage, Structure 18**

| **Species** | **Element** | **No** | **Comments** |
|---|---|---|---|
| Cattle | Skull | 19 (15-23) | *1 calf, 2 juveniles, 1 sub-adult, 15 adult* |
| | Post-cranial articulation | 1 | *Calf vertebrae V6-V7* |
| | Additional | | *Vertebrae and scapula* |
| Red Deer | Skull | 1 | *1 female fawn* |
| | Additional | | *Vertebrae, radius* |
| Sheep | Skull | 8 | *4 lambs, 4 adults* |
| | Mandible | 7 | *6 lambs, 1 adult* |
| | Additional | | *Foot bones, vertebrae, scapula, humerus, radius, pelvis* |
| Otter | Skull | 0 | |
| | Additional | | *Foot bones, vertebrae, ribs, foot* |
| Vole | Skull | 3 | |
| | Mandible | 7 | |
| | Additional | | *Post-cranial* |

### 4.3.8 Overview of Structure 18 passageway skull deposit

A minimum of fifteen cattle skulls and eight sheep skulls were deposited with a passageway linking Room 1 and Room 3. The skulls were deposited in a random configuration, although they may have been in a more organised when first deposited and subsequently collapsed, interspersed with clean sand and a few associated post-cranial bones.

All skulls were incomplete. The proportion represented varied but in almost all cases included neurocranium bones, which would have unambiguously distinguished the species, and possibly the individual animal, to the LON community. The remains do not appear to represent a great loss of resource because (i) mandibles had been removed to allow access to the tongue, (ii) scape and cut marks indicate skinning and fileting on some skulls (iii) frontal bone breaks may have allowed access to brain. The skulls had not been further modified after butchery.

The sheep and cattle skulls in both the passageway and in the niches/cells showed only slight evidence of weathering. This may point to limited, or no, exposure after loss of protective skin and flesh prior to final deposition. Once within the passageway the skulls appear to have been protected from wind, rain and plant root damage. The only canine gnawing detected was on two calf vertebra fragments. It is not possible to establish whether the skulls were deposited during one event, or over a period of time.

The majority of cattle skulls were from adults, ten over seven years old. Nine adult skulls are probably females, based on basal horn core circumferences, but horn core basal index guides contradict this. There was also one sub-adult, one juvenile and one calf in the passageway, and one calf and one juvenile in North Cell, Room 1.

This cattle age configuration does not reflect the age of death profile for cattle bones from LON midden and infill contexts, with calves, juveniles, sub-adults and young adults under-represented. The preponderance of older cows, including those over seven years of age, suggests they were maintained for breeding, milking and/or traction beyond maximum meat production and slaughtered when their usefulness was declining (Legge, 1981), although the possibility that they may have been sacrificed cannot be excluded.

Sheep skulls were represented by two lambs, which must have been killed in late summer/early autumn and at least six adults. There was no representation from juveniles or sub-adults.

A few cattle skulls had chop marks on the occipital condyles but others did not, perhaps suggesting dismemberment of the post-cranial body from the skull was not identical on every occasion. The cervical and cranially located thoracic vertebrae from a calf and from sheep may reveal that, in some instances, the first few vertebrae remained with the skull. One sheep skull displayed scorching on the occipital condyles, but this was the only burning noted. These slight variations may provide supporting evidence that the skulls were not from one event, but from a series of different events.

A scapula was the only substantial post-cranial cattle bone recovered from the passageway. It could be considered that it was used as a tool when creating the closure in the passageway, or alternatively, it was a bone that was easily recognised as a cattle bone, and used to represent an animal in the same manner as the cattle skulls, as has been noted in some Neolithic continental European cattle deposits.

Four cattle skulls had an intercornual ridge with a double low arch, and two others appeared to have a single arch. The horn cores grow laterally from the skull, then upwards and outwards. One skull, with intact horn cores, was long horned. All horn cores bases were oval, including those assumed to be female, based on the basal circumference, although two horn core base circumferences were at the top of the range of the published figures for Neolithic domestic cows. In addition, one skull had a maxillary molar $M^3$ that appeared to exceed the expected dimensions for domesticated cattle. See *Chapter 9*.

One of the cattle skulls had a perforation on the frontal/parietal margin, thought to be associated with inheritance. This anomaly and others such as a double infraorbital foramen on the maxilla, variation in the number of foramen on the condyloid fossa and perforations on the frontal bone anterior to the supraoccipital groove are all recorded for the first time from Neolithic cattle in Orkney. One sheep skull had polled horns, another was hornless, but these anomalies have already been recorded in Neolithic Orkney, at the cairn site of Holm of Papa Westray North.

As with skulls in Structure 9, no horn core remodelling was detected to indicate use of rope tethers. Pathology may be age related and porous bone adjacent to orbits on two cattle skulls possibly associated with some re-absorption of bone due to either nutritional or lactation stress.

## 4.4 Similarities and differences between Structure 9 and Structure 18 skull deposits

Similarities between the animal skull depositions from foundation course, Structure 9 and Passageway, Structure 18 are as follows:

- Dominated by cattle skulls but sheep skulls present
- Wild animals may be present (possible wild cattle skull in Structure 9, and red deer fawn skull in doorway to passageway)

- Neurocranium and horn cores present although representation of other skull bones varies
- Skulls deliberately placed and covered
- Estimated ages do not reflect age of death profiles from LON midden and infill contexts
- Additional cattle bones in deposit (pelves in Structure 9, scapula in Structure 18)
- Female and males and/or castrates cattle
- Animals healthy although a few congenital anomalies noted

The differences were as follows:

- Skulls carefully placed in Structure 9, skulls intermixed with no clear orientation in Structure 18
- Calves present in Structure 18, not in Structure 9, apart from two calf mandibles
- Skulls in Structure 9 more weathered and distorted than in Structure 18
- Fewer male and/or castrate skulls in Structure 18 deposit
- Skulls from Structure 9 deposited with midden material, skulls in Structure 18 surrounded by windblown sand
- Deposition in Structure 9 at preliminary building phase, deposition at Structure 18 associated with “change of use” at Structure 18

## 4.5 Discussion of skull deposits from Structure 9 and Structure 18

### 4.5.1 Description

Special cattle and sheep skull depositions were recovered from two LON structures. These skulls were represented by a range of bone fragment numbers. Weathering and loss of maxillary teeth suggests that at least some skulls were curated prior to deposition.

The selection of skulls may have had both symbolic and practical overtones. The cattle skulls, some of which may have been individually recognisable to the community of LON or their Orcadian neighbours, represent animals from a mix of ages and from females, bulls and/or castrates.

### 4.5.2 Function

The skull (and pelves) deposit from Structure 9 was carefully laid between the inner and outer circle of stone foundations and covered with midden wall core material and small stones. Deposition occurred over a relatively short period and had no architectural function. For example, there is no evidence that skulls were laid for drainage purposes since they were not linked and had no downward profile, although use of cattle horn cores is claimed as a porous filling for land drains in 17th and 18th century Britain (Wilson, 1999, p299). Similarly, the filling of the passageway of Structure 18 with skulls had no practical building purpose; a more robust infill could have been constructed using stone pebbles. Herva defined building deposits as “not functional in terms of mechanical causation and consist of objects deliberately hidden under or in buildings” (Herva, 2005, p215).

Skulls hidden from view after deposition as building deposits and the possible display of skulls in building niches at LON aligns with two of the four categories for cattle bone treatment during the pre-historic period in the Near East, continental Europe and Britain. See *Chapter 3*. Cattle burials with, or without, humans, were, however, not noted at LON.

These deliberate depositions could be termed as ritualistic (definition “a set of fixed actions… performed regularly, especially as part of a ceremony” dictionary.cambridge.org). From a modern Western perspective ritual is considered non-functional, contrasting with practical and technological activities. However, based on ethnographic and ethnohistoric evidence, deposition of cattle skulls in Neolithic Orkney may have been viewed as a practical act, perhaps to achieve a substantive change in material conditions or enable the reproduction or renegotiation of social order (Brück, 2012, Chadwick 2012, p296).

### 4.5.3 Age of death profiles

Age of death profiles highlight that many cattle, male and female, were being kept beyond the age for maximisation of meat production. Female cattle produce more calories by producing milk and calves over a lifetime than simply being raised for meat (Legge, 1981) and since there may be female cattle over the age of seven years in the LON assemblage, it suggests that these animals may have been kept for milking, and possibly also traction. Keeping cattle “on-the-hoof” until after maximum meat production for a ceremonial occasion is, however, not beyond possibility, since resource optimisation may not have been viewed from the same perspectives in Neolithic Orkney (Twiss, 2012, p359).

### 4.5.4 Manipulation of skulls

Cattle and sheep skulls deposited in Structures 9 and 18 had not been transformed into other objects, unlike, for example twenty-one frontlets were created from red deer skulls and adapted to be worn on human heads and mask the face at the Mesolithic site of Star Carr, Yorkshire (Clark, 1954, Conneller, 2004, Hutton, 2013, p27, Mithen, 2003, p137). There was also no indication that occipital bones had been removed or manipulated so that the cattle and sheep skulls could be hung against a building or a mounting, a feature of cattle skulls from a Viking farmstead/ meeting room at Hofstadir, Iceland (Lucas and McGovern, 2007, p11). Neither was there any evidence that the cattle skulls were trimmed to retain only horns and frontal bones, as was noted, for example, at the Sudanese Neolithic burial site in Kerma, Sudan (Chaix, 2001).

Neolithic cattle from Skara Brae, Mainland, and from Pool, Sanday may have been dispatched by pole-axing (Bond, 2007a p226, Illustration 7.2.10, Watson, 1931, p198 and Plate LVII). This was also the conclusion from the examination of an almost complete skull from Pool, Sanday (Bond, 2007, p226 Illustration 7.2.10). However, another interpretation of cattle skull damage could be that skulls had undergone post-mortem crushing and this could be confused with poleaxing (Armour-Chelu, 1992, p195).

One possible function for carved stone balls, mace heads and other special stone implements recovered from Scottish Neolithic settlement and ceremonial sites may have been to inflict blunt force trauma to a skull (human?)(ScARF Neolithic Panel Report) but perhaps they could have been used for symbolic pole-axing cattle during ceremonies.

## 4.6 Cattle bone depositions from other Neolithic Orkney sites

### 4.6.1 General

It is possible other Neolithic Orkney foundation structures contain similar deposits which have not been exposed by stone-robbing and subsequently preserved by midden and/or sand deposits, but no evidence has been identified to date.  It seems probable that natural deposition of some animal bones in cairns occurred. When deliberate animal bone depositions appear mature cattle skulls were not selected preferentially.

### 4.6.2 Cattle Skulls from Orkney Neolithic settlements

#### 4.6.2.1 LON

The two LON skull deposits from Structures 9 and 18  are not the only ones recorded from Neolithic sites in Orkney. Further excavation by EASE Archaeology in 2014 revealed cattle skulls adjacent to the external base course of the enclosing wall around Structure 8 and in closing deposits in hearths of Structure 7 and 21 (Area 5) (G. Wilson pers. comm.) The previous excavation of Structure 18 at LON by D. Clarke extracted two cattle skulls in the rubble infill of Room 1 along with an apparently articulated eagle skeleton (Clarke and Sharples, 1985, p68).

#### 4.6.2.2 Skara Brae, Mainland

D. Clarke’s excavations uncovered a complete cattle skull, lying in the same configuration as the skulls in Structure 9 (Noddle, 1979, pp293-294).V.G. Childe’s 1929/30 excavations produced twenty horn cores or skulls, including three semi-complete or partial skulls (Childe, 1931 Plates LVII and LVIII, Watson, 1931, p198). A skull and skeleton of a short-horned ox was reported above the collapsed slabs at the aperture of Hut 6, period IV and a complete skull of a calf on the left hand bed in Hut 7 (Childe and Paterson, 1929, Childe, 1931). A. Whittle is correct in disputing V.G. Childe’s interpretation that the inhabitants of Skara Brae lived in their own squalor (Whittle, 1988, p40) so it has to be assumed that these cattle skulls may not have been from their original location. It is also noted that cattle limb bones may have been used as structural elements in an outer wall at Skara Brae and the revetment in the cairn at Pierowall Quarry (Sharples, 1984).

#### 4.6.2.3 Pool, Sanday

At least three cattle skulls from the Neolithic midden which appeared intact when deposited, with one skull upside down on the surface of the midden, partially covered by sand, in the same orientation as LON Structure 9 cattle skulls (Bond 2007, p228).

#### 4.6.2.4 Tofts Ness, Sanday

An articulated cattle skeleton was recovered from the Neolithic midden, but interestingly, although mandibles were present, the skull was missing, perhaps for curation/deposition elsewhere (Bond 2007b, p195, Illustration 6.3.2.2, p197).

### 4.6.3 Mammal deposits in Orkney Neolithic cairns

Orkney has a remarkable concentration of cairns, burial places that may have been the focus of ancestor worship and related rituals and generally dominant in the landscape (Cummings and Pannett, 2005, Fraser, 1983, Henshall, 1985, p83, 2004, p85 Hutton, 2013, p42, Renfrew 1979, p222).

Cattle bones have been deposited in most Neolithic Orkney cairns (both Orkney-Cromarty and Maes Howe construction types), as well as sheep, red deer and a few pig, otter, dog, pine marten and sea mammals bones, but do not dominate the mammal bone collections, apart from Midhowe, where immature cattle bones were numerous (Henshall, 1985, p106). There is little evidence of cattle skull deposits, apart from fragmented immature cattle skull bones at Quoyness, Rousay which displayed evidence of butchery, along with accompanying post-cranial immature bones (Childe, 1952, p131). Although two cattle skulls and a red deer skull are reported as present in the Isbister cairn (Jones and Richards, 2003, p49), the author of the site report states that “heads and lower limbs and feet [of mammals] tended not be taken into the tomb” (Barker, 1983, Hedges, 1983, p229, Ritchie, 1959).

If feasts were held outside the cairns as part of the mortuary ritual it is perhaps surprising that so few cattle skull and post-cranial bones were recovered. It may reveal that only small numbers of people attended these ceremonies, or that feasts were not located at cairn sites, or cattle bones from the feast were not left “in situ” although it has been suggested that some Grooved ware pottery deposited within passage cairns were likely to contain cattle products (Jones, 1999, p71).

Some researchers consider animal and bird bones deposited with human dead in Orkney cairns evidence of funeral or grave goods (Clutton-Brock, 1979, p114, Morris, 2005, Renfrew 1979, p156, Richards et al., 2013, Sharples, 1984). It has even been suggested that these bones may have been totems of the particular group using the cairn (Baker, 1993, p148, Fraser, 1983, p400, Jones 1998, Morris 2005, pp10-11, Renfrew, foreword, Hedges, 1983). It is difficult, however, to interpret deposits within cairns because there may have been pre-excavation disturbance and destruction (Davidson and Henshall, 1989, p52) and recent radiocarbon dating has demonstrated that some animal/bird bones post-dated initial use of the cairns, so even if these animals represented totems or offerings they were later introductions (Schulting et al., 2010, p26). For example:

- A newborn/foetal horse bones from Quanterness, Mainland (Clutton-Brock, 1979, p118), now dated cal AD 1261
- Two sea eagle bones at Isbister cairn, South Ronaldsay, referred to as the "Tomb of the Eagles" (Hedges, 1984, title) approximately one thousand years younger than estimated construction date of the cairn (bone ages calculated using the assumption of 85%, 75% and 50% marine diet intake varied from 2459 to 2141 cal BC and 2396 to 2191 cal BC respectively) (Sheridan, 2005, p182)
- Three dog bone samples from Cuween, Mainland, associated with the deliberate deposition of dog skulls (and some post-cranial bones) in lower fills of chamber (Charleson 1902, p733, p738) dated 2677 to 2305 cal BC, indicating deposition at cairn subsequent to the estimated construction date (Sheridan, 1995, p177, p182)

In addition, radiocarbon dates from the cairns of Holm of Papa Westray North and Point of Cott, Westray, have produced animal bone dates later than those obtained for human bone, after the cairns ceased to be used for funerary purposes (Ashmore, 2009, p63, table 20, Schulting et al., 2010, p28). The dates of cattle and red deer bone from Knowe of Rowiegar, Knowe of Ramsay and Knowe of Yarso, Rousay (Renfrew et al., 1976, p202) also relate to secondary activities in these tombs (Schulting et al., 2010, p28).

An argument has been made for natural, rather than man-made, deposition of animal bones in Orkney cairn sites, particularly rabbit, otter, dog and sheep (Barber, 1988, 1997, p67 Balasse and Tresset, 2009, p81, Halpin, 1997, p48, Henshall, 2004, p87, McCormick, 1984). To support this argument it has been noted that, in recent times at St Kilda, Western Isles, a large proportion of dead feral Soay sheep have been recovered from cleats (small stone huts) or ruined buildings, indicating these structures were used for shelter by ill or starving animals prior to death. F. McCormick suggested that Pierowall Quarry, Westray, and other Orkney cairns may have been used for the same purpose by young and ill sheep, producing a large number of naturally deposited animal skeletons within, or in the forecourt, of cairns

(McCormick, 1984, 2:D14), although this view is not endorsed by the excavator (Sharples, 1984, p111).

Following the same theme, it is possible that sea eagles at Isbister were attracted by carrion at the cairn and used them as nesting sites (Halpin, 1997). Dog and otter may have made use of cairns as lairs (Halpin, 1997, p47, p50) leading to prey being imported into the cairns, but this does not explain the lack of gnawing on the bones (Barker, 1983, Clutton-Brock, 1979). A. Henshall also considers that otters, foxes, dogs and large birds used cairn interiors for dens or roots (Davidson and Henshall, 1979, p87, Henshall, 2004, p87-88). J. Barber goes further, suggesting that animal bones in tombs can only be considered part of the funerary rites if “unequivocal evidence for their association with the funerary function of the tombs has been recovered” (Barber, 1988, p61).

While agreeing with the weight of evidence for natural depositions of smaller animal bones within cairns A. Ritchie argues that large animal bones, such as those of red deer and cattle, must have been introduced because their size would limit their access to the tombs, even if open, and because it was not red deer behaviour to enter enclosed spaces (Ritchie, 2004, p97, p102). Also, in contradiction to the growing body of opinion of the natural deposition of bones within cairns, a recent publication suggested that animal bones from Vesta Fiold, Mainland, were deliberate inclusions in the cairn during construction (Richards et al., 2013, pp170-171).

Concerns have been expressed that faunal materials from Orkney settlements such as Skara Brae, Mainland, have not be compared to those of cairn sites (Hodder, 1992, p34). However, as discussed above, there is a certain ambiguity as to the sources and timing of cairn animal bone deposits. The main point, in terms of comparison between Orkney cairn deposits and LON cattle and sheep skull deposits, is that there is no evidence of mature cattle and sheep skulls being selected for deposition within the Mid to Late Neolithic Orkney cairns either during primary or secondary activities, apart from one sheep skull at Quoyness, Rousay.

### 4.6.4 Mammal deposits at Orkney Neolithic ceremonial sites

At the ceremonial site of Ness of Brodgar, at Structure 10, during decommissioning ca 2300 cal BC, a cattle skull had been placed at the base of a bone deposit with most surrounding post-cranial bones also being from cattle (75% of sample examined are tibiae) (Card and Thomas, 2012 p117, Mainland et al., 2014).

Within ditches at the Late Neolithic ceremonial site at Stones of Stenness sheep, cattle, human and wolf/dog bones were recovered. The cattle bones included mandible fragments from a neonatal and juvenile animal, as well as a maxillary fragment from a calf less than six months of age. An adult cattle mandibular molar, $M_3$, a section of mandibular ramus, a fragment of a cervical vertebra and several adult and juvenile foot bones were recovered. J. Clutton-Brock suggests that it is “difficult to make any inferences about the sporadic collection of mammal bones from the ditches… could represent unwanted refuse from food, sacrifice, clothing or artefact manufacture” (Clutton-Brock, 1975/76, p36). There does not appear to be any evidence that there was deliberate deposition of cattle skulls at this site.

## 4.7 Human deposits from Orkney Neolithic settlements

There was a foundation deposit at Neolithic Skara Brae, Mainland, but in this case, it was not cattle skulls but two female skeleton encased in a tomb that formed an integral part of Hut 7 so that “their ghosts might sustain that structure” (Childe and Paterson, 1929, p257, Childe, 1931, pp140-142). Also, at the Neolithic settlement of Barnhouse, in the floor of the Ceremonial House 2, there was a covered pit containing highly degraded bone fragments, which may have been human or animal (Richards, 2005, p137), another potential foundation deposit. These finds illustrate that the concept of using hidden, previously living, deposits to animate building was not unfamiliar to Late Neolithic societies in Orkney, assuming that these deposits were not a later insertion.

## 4.8 Comparison in treatment between human and cattle skulls in Neolithic Orkney cairns

Comparison with treatment of human skulls in Orkney cairns offers an additional route of inquiry to LON cattle and sheep skull depositions. The following cairns contained human skulls separated from post-cranial bones:

- At Midhowe, Rousay, in addition to articulated crouched inhumations, nine severed human skulls, some placed in an upright position (Henshall, 1985, p100)
- At Knowe of Yarso, Rousay, an unorganised deposit of post-cranial human bones and over twenty-four adult skulls with no mandibles retained (Callander and Grant, 1935, Henshall, 1985, p102, Noble, 2006, p135)
- At Isbister, South Ronaldsay, human skulls stored along one side of the chamber, together with piles of other bones (Henshall, 1985, p103)

- At Cuween, Mainland, at least six detached human skulls and another within blocking material of roofed entrance (Charleson, 1902)
- At Quoyness, Sanday, detached skulls recovered from side-cells and in two cists to right and left of entrance passage (Childe, 1951, Farrer, 1868)
- At Holm of Papa Westray North complete and partial skulls some with teeth missing indicating later repositioning (Harman 2009b, p44)

In contrast, the cairn at Quanterness, Mainland, had fewer skulls than expected if post-cranial bones are used to calculate minimum numbers of individuals (Chesterton, 1979, p102) but this cairn was not fully excavated so it is possible that the skulls had been moved to side chambers, or alternatively, removed from the cairn.

Deposition of human skulls was not exclusive to Orkney since Neolithic sites in the Clyde region, Torlin and Clachaig in Arran also contained amalgamated human skeletons with skulls lying in the corner of compartments (Noble, 2005, p32, 2006, p132).

It is of interest that at Holm of Papa Westray North, four human skulls were selected for incorporation into filling that sealed off an end cell, along with two otter skulls and five sheep skulls, thought to have been acquired from the main chamber of the cell itself (Ritchie, 2004, p100). Although the excavator does not discount the possibility that material was randomly gathered in the darkness of the cairn, it does appear that this blocking exercise did include the deliberate inclusion of human skulls and perhaps presages the cattle and sheep skulls used to block the passageway in LON, Structure 18.

Although J. Chesterton considered that human remains had been excarnated externally in Mid-Neolithic Orkney prior to inclusion into cairns of Quanterness and Isbister (Chesterton, 1979) this method of preparation has now been challenged (Barber, 1997, p85, Henshall, 2004, p85, Lawrence, 2006, p57, Reilly, 2003, pp151-152, Ritchie, 2009, p30, Schulting et al., 2010, p9), although decay of bodies within the cairns prior to further manipulation or removal/redisposition of certain bones is not discounted (Lawrence, 2006, p57, Reilly, 2003).

Familiarity with curation and handling of skulls and other non-articulated human bones therefore existed in Mid Neolithic Orkney and other regions of Scotland, and these dry remains may have been infused with meaning. Evidence indicates that LON deposited cattle skulls and pelves were butchered, so their skeletons would be divided soon after death, but the same process of excarnation, curation and deposition could have been applied to selected animals. The difference, however, between human and mammal skulls is that their curation and deposition was associated with a Late Neolithic LON settlement, not with the Mid Neolithic Orkney cairns and there is no evidence that cattle and human skull depositions were inter-mixed.

Removal and special treatment of human skulls can be traced back to the earliest Neolithic communities in the Near-East, starting in the 10th to 9th millennium BC and lasting to the end of the 7th millennium BC. Often the skulls were plastered, and embellished, and sometimes buried in skull nests, with one of the most well documented examples being from Jericho where a circle of skulls all look inwards (Clarke, 1977, p52, Lewis-Williams and Pearce, 2005, p75, p78, Schmidt, 2007, p35, p39). Human skulls were also buried in prominent locations at the Early Neolithic causewayed enclosures in Britain, for example, Abington, Oxfordshire; Offham Hill and Whitehawk Camp, Sussex; Staines, Surrey; Etton, Cambridgeshire; Hambleton Hill, Dorset (Edmonds, 1999, Healy et al., 2011, p115, Jones, 2008, p182).

Separated human skulls may be the relicts of ancestors and perhaps deposited to provide legitimacy for occupation of land or to make connections with the past (Jones 2008, p178, Noble, 2006, p135). However, other reasons for skull deposits have been proposed such as trophy heads or sacrificial victims (Bongogfsky, 2005, Lewis-Williams and Pearce, 2005, pp80-81, Schmidt, 2007, p59).

It is remarkable that the removal of skulls, first noted in the 10th/9th millennium BC in the Near East should have echoes in the deposition of human skulls in the 4th millennium and cattle in the 3rd millennium BC in Neolithic Orkney. This may be the result of parallel processes of ritual evolution, or from belief systems nurtured over many millenniums, since skulls are a clearly recognised element from a skeleton. It is also interesting that the circle of Jericho human skulls faced inwards, the same composition at the cattle skulls in LON foundation course, Structure 9. What is not present in Neolithic Orkney is plastering, embellishment or covering with ochre of human skulls, as was the case at some sites in the Near-East, or of cattle skulls, as, for example, at Çatalhöyük (Hodder and Meskell, 2011, p249).

## 4.9 Artistic Representation of mammals in Orkney

### 4.9.1 Depictions of cattle and sheep

No artistic representations of cattle or sheep have been identified from LON or other Neolithic Orkney sites, although there are examples of painted, peck-marked, scratched, carved and ground motifs on portable or structural stonework (Bradley et al, 2000, Card and Thomas, 2012). Rock art and passage tomb art in both Britain and Ireland is dominated by abstract representations (Cochrane and Jones, 2012, p2, Shee Twohig, 1981).

This lack of cattle representation on non-organic material in Neolithic Orkney is of interest and cannot be due to a lack of artistic expertise. A considerable number of elaborate stone balls, carved with knobs, bosses or patterns, were excavated from Skara Brae, Mainland (Childe, 1931, pp100-105, Clarke and Sharples, 1985, p81, plate 4.13, Shepherd, 2000). A few less elaborately carved stone balls have also been recovered from LON (G. Wilson pers. comm.). In addition, a sandstone figurine from Area 5, LON, as well as other less well-defined examples, demonstrates carving abilities (Moore and Wilson, 2011, p104-106, G. Wilson pers. comm.). Sophisticated levels stone carving techniques are demonstrated by the pecked spiral design of the lintel stone from the Maes Howe-type cairn at Pierwall Quarry (Sharples, 1984, Westray Heritage Centre). Pecked motifs, not representing animal shapes, were also noted from three Orkney chambered tombs and the destroyed monument of Eday Manse (Bradley et al., 2000, Card and Thomas, 2012, p113). See *Photographs 19 and 20.*

**Photograph 19: Pierowall Quarry lintel photographed at Westray Heritage Centre**

**Photograph 20: Links of Noltland Figurine © Historic Scotland**

Animal stone carvings do appear in Scotland, however, after the Neolithic/Bronze Age period, for example the impressive Pictish bull carvings at Burghead, Morayshire associated with the later Iron Age (NMS, Thoms, 1961, p48, fig 11). It is of note that these carvings depict bulls with relatively short horns, differing from the long-horned LON cattle skulls (Harden, 2010, p16, p25)

There is evidence of artistic representation of cattle from the earliest Neolithic period in the Near East to the Late Neolithic in North Atlantic Europe and representation of bucrania widespread throughout continental Europe during the 4th and 3rd millennium BC, *See Chapter 3.* However, artistic representations, as opposed to actual animal skulls, were not part of the lexicon in Neolithic Orkney communities and the only indication of cattle and sheep being afforded special status are therefore skull deposits. It is, of course, possible that cattle representations were carved on wood, or on other organic materials, of which no traces would remain.

### 4.9.2 Hidden depositions

Most abstract rock carvings in British and Irish Neolithic structures are designed to be seen, and possibly to designate transition or passage from one area to another, for example, entrances, lintels and sill stones (Loveday 2004, p123, Robin. 2012). However, there is also evidence that some Neolithic artistic representations were hidden, or partially hidden such as the ornamentation on some upper roof stones and backs of some kerbstones of the Irish passage grave at Newgrange (Shee Twohig, 1981, pp118-119). At the Late Neolithic Orkney ceremonial site at Ness of Brodgar one of the packing stones for a standing stone in the eastern forecourt had ground marks that could not be viewed after installation. In addition, many other cup-marked stones were at least partially hidden from view during use of Structure 10. This has led the excavators at Ness of Brodgar to suggest that that in these instances, the manufacture was part of the process and visual characteristics cease to be important. These portable rock art placements might be considered an act of votive deposition (Card and Thomas, 2012, pp120-121). It is therefore possible that these pieces of portable art, along with figurines at LON, has some echoes with the deposition of cattle skulls, that is, the production of skulls and hiding them from view within a building.

## 4.10 Overview

Cattle and sheep skull depositions at LON are symbolic. Domesticated animals, particularly cattle, "became central to the Neolithic symbolic system in the whole of western Europe during the end of the fifth and the fourth millennia cal BC" (Tresset and Vigne, 2007, pp203-204) and this statement may be relevant to Orkney in the early third millennium cal BC.

The LON cattle and sheep skull deposits represent either remains of animals previously living at the settlement, or imported. The skulls may have been chosen because they are easily recognisable to species, perceived to contain the power/essence of the animal but not involving too great a loss of food resource. Apart from some pelves and a scapulae deposit, no other particular animal post-cranial bones were placed with these skulls, although see *Chapter 6*. Skulls were represented by differing numbers of bones but the frontals and horn cores were always present, perhaps because these bones are dense and more resistant to taphonomic influences, or because these bones were unambiguously recognisable as cattle.

The skulls were deposited within two structures: Structure 9 and Structure 18. Different spacing between skulls in the foundation of Structure 9 might suggest skulls placed by more than one person. Structure 9 was separate from, and to the north of, a cellular complex of buildings within Area 5. However, its hearth was not of exceptional size at 1.1m by 0.95m (Moore and Wilson, 2011) and so not, for example, suitable for roasting complete cattle carcasses. Structure 18 was a two-chambered building inserted into dunes some distance from Area 5 but adjacent to other Neolithic buildings, closer to the sea than most settlement structures, and although not discussed in this report because they were only excavated after mammal bone identification for this thesis was complete, had several articulated cattle limb bones deposited in the smaller of the two rooms.

It is possible that both buildings fulfilled a particular, possibly non-domestic, role on the site, similar to that suggested for Hut 8 at Skara Brae, Mainland (Childe, 1930, p173, 1931, Clarke and Sharples, 1985, pp66-67, Richards, 1991, pp37-39), or Ceremonial House 2, Barnhouse, Mainland (Richards, 2005), but the LON 2014 excavations have uncovered mammal skulls at the base of walls enclosing the Area 5 complex, indicating that skull depositions may have been inserted into other building foundations at LON.

# *5 Red Deer*

## 5.1 Introduction

Earliest radiocarbon dated Orkney red deer bones are Late Neolithic, although a small number of red deer bones are reported from Early Neolithic contexts at Pool and Tofts Ness, Sanday (Bond 2007, p210, table 7.2.1, Nicholson and Davies, 2007, p175, table 6.3.1.6). See *Table 7*. LON Radiocarbon results in *Appendix 2*.

**Table 7: Red deer radiocarbon dates from: HPWN (Holm of Papa Westray North cairn, Neolithic); Vesta Fiold (Cairn, Neolithic); LON (Links of Noltland, Late Neolithic)**

| Site | Dates cal BC 95.4% | Source | Bone |
|---|---|---|---|
| HPWN | 2870-2490 (2) | Ashmore, 2009, pp59-66 | astragalus |
| HPWN | 2880-2570 | Ashmore, 2009, pp59-66 | antler |
| Vesta Fiold | 2800-2500 | Richards et al., 2013, p160 | metatarsal |
| Below LON St 9 | 2859-2491 | | phal2 |

## 5.2 Midden deposits

### 5.2.1 LON (excluding articulated skeletons)

Red deer bones only represent a small proportion of LON identified bone fragments (excluding antler). For details of midden deposits see *Table 8*.

**Table 8: Red deer LON (Links of Noltland) midden deposits**

| Species | Element | No | Comments |
|---|---|---|---|
| Red Deer | Skull | 1 | Temporal zygomatic arch |
| | Antler | 6 | 6 shed antler burrs |
| | Mandible | 1 | Sequence of adult teeth assumed to be from one mandibular tooth row |
| | Articulated post-cranial | 2 | Left carpal bones<br>Left tibia, calcaneus and astragalus |
| | Additional | | Includes foot bones, vertebrae, ribs, scapula, humerus, radius, ulna, pelvis, femur, tibia and loose teeth |

The midden below Structure 9 (contexts 9681/9690), however, had a higher proportion of cattle and red deer bones and fewer sheep bones than other contexts examined (see *Chapter*

*6*). However, only a small proportion of this area was excavated, so the higher level of red deer bone may not be representative of the complete midden below this structure. The radiocarbon date for a red deer 2nd phalanx was 2859 to 2491 cal BC.

The only complete red deer bones recovered from LON midden material were tarsals, carpals and phalanges. Evidence of skinning/disarticulation was noted on some LON red deer bones from (i) context 7032 (ii) below Structure 9 (iii) foundation course, Structure 9. In addition, some spiral breaks on long bone diaphyses fragments might imply marrow was being extracted, or bones being used as raw material for tools. An ulna from the midden below Structure 9 had been worked into a point, providing evidence that at least one red deer bone was used for tool manufacture. Two sets of associated carpals, with no cut marks on either set, suggest little movement of bones after deposition in midden context 9031. An associated astragalus, calcaneus and distal tibia in the hearth of Structure 9, context 9125, also demonstrate little movement after deposition.

### 5.2.2 Other Neolithic Orkney settlements

The LON red deer bone representation in midden material reflects the published results from other Orcadian settlement faunal assemblages, where red deer make a low but persistent contribution to mammal bone collections. For example:

- At D. Clarke's excavation at the Late Neolithic site of Skara Brae, Mainland, red deer make up approximately one percent of all recovered bone (Clarke and Sharples, 1985, p77) and at the earlier Skara Brae excavation by V.G. Childe "bones of sheep and cattle are absolutely predominant and deer seem rare" (Childe, 1931, p62)
- At Pool, Sanday six red deer bones identified in the Neolithic phases, less than one percent of the total identified bones (Bond, 2007, p210, table 7.2.1)
- At Tofts Ness, Sanday in the Neolithic/Early Bronze Age phases red deer bones less than one percent in phases 1 and 3, less than two percent in phase 2, with half of these bones being antler which may have been shed (i.e. acquired by gathering rather than killing the animal). However forequarter, hindquarter, skull and feet bones from both adult and juvenile animals were recovered, perhaps indicating a local population. The only butchery mark noted was a chop mark across the neck of a scapula (Nicholson and Davies, 2007, p175, p183, table 6.3.1.6)
- At D. Clarke's previous excavation at LON, 1979-81, 11% of total identified bones were red deer, most associated with a special deposition of fifteen articulated partial

> or almost complete red deer skeletons. Separate allocation for red deer bones from general midden/articulated deposits was not reported (Armour-Chelu, 1992)

Seven red deer bones were noted from Mid Neolithic Knap of Howar (less than 1% identified bones), but this identification has now been discounted (Harman, 2009, p37, Noddle, 1983, p94, table 1, Tresset, 2002, p23). This reappraisal means that no red deer bones have been recorded to date from the Mid Neolithic period in Orkney.

## 5.3 Articulated deposits

### 5.3.1 LON

### 5.3.1.1 General

Articulated red deer skeletons were excavated from various locations at LON. All included some root-etched bones, but none were gnawed. The skeletons were from two areas, infill to Structure 10, Area 5, context 9134, and deposited material over structural remains, west of Structure 18, contexts 9098, 9921, 9922, 9929 and 9986. See *Table 9.*

**Table 9: Red deer articulated deposits from LON (Links of Noltland, Late Neolithic)**

| Context | Find | MNI | Comments | Associated bones |
|---|---|---|---|---|
| 9134 | 11013 | 3 | One almost complete skeleton | |
| 9134 | 9707 | 7 | Predominately ulnae | |
| 9098 | 5203/12235 | 1 | Left lower foreleg and skull fragments | |
| 9921 | 20163 | 2 | Partial skeletons | Cattle, sheep |
| 9922 | 21206 | 2 | Partial skeletons | |
| 9929 | 20880 | 1 | Almost complete skeleton, skull missing | Cattle, sheep, pig |
| 9986 | 22677 | 1 | Limb bones and vertebrae | Cattle |
| 9986 | 22679 | 2 | Partial skeletons | Cattle, sheep |

### Context 9134, Area 5

***F11013***

The first red deer bone accumulation, F11013, was labelled as one animal at excavation, but was, on examination, one almost complete skeleton plus additional red deer bones. The articulated skeleton included all bone elements apart from the left scapula, os malleolare, os centrotarsale and lunate carpal, both left and right pelves and patellae and two 3$^{rd}$ phalanges. Small bones such as residual metacarpal bones and sesamoid bones were, however, recovered. Vertebrae (cervical, thoracic, lumbar and caudal) were noted, but predominately represented by fragments, with lumbar and caudal fragments rare. The radiocarbon date for a red deer femur from the articulated specimen was 2580 to 2349 cal BC.

This skeleton was from an adult, with all long bone epiphyses and vertebral centrum epiphyses fused. No canine teeth or antler pedicles attached to cranial fragments were recovered, so the animal may have been female. Left and right mandible and maxilla tooth rows were recovered. See *Table 10.*

**Table 10: Tooth sequence for articulated red deer skeleton F11013**

| | *P2* | *P3* | *P4* | *dp2* | *dp3* | *dp4* | *M1* | *M2* | *M3* |
|---|---|---|---|---|---|---|---|---|---|
| Mand(L) | * | * | * | | | | * | * | * |
| Mand(R) | * | * | * | | | | * | * | * |
| Max(L) | * | * | * | | | | | | |
| Max(R) | * | * | * | | | | * | * | * |

All maxillary and mandibular permanent teeth, including 3$^{rd}$ columns of M3, were in wear, suggesting an age of four or more years. Crown heights were sufficiently high, however, to indicate this was not an old adult (Lowe, 1967). Using another red deer dentition scheme, the mandibular tooth wear is between to stage “e” and “f” (50-138 months), with $PM_4$ in light wear, close to stage “e”, but $M_3$ in more extensive wear, closer to stage f (Brown and Chapman, 1991a, p526 fig 4).

No evidence of butchery was noted on the articulated skeleton. The following long bones from both sides of the skeleton were intact, or cross-matched with recent breaks: femur, tibia, metatarsal, humerus, radius, ulna (left only) and metacarpal, so there is no evidence that these bones had been processed to extract marrow or used as raw material for tools.

Minor but widespread pathology was present, particularly slight lipping on several articular surfaces, with both fore and hind limbs affected. In the previous LON excavation one red deer skeleton of approximately five years old had bony remodelling and growth of osteophytes around margins of radii, femur and tibia, and it was concluded, since the condition was widespread, that this was not traumatic in origin despite the relatively young age of the animal (Armour-Chelu, 1992, p237).

The most notable pathology observed on the articulated red deer skeleton was fusion and extensive osteophytic growth on the right os centrotarsale and its merger with the cunieform bone. This could be considered as spavin (*ostitis rarefaciens et condensans*) “the chronic fusion between tarsal bones”, thought to originate from the os centrotarsale bone. This condition is the result of primary dry tarsal joint inflation, caused inter-related factors such as inherited, structural or functional disorders, more often associated with horses, cattle and camels and modern racing dogs (Bartosiewicz and Gál, 2013, p35, p123, p125, Brothwell and Baker, 1980, pp117-120). The condition may result in relatively mild lameness for the animal which improves with the natural advancement of ossification (Bartosiewicz and Gál, 2013, p124, Brothwell and Baker, 1980, p119).

At the previous LON excavation a mature red deer had the os centrotarsale bone fused at the edges with the proximal metatarsus articulation (Armour-Chelu, 1992, p240, fig 30), so although spavin is considered rare in any deer species (Bartosiewicz and Gál, 2013, p125), there were at least two examples of this condition at LON. In addition, the Orcadian Iron Age site of Howe, Mainland, recorded four instances of spavin for red deer, in each case associated with the os centrotarsale (Smith 1994, Appendix 1:E9, table 41), perhaps indicating that an inherited element is involved with this condition in Orkney red deer.

In addition to the articulated red deer skeleton, bones from at least two other red deer, an adult and a fawn/juvenile with unfused 2nd phalanges were recovered in association with F11013. The second (right) adult maxilla had a damaged molar tooth row with the 1st molar ($M^1$) having excessive wear on the posterior occlusal surface, almost down to the cervical line and a posterior buccal root not fully developed, with the space being taken by the $M^2$ anterior buccal root. The lingual side of $M^1$ roots had a bubble-shaped protuberance and the buccal aspects of $M^2$ roots were curved and flared in an anterior direction and $M^3$ posterior roots are curving towards the anterior roots. This asymmetry and distortion may have increased difficulty in chewing food.

### *F9707*

A collection of fifty red deer, or probable red deer, bones, were also excavated from context 9134. Many were ribs or vertebrae fragments, and these bones would not increase the MNI of three if added to those from F11013. There are also two antler fragments, one fragment apparently from a shed antler, the other a tine fragment with some evidence of wear, which could have occurred in life through stags fighting or as use as a tool. No evidence of butchery was observed.

The most notable feature of this deposit was the large number of red deer ulnae, seven left and four rights. Only three ulnae had significant lengths of the fragile distal diaphysis still attached, the rest were represented by the olecranon, anconeal notch, trochlear notch and lateral and medial coronoid processes. The breaks in the diaphysis appeared to be “dry breaks”, with rough, jagged edges, and there was also root etching on the bones. Two left and one right ulna were fused proximally, four left and three right ulnae unfused, and one not determined (although muscle attachment remodelling suggests a mature age). Loose fragments of proximal epiphyses and diaphysis were also recovered but could not be cross-matched. Added to the ulna from red deer skeleton F11013, there was a minimum of eight red deer represented in context 9134, four adults and four sub/adults/juveniles/fawns. See *Table 11*.

**Table 11: Measurements (mm) of red deer ulnae from LON, context 9134, F9707 (fused and unfused)**

| L/R | BPC (mm) | SDO (mm) | DPA (mm) | LO (mm) | Fused/ Unfused |
|---|---|---|---|---|---|
| L | 25.6 | 36.5 | 40.8 | 62.8 | F |
| L |  | 38.4 | 44.0 | 60.8 | F |
| R | 28.9 | 40.8 | 44.9 | 64.5 | F |
| L | 23.0 | 33.6 | 35.7 |  | U |
| L | 28.0 |  |  |  | U |
| L | 23.0 |  |  |  | U |
| L | 22.7 | 30.1 | 34.8 |  | U |
| R | 22.8 |  |  |  | U |
| R |  |  | 34.2 |  | U |

Pathology was noted with two mature ulnae which had well-developed muscle attachments and lipping at edges of articulations. The shape of the lateral coronoid process from one left ulna varied from the NMS Collection Centre Islay male red deer reference bone, appearing closer to that of a reindeer bone, but collagen testing confirmed it as red deer. Another ulna, probably mature, had a small unrepaired hole in the lunate aspect of the articulation: the bone had broken at this hole but was cross-matched. One unfused ulna had two cut/scape marks on the proximal diaphysis, which may be butchery marks, the only such modifications noted from the ulnae bones.

The ulnae bones may have come from eight complete deer skeletons, but no other forelimb bones were recovered adjacent to F9707 and it seems unlikely that only ulnae would survive if full skeletons were initially located in the infill rubble. Alternatively, there may have been three red deer skeletons in this area of rubble and a cache of eleven ulna bones, low-meat bearing bones, possibly procured from another location within or outwith the site, or a deposit of tools, now broken.

#### 5.3.1.2 Context 9098

An articulated portion of an adult red deer left forelimb was recovered as part of a bone concentration located in midden to the north of Structure 9 (F5203). This consisted of four left carpals (lunate, scaphoid, hamate and ulnar), an accessory carpal, a complete but fragmented fused left radius and a distal diaphysis of a left ulna. There may have been faint cut marks on the lunate carpal. In addition, a fragmented skull frontal, pedicle and antler portion was recovered from the same context (F12235). The brow tine was in position but other tines appear to have been removed. The antler has developed to at least stage “d” (Schmid, 1972, p89). The articulated lower forelimb and the frontal/antler could be from the same animal.

#### 5.3.1.3 West of Structure 18

Red deer skeletons were recovered in material covering a ruined Neolithic building located west of Structure 18. The finds were close to the earlier deposit of  red deer (Armour-Chelu, 1992, p222, p267, Sharples, 2000). Discussions with the excavation director, G. Wilson, suggested each find number should be treated separately and not as part of the same deposit. It is noted that bones from other species were lifted with these red deer skeletons, either co-deposited or from underlying midden material.

##### *Context 9921, F20163*

Although labelled as red deer skeleton, this deposit also contained cattle and sheep bones, including maxillary and mandibular teeth from a calf, with $dp_4$ mandibular molar at wear stage “g”. There was also a left maxillary molar $M^3$ (in wear) from adult cattle. The sheep bones consisted of a mandible fragment, an unfused proximal tibia and an unfused proximal humerus, an ulna fragment and a maxillary molar tooth.

All skeletal areas of red deer were represented in this deposit, including the skull. However, there were two right hindlimb portions (femur, tibia, patella, os centrotarsale and metatarsal) and no left hindlimb bones. All long bones were unfused and significant numbers of unfused epiphysis were recovered. A set of maxillary teeth from both sides indicated that one animal may have been between 5 and 10 months of age ($M^1$ in light wear) (Brown and Chapman, 1991a, p526, Lowe, 1967), the other red deer was also a fawn/juvenile based on the state of epiphyseal fusion of the hindlimb bones. There are no butchery marks and breaks in long bone diaphyses were "dry breaks".

### *Context 9922, F21206*

Red deer bones from at least two young animals were recovered in this deposit, in addition to three unfused left ulnar epiphysis. There are two mandibular and three maxillary tooth rows. Both animals have deciduous dentition, with one animal having mandibular 1st molar ($M_1$) tooth in light wear, (F21206A) the second having maxillary $M^2$ 1st column just coming into wear (F21206C) so one may be between 5 and 10 months, one between 10 and 14 months (Lowe, 1967), or 10 and 18 months (Brown and Chapman, 1991a, p526). See *Table 12.*

**Table 12 : Tooth wear sequence for red deer skeletons from context 9922, F21206 l/w-light wear**

| | *P2* | *P3* | *P4* | *dp2* | *dp3* | *dp4* | *M1* | *M2* | *M3* |
|---|---|---|---|---|---|---|---|---|---|
| Mand(L) | | | | * | * | * | l/w | | |
| Mand(R) | | | | * | * | * | l/w | Crypt | |
| Max(L) | | | | * | * | * | l/w | | |
| Max(R) | | | | * | * | * | l/w | | |
| Max(L) | | | | * | * | * | * | Just in wear | |

Duplicate bones included left maxilla, left scapula, left and right humeri, left ulnar carpal, right femur, left tibia and left calcaneus. Several epiphyses could be retrofitted. There were faint marks, possibly cut-marks, on both left and right calcanei, both in the same position. No spiral fractures were noted on long bones. Twenty-one bones were complete, or almost complete, and these included phalanges, carpals, tarsals, metatarsals and metacarpals.

### *Context 9929, F20880*

This deposit, although labelled a red deer skeleton, also contained cattle and sheep bones, and a pig tooth fragment. The cattle bones are, as a minimum, one calf, and included a distal humerus and an unerupted permanent incisor with no root development. There are some cut marks and spiral breaks on the humerus diaphysis, indicating butchery. The sheep bones include a maxillary molar $M^3$ in light wear, perhaps a sub-adult, an unfused thoracic vertebra epiphysis and a metatarsal fragment with a spiral fracture.

The red deer bones were from one individual, plus an additional unfused humerus distal fragment. Both animals are fawns. All body elements of one skeleton were represented apart from the skull, including associated epiphyses and sesamoid bones. One left mandible, with a toothrow "*in situ*" and $M_1$ in light wear and $M_2$ unerupted suggests an animal aged between 5 and 10 months (Brown and Chapman, 1991, p526, 1991b, p89). There were no cut marks noted and long bone diaphysis had "dry breaks". There were only three complete bones, an astragalus and two phalanges.

### Context 9986, F22677

This red deer bone deposit contained two cattle bones, a metatarsal distal fragment and an incisor. The red deer bone collection was dominated by foot bones, including unfused epiphyses, but fragments of ulna, radius, tibia and femur were also recovered. Vertebrae fragments were present, but no skull bones, pelves or scapulae. No bones were fused, including the phalanges, and the presence of right deciduous mandibular molar $M_2$ in light wear with only half-developed roots indicates a fawn/juvenile. There are no cut marks or evidence of spiral breaks on any bones. The only complete bone was a 3rd phalanx.

### Context 9986, F22679

This red deer deposit included two cattle bones and a sheep mandible fragment. There were no red deer skull fragments, apart from some loose maxillary teeth, but all other skeletal elements were represented. Bones from at least two animals were present. Duplicates included right ulna, left ulnar carpal, left and right calcanei, left and right astragali, left femur proximal diaphysis, right tibia, metatarsal distal fragments and right os malleolare. No long bone or 1st/2nd phalanges were fused, but some epiphyses were recovered with the bones.

Both mandibular and maxillary loose dp4 teeth, with third columns in light wear, a loose $M_1$ in light wear and a loose unerupted $M_2$ reveals one of the animals was a fawn. In addition, all bones, including rib proximal epiphyses were unfused, apart from one humerus distal fragment, indicating fawn/juveniles. There were no cut marks or spiral breaks in long bones, although a small groove was noted adjacent to a dry break on one left metatarsal diaphysis. There was also a small split on the anterior surface on a left os centrotarsale, and it is of note that this lesion was present on such a young animal. Complete bones included carpals, tarsals, a metatarsal and phalanges.

#### 5.3.1.4 Summary for red deer deposits west of Structure 18

Red deer from this area, aged from teeth eruption sequences, were from young animals, either between 5 and 10 months or between 10 to 14/18 months. Lack of epiphyseal fusion supports this conclusion. All long bone breaks were “dry-breaks” indicating bones had not been processed for marrow. No clear cut marks were observed, but two faint marks on left and right calcanei might indicate human modification since both marks were in similar locations. Cattle, sheep and one pig tooth fragment were associated with the red deer skeletons, but cut marks and spiral breaks of long bones show that these bones had been butchered and may have had a different depositional history to that of the red deer.

### 5.3.2 Articulated skeletons from other Neolithic Orkney settlements

#### 5.3.2.1 Earlier LON excavation (D. Clarke 1979-81)

Fifteen almost complete and partial red deer skeletons were excavated in the previous D. Clarke’s excavation (Armour-Chelu, 1992, p113). These red deer were recovered from an area of approximately 3.5 by 3m, west of Structure 18 and adjacent to the current LON red deer articulated skeletons in contexts 9921, 9922, 9929 and 9986. No gnawing or butchery marks were noted. The minimum number of individuals (MNI) of fifteen is not a finite number, but a minimum estimate, so results from the current excavation cannot be added to those from the previous excavation unless all individual bone fragments from both excavations are assessed.

The ages of these animals were determined as:

- 11 at approximately nine months (late winter/spring death)
- 2 at approximately two years
- 2 at approximately five years

However this was later re-quoted by N. Sharples (and by Morris, 2005) altering the fawn/juveniles season of death (Armour-Chelu, 1992, p142, Morris, 2005 p10, Sharples, 2000, p111):

- 11 at fourteen months (summer death)
- 2 at two years
- 2 at five years

In association with the red deer skeletons were shed antlers, bones from a cod and two bird wings. It was deduced that all the red deer were deposited in a single episode, because of the juxtaposition of the bones. At the time of the excavation it was considered that the red deer skeleton deposit was adjacent to a wall some distance from the settlement, but structures have now been located by the current LON excavation in this vicinity. This red deer deposit were not directly dated, but thought to be associated with the date from underlying midden of 2650 to 1950 cal BC (Sharples, 2000, p112). Two mature maxillae contained canine teeth indicating they were male and bone measurements imply the other two mature specimens were probably female. A skull associated with one of the animals in the deposit bore antlers (distribution between two and five year olds not specified).

In addition to this red deer deposit, D. Clarke's excavation uncovered partially articulated skeletons from large mammals, perhaps in the first stages of butchery, thought on preliminary examination to be red deer and dated to 2500 to 1750 cal BC (Sharples, 2000, p112, p113, fig 9.2).

#### 5.3.2.2 Skara Brae, Mainland

A red deer skull with intact antlers was recovered from the re-occupation period at Skara Brae (Childe, 1931, plate XXXIII). This fourth, and last, occupation layer, above Hut 7, contained numerous shells and antlers, which led V.G. Childe to consider that the ruins of this structure had been used for shelter and feasts after abandonment (Childe, 1931, p62). In the mid-19th century red deer bones were also recovered from sand covering the Skara Brae settlement (Petrie 1867, p210). It was noted that although animal bones from the midden at Skara Brae were split, splintered or broken, the legs of red deer bones deposited in the sand were unbroken. However this observation was followed by a statement that horse bones and teeth were frequent in the midden, yet there have been no Orcadian horse bones dated to the Neolithic period, so unbroken red deer bones may be from a later period (Petrie, 1867).

#### 5.3.2.3 Bay of Skaill, Mainland

Close to the settlement at Skara Brae, a bone deposit, predominately, but not exclusively, red deer, was recovered adjacent to a field wall. The deposit included skeletal remains of at least four red deer, with bones on the east side of the wall partially articulated, associated with a hearth but predominately unburnt, those on the west disarticulated and associated with Skaill knives (Sharples, 2000, pp110-111). Two radiocarbon dates for a red deer antler fragment from an articulated skeleton associated with Skaill knives were 2418 to 2146 and 2332 to 2043 cal BC (Ashmore, 2005, p177).

#### 5.3.2.4 Point of Buckquoy, Birsay, Mainland

Red deer bones, including antler, dominated the animal bone assemblage from below Hut 1 at this multi-period site. A sample of mammal bone, including red deer, was dated to 2630 to 2180 cal BC, but this determination included more than one bone, and possibly more than one species, and is not reliable (Ashmore 2004, p125). From the same area in a later excavation red deer bones, predominately juveniles or sub-adults, were abundant, but produced a later date of 2285 to 1690 cal BC for a sample of red deer bone and antler (Rackman, 1989, pp77-80, pp87-91). At Cuttings 5 and 6 a minimum of five red deer were noted, including both juvenile and adult animals, with front limbs, probably articulated, dominating the assemblage and a radiocarbon date from a sample of mixed bones, mainly red deer was 1770 to 1370 cal BC (Rackman et al., 1989, pp101-102, Rackman and Young, 1989, p105).

#### 5.3.2.5 Ness of Brodgar, Mainland

An articulated red deer skeleton, from ceremonial Structure 10, Area 1, aged between 33-65 months, was recovered overlying a bone deposit. Two other articulated red deer deposits were represented in Structure 10 bone layer and in upper deposits overlying terminal layers in Structures 1 and 10. These articulated skeletons might represent final or closure acts of deposition (Mainland et al., 2014, p872, p876).

#### 5.3.2.6 Summary of articulated red deer from other Orkney sites

The articulated red deer deposit found at the earlier excavation at LON is not unique; other examples were excavated during the present LON excavation and from sites on Mainland, Orkney. Few reliable dates are available for these deposits, but those that have been determined indicate depositions are associated with the end of the Late Neolithic/ Chalcolithic period, or even, in the case of Point of Buckquoy, Bronze Age. No butchery marks were noted on these depositions, the exceptions being at Bay of Skaill where some disarticulation marks may be associated with Skaill knives.

## 5.4 Red deer bones from Neolithic Orkney Cairns

### 5.4.1 General

Red deer bones have been excavated from some Orcadian cairns and at two cairns, Knowe of Yarso and Knowe of Ramsay, Rousay, red deer dominated mammal bone collections. Red deer bones were not dominant at Quanterness, Mainland, as suggested by J. Mulville (Mulville, 2010, p45, Clutton-Brock, 1979, p112). Knowe of Yarso and Knowe of Ramsay cairns are both located on south-facing terraces in Rousay, overlooking the coastal plain, close to another three Neolithic cairns Lairo, Taversoe Tuick and Blackhammer. No mammal bone remains are recorded for Lairo (Grant and Wilson, 1943) and bones from a minimum of three red deer were recovered from Blackhammer (Callander and Grant, 1937).

### 5.4.2 Knowe of Ramsay, Rousay

An MNI of fourteen red deer was reported from this cairn, based on right calcanei. Few bones were intact and both mature and juvenile deer were present. Skeletons from food birds such as gannet and great auk, some sheep and cattle bones, and remains of a conger eel were also recorded. All elements of red deer skeletons were represented (Platt, 1935, pp415-419). There was evidence of fires being kindled within compartments 6 to 11 that post-dated the deposition of human skeletons (Callander and Grant 1935, p413, Davidson and Henshall, 1989, p136). Precise contexts for red deer bones are not recorded and the tomb had been disturbed prior to excavation. The radiocarbon dates from a sample of non-identified animal bones from this site have been corrected to 2900 to 2200 BC and 3350 to 2600 BC, and for red deer (?) 3350 to 2550 BC (www.canmore.rchams.gov.uk accessed 22/10/14), giving a wide date range for possible deposition.

Assessment of material retained at NMS Collection Centre from this cairn identified two shed antler burr fragments. The archived bones did not, however, represent material from fourteen red deer and only four calcanei (right), all adult, were present. The only pathology noted was one adult red deer scapula bone with a slight dislocation at the glenoid process. Nine burnt bones representing axial, forelimb, hindlimb and feet bones and one antler fragment were present, all “lightly” or “slightly” charred. The burnt bones were from sub-adult and adult animals.

A few bones displayed evidence of butchery. For example, cut marks were noted on a left astragalus, a right metatarsal, an unsided metatarsal diaphysis, a rib corpus and a right pelvis fragment. Another right metatarsal diaphysis appears to be covered with an excessive number of grooves/cuts, either butchery marks, or possibly as use as a stretcher. A distal humerus, radius and tibia all had diaphysis spiral breaks, indicating bones broken shortly after death. Other bones exhibited dry breaks. There is therefore evidence of butchery that confirms the original animal bone report which states that the majority of bones were broken, either for marrow extraction or for use as tools (Platt, 1936, p415).

The Knowe of Ramsay red deer collection includes bones from animals of different ages, not all of which could have died at the same time of year. For example, loose deciduous dp2 and dp3 teeth, not in wear, and two metatarsals with in recent longitudinal fusion reveal the presence of at least one neonatal animal. A mandibular $dp_4$ in light wear indicates a fawn of just over two months of age. A mandible fragment, left, with deciduous molars $dp_3$ and $dp_4$ teeth in wear, and permanent molar $M_1$ with the second column just coming into wear, represents an animal of between 5/6 and 10 months. Mandibular fragments (two right, one left) with $M_3$ erupted to bone line represents a minimum of two animals approximately eighteen to twenty four months old (Lowe, 1967, p138, Chapman and Brown, 1991a, p526, 1991b, p89). Two fused right distal tibia fragments and four fused right calcanei demonstrate the presence of at least four adults.

### 5.4.3 Knowe of Yarso, Rousay

A minimum of thirty-six red deer were widely distributed throughout this cairn. Limpet shells, from both exposed and sheltered areas of the beach, a few dog, bird, fish and sheep bones and one cattle rib were also present. Six dog bones were also identified, apparently from the same animal but found in different areas of the cairn, indicating mixing of interior material (Platt, 1935, pp341-343). Human and animal bones were “mixed up promiscuously” and a red deer tooth actually lay within one of the human crania. Disturbance had occurred when stones from the upper part of the cairn had been removed for other building purposes (Callander and Grant, 1935, p333). The revised radiocarbon date for red deer (?) bones from this cairn is 3350 to 2450 BC (www.canmore.rchams.gov.uk, accessed 22/10/14).

Red deer bones kept in the NMS Collection Centre were examined, but did not represent thirty-six individuals. Bones from skull, mandible, forequarter, hindquarter and foot bones plus loose teeth were present, but no vertebrae, ribs or ulnae, so perhaps only measurable or age-definitive bones were preserved. Alternatively only selected elements of the red deer skeleton entered the cairn but the original animal bone report states “most individual bones of the skeleton were found” (Platt, 1935, p349). The only complete bones were astragali, calcanei, patellae, and phalanges. This finding reflects the statement in the original report that animal bones “were much broken…presumably deliberately split to get at the marrow” (Callander and Grant, 1935, p334, Platt, 1935, p341). Cut marks were noted on the diaphysis of four humeri, three metacarpi, one metatarsal, one femur and the edge of an os centrotarsale. Diaphysis fragments of long bones had either spiral or stepped/spiral breaks, on some occasions with slight burning or percussion marks adjacent to the break. There is therefore clear evidence that the red deer bones had been butchered.

A few red deer bones were burnt, mostly slightly or fully charred, but one bone, a calcaneus, was locally calcined. Fires had been kindled within the cairn and one human skull, which had been in contact with fire, demonstrates that burning occurred after at least some of the skulls had already been deposited. Flints included leaf-shaped arrow heads, scrapers and knives (Callander and Grant, 1934/35, p339, Davidson and Henshall, 1989, p139).

A minimum of eleven red deer skeletons, were examined at the NMS Collection Centre, based on an MNI calculated using the left mandible. Tooth wear and some lipping/remodelling at articulations suggests that some specimens were older adults. One partial mandible, one loose mandibular $dp_4$, and unfused bones such as proximal 1st phalanx, proximal calcaneus, distal metatarsus, distal femur and distal radius demonstrates the presence of juvenile/sub-adults. Two bones, a humerus diaphysis and a distal metatarsal diaphysis had been gnawed by non-carnivores. One skull bone had a vertical crack running through the parietal bone, perhaps as the result of a blow to the head.

Although the red deer bones may have originally been from complete carcasses carried into the cairn, the excavator and the faunal specialist do not describe semi-articulated skeletons; a feature alluded to in a later publication (Callander and Grant, 1935, Morris, 2005, p10, Platt 1935).

### 5.4.4 Neolithic Orkney cairns with red deer bones curated at NMS Collections

Mammal bones from another five Neolithic Orkney cairns stored at NMS Collection Centre include small quantities of red deer bone:

- Blackhammer
- Calf of Eday

- Holm of Papa Westray North
- Quoyness
- Rowiegar

Unlike Knowe of Ramsay and Knowe of Yarso, red deer are not the dominant species at these sites. Most red deer bone from Holm of Papa Westray North were not adult.

### 5.4.5 Published reports of red deer from Neolithic Orkney cairns

- Isbister, South Ronaldsay: small number of red deer skull, axial, forequarter, hindquarter and feet bones recovered from both adult and sub-adult/juveniles (Barker, 1983)
- Quanterness, Mainland: bones from a neonatal or foetal fawn, a sub-adult, and a minimum of two adult red deer, adults being represented by forequarter and foot bones, the fawn and sub-adult by foot bones. A shed antler burr fragment also present. The bones of the smaller adult red deer may have been intrusive (Clutton-Brock, 1979, pp119-120)
- Point of Cott, Westray: red deer bones, which may be from one juvenile, represented by a mandible, loose teeth and a metacarpal, recovered from the blocking of the passageway and compartment 1 (Halpin, 1997, p46)
- Pierwall Quarry, Westray: small number of red deer antler and hindfoot bone fragments recovered from the Neolithic contexts at Pierowall Quarry, Westray (MacCormick, 1984, p108, table 2)
- Vesta Fiold, Mainland: six red deer bones, including a neonatal animal (Richards et al., 2013, p168)
- Howe, Mainland: Phases 1/2, the punitive Neolithic phase, possibly a cairn, contained some red deer bones. Larger number recovered from later Iron Age phases of this site and are used size comparison with LON and Knowe of Yarso bones (see *Chapter 9)* (Smith, 1994, p139, table 11)

Others cairns, such a Midhowe, have no record of red deer apart from antler (Platt, 1934, pp348-349).

### 5.4.6 Summary of red deer bones from Orkney Neolithic cairns

Red deer bones dominated the mammal bone assemblages of Knowe of Ramsay and Knowe of Yarso cairns, but were also present in other Orkney Neolithic cairns. There is evidence that at least some red deer carcasses had been butchered. Different ages of red deer were represented, and at Knowe of Ramsay it appears that these deer did not all die at the same time of year.

## 5.5 Red Deer Antler

### 5.5.1 General

Red deer males have adopted an evolutionary strategy of growing and shedding antlers on an annual basis, despite the associated energy and mineral loss from other bones such as ribs and limbs (Chen et al., 2009, p694, Davis, 1987, Goss, 1983, MacGregor, 1985, Price et al., 2005). Red deer antlers are used for display, fighting, digging wallows and marking trees (Clutton-Brock, 1984, p17). In order to perform these functions antlers have a similar tensile strength to other bones such as a femur or tibia, but greater elasticity as a result of lower mineral and higher organic component. They also have a more homogeneous microstructure resulting in rapid growth within the annual cycle. Antler therefore has an enhanced capacity to absorb shocks and sudden impacts, a feature making it particularly suitable for use as a raw material for tools or picks (Chapman, 1975 quoted in Clutton-Brock, 1984, Clutton-Brock, 1984, p17, MacGregor, 1985, Alexander, 1994).

Antlers yield a large quantity of material for tool production over the lifetime of a stag. Collecting shed antlers requires little risk or effort (Legge, 1981) but does involve commitment to collect them fairly rapidly before deterioration by weathering and possible gnawing (Clutton-Brock, 1984, p36). Antlers are shed within a day or two of each other and do not wobble in the days/hours before they are shed, unlike deciduous teeth (Price et al., 2005 p209) snapping off from the reabsorbed pedicle when their weight is too much for the remaining bone contact surface. They are usually deposited in the same locality each year (Clutton-Brock, 1984, p16).

### 5.5.2 Antler at LON

Three antler beams were deposited in the foundation deposit, LON Structure 9. Antlers F4469 and F6690 were adjacent to skull F4468 on the west foundation; the third was adjacent to skull F4254 in the east foundation. Another antler was recovered from the infill of Structure 9, F6306.

It was not possible to determine if wear marks were present on these antlers since they disintegrated during excavation. However, the LON antler beams mirror the configuration of antler picks from the Neolithic flint mine of Grimes Graves, Norfolk and the Neolithic ditch and bank at Durrington Walls, Wiltshire (Clutton-Brock, 1984, diagram on cover-page, Plates 2, 3, 6-10) so it is possible that the antlers from the foundation course Structure 9 were picks or blanks for manufacturing tools. To prepare an antler pick the crown is removed by breaking the beam either above or below the bez line. The remainder of the beam, the brow tine and burr are retained but most bez and trez tines are also removed (Clark, 1952, p175, Clutton-Brock, 1984, p24). Alternatively, tines were removed as part of initial manufacturing processes.

Antlers F6690 and F6306 were shed; the antler adjacent to skull F4254 attached to a pedicle/frontal bone and the status of F4469 not determined. The two LON antlers, measured in the field, had maximum medial lengths of 550mm (F4469) and 570mm (F6690). The length of the Grimes Graves antler picks for 244 specimens ranged from 150-600mm, averaging 437mm, those for 332 Durrington Walls's specimens ranged from 0-600mm, averaging 318mm, so the antlers recovered from LON Structure 9 are close to the maxima of these ranges. See *Table 13*. F6690 had a brow tine length of 220mm, which is again within, but at the upper level of, the ranges for Grimes Graves and Durrington Walls (Clutton-Brock, 1984, p35, figs 19 and 20).

**Table 13: Lengths of antler beam: LON (Links of Noltland, Late Neolithic): Grimes Graves (Neolithic/Bronze Age); Durrington Walls (Neolithic)**

| Site | No | Length range (mm) | Ave length (mm) |
|---|---|---|---|
| LON F4469 | 1 | 550 | |
| LON F6690 | 1 | 570 | |
| Grimes Graves | 244 | 150-600 | 437 |
| Durrington Walls | 318 | 0-600 | 318 |

Other shed antlers at LON were recovered from the midden below Structure 9, context 9690, rubble infill to Structure 8, context 9134, and rubble infill to Structure 9, context 9104 and from a sondage through midden material, context 9192. An antler still attached to the frontal bone was recovered from midden material associated with context 9031. In addition, antler tine fragments were recovered from numerous LON contexts.

### 5.5.3 Antler from Neolithic Orkney settlements

No significant antler finds have been reported from Neolithic settlement sites in Orkney, apart from:

- Rinyo, Rousay, one antler in NMS Collection Centre with brow tine in position, next two tines missing, basal circumference of 152mm (Childe and Grant, 1939, 1947)
- Skara Brae, Mainland: four shed antlers which “must have been picked up as raw materials” (Watson, 1931, pp203-204). Within Hut 9, an antler perforated and hollowed out to serve as mount for a stone axe (Childe, 1950, p19)
- Pool, Sandy: one shed antler burr (PL6836), too poor condition to determine if a tool such as a hammer or a source for antler working (Hunter, 2007, p459)
- Tofts Ness, Sanday: antler fragments (approximately 50) (Nicholson and Davies, 2007). In addition, sketch plan of a semi-articulated cattle skeleton recovered from Neolithic midden includes a shed antler with brow and bez tine attached and an adjacent “? trez tine” (Bond 2007b, pp195-196, Illustration 6.3.2.1)

During the Iron Age in Orkney, two antler picks were reported from Phase 6.3 from Tofts Ness (Davies, 2007, p338, p340 Illustration 7.7.9).

### 5.5.4 Antler from Neolithic Orkney cairns

The following antler fragments have been recovered from Neolithic Orkney cairns:

- Quanterness, Mainland: antler burr fragment, Area III, layer 64, stratum 4 (Clutton-Brock, 1979, p119)
- Pierowall Quarry, Westray: shed burr and beam recorded in shillet layer on top of, and to a degree mixed with, collapsed walls of Neolithic structure (MacCormick, 1984 Appendix 2:E3)
- Knowe of Ramsay, Rousay: two antler burrs fragments, Cell 5, (Platt, 1936, p416)

Shed burrs were also noted at the NMS Collection Centre from the Neolithic cairns of Quoyness, Sanday and Knowe of Rowiegar, Rousay. In addition, G. Petrie’s notes from a 19th century excavation of Holm of Papa Westray North cairn recorded twelve pairs of antlers but only a small proportion now survive (Harman, 2009, p55, Ritchie 2009, p3). However, in the late 20th century excavation over four hundred antler fragments were recovered including twelve or thirteen antler burrs, five with brow tines attached and one with brow and trez tine attached. A minimum of seventeen or eighteen antlers were present, most from animals of at least four/five years (Harman, 2009). The antler fragments outnumbered other red deer bones from the cairn by approximately 10:1 and were from older animals than those represented by post-cranial bones. Most of the antler came from infill but some were floor deposits (Ritchie, 2004, p98). The presence of deer antler within the cairn is unlikely to be the result of natural antler shedding because the entrance passage is low in height (Balasse and Tresset, 2009 p81, Ritchie, 2009, p32). At least one crown was recovered, as well as numerous tine points, suggesting that antlers may had been converted to picks "*in situ*". The faunal specialist suggests that "some at least may have been used as picks when the tomb was being dismantled and filled in" (Harman, 2009, p57).

### 5.5.5 Antler survival

The evidence from LON foundation deposits and a review of the other finds from Orkney sites suggest that perhaps antler tools were in use during the Neolithic period. Survival of bone from taphonomic processes is, to some extent, related to bone composition (Lyman, 1994, pp234-237, Shipman 1981 p25). The photon densitometry of antler is not recorded by L. Lyman (1994, p246, table 7.6) but M. Stiner attaches a similar value to antler as atlas/axis bones which is lower than head, axial, limbs and feet bones (Stiner 2002, p982, fig 3, 2004, p129, fig 11). Structural density by simple Archimedean displacement after removal of gases has been calculated and reveals greater porosity in antler than cattle limb bones and lower density (Currey, 1970, 1984, p90, table 1.3). Antler also have a higher surface area to volume ratio for mechanical and chemical attrition than cattle limb bones (Lyman, 1994, p239) particularly if areas of the more porous inner core are exposed, as is the case if antlers are modified for picks or tools.

## 5.6 Overview

Red deer bones at Neolithic cairn and settlement sites in Orkney are wide-spread but infrequent. Age and skeletal representation demonstrates that red deer inhabited Orkney during this period. Butchery marks on Late Neolithic midden material demonstrates red deer were processed for meat, and perhaps other products such as hide, so consumption of venison was not prohibited. Butchered bones within two cairns, Knowe of Ramsay and Knowe of Yarso may have remains of feasts post-dating the deposition of human remains. Possible explanations for the articulated red deer deposits recovered in Neolithic Orkney are discussed in *Chapter 11*. The importance of antler in Neolithic Orkney for practical, and possibly symbolic, use may be under-estimated.

# 6 Mammal bones recovered from LON

## 6.1 Introduction

Mammal bone analysis was carried out on eight areas of LON, excavated in 2007, 2010 and 2011, selected to support the investigation of the cattle and sheep skull and articulated red deer skeletons depositions. This analysis explores the relationship between the LON community and mammals and the route from living mammals to excavated bone fragment deposits.

The areas examined are as follows:

- Midden below Structure 9
- Floor of Structure 9
- Wall core material from Structure 9
- Midden covering Structure 9, context 9031
- Midden covering part of Area 5 (including Structure 8 and 10) context 7302
- Infill of kiln in Structure 10 associated with red deer skeleton deposition
- Two additional areas of midden covering Area 5 (~context 7302a and ~7302b)

Examining mammal bone fragments from selected LON areas allowed full analysis of material, for example, species composition, measurements, age at death, pathology, level of burning and fragmentation, setting aside other areas for future research. The disadvantage of this approach is reduction in the ability to make a reliable statement on the whole LON mammalian assemblage. The selection of specific contexts, despite being based on the generation of data to support interpretation of mammal skull and articulated red deer deposits, is ultimately a subjective decision and information inevitably lost. The areas already excavated when the animal bone identification was undertaken and not examined for this thesis included:

- Bronze Age material
- Infill material from structures in Area 5 (except contexts associated with an articulated red deer deposit)
- Material from upper infill layers of Structure 18 (except skull depositions),
- Material associated with Structure 7 and its overlying midden

The other approach considered was the one adopted for Schipluiden, a Neolithic settlement on the Dutch North Sea. The zooarchaeologist selected only readily identifiable fragments for analysis and categories such as “medium-sized mammal” were excluded. This approach was justified on the basis that it still generated data on seasonality, butchering, age at death profiles, bone working, and spatial distribution of specific categories (Zeiler, 2006). Another version of this approach identification of only nominated bone parts for each species such as humerus distal epiphysis or scapula glenoid articulation (Davis, 1987, p35, table 1.4).

These alternative approaches would have permitted examination of a greater number of contexts and resulted in a clear, consistent identification approach for the assemblage. However, a decision was made to record all bone fragments in order to assess not only the type and proportions of species present but the relationship between identifiable/unidentifiable bones, weight of burnt bones and fragment size. It is possible to reduce the current LON database to selected mammal bone elements, since the York recording system designates zone(s) for each identified bone, but if a restricted identification suite had been adopted, any future researchers would be constrained by the initial selection of predetermined elements, unless time was allocated to identify additional bones or bone fragments of interest (Driver, 1992, Reitz and Wing, 199, p145).

Notwithstanding, in this thesis much of the LON data used for analysis would have been included in any pre-determined element list, so there is an argument that for the remainder of the LON site, in order to examine the extensive number of bone fragments recovered, a predetermined selection system should be adopted although perhaps with a more extensive than the zones listed by S. Davis (Davis, 1987, p35, table 1.4) and including selected cranial elements, since LON mammal skull deposition is of interest.

The mammal bone assessment starts with an initial hypothesis that, although there may have been some import or even export of mammals, either as live or dead stock, LON operated as a rural production and consumption centre (Amorosi et al., 1996, p129). All elements of cattle, sheep and red deer skeletons were present at the site.

The mammal material examined was hand-collected or sieved at 10mm at the excavators of the site. The material does not include subsequent sieved or flotation samples because these were not available at the time of examination. The inevitable underrepresentation of small mammal bones and sheep bones such as carpals is acknowledged.

## 6.2 Details of LON areas studied

### 6.2.1 Midden below Structure 9

Contexts examined:

- 9861: midden
- 9690: midden

Midden deposits underlying Structure 9, the Neolithic structure with walls razed in antiquity and cattle skulls deposited in foundations. This area was investigated to determine if its mammal bones were similar to other LON middens or whether the area had a designated purpose prior to the construction of Structure 9.

### 6.2.2 Floor of Structure 9

Contexts examined:

- 9104: rubble infill into Structure 9
- 9111: ashy floor deposit
- 9117: upper hearth fill
- 9118: floor in compartment E
- 9119: floor in compartment W
- 9120: floor in compartment S
- 9122: floor surrounding hearth
- 9125: hearth fill
- 9166: black ashy soil
- 9173: central floor and
- 9189: floor deposit

These deposits were investigated to determine if differences existed in faunal assemblages from the floor area compared with midden deposits underlying and overlying Structure 9. This is the only LON area examined that may include primary deposition of small pieces of discarded or lost (dropped) material that do not warrant the effort to clear them up periodically (LaMotta and Schiffer, 1999).

### 6.2.3 Wall Core from Structure 9

Contexts examined:

- 9116: wall core/foundation deposit
- 9123: wall core/foundation deposit

Wall core/foundation deposits in Structure 9 associated with cattle skull deposition. Contexts examined to determine if the material surrounding cattle skulls differed from those of other midden areas.

### 6.2.4 Midden covering Structure 9

Contexts examined:

- 9031: midden material overlying Structure 9

Midden overlying Structure 9 was examined for comparison with the more southerly and deeper midden, context 7302. Context 9031 material was also compared with Structure 9 floor, hearth and foundation course and with midden material below Structure 9.

*Radiocarbon dates for context 9031*

*(i) 2871 to 2573 cal BC: sheep calcaneus, part of an articulated sequence*

### 6.2.5 Midden covering part of Area 5, (including Structures 8 and 10) context 7302

Context examined:

- 7302: midden

Deepest section of a midden deposited after abandonment of the structural complex in Area 5. Although labelled as one stratigraphic unit, this context was excavated in eight 100mm deep spits, spit 1 being the uppermost spit, spit 8 being in contact underlying building material. A total of 82% of animal bone material recovered came from the upper spits 1, 2, 3 and 4. Preliminary examination of context 7302 was to determine whether spits could be treated as a single entity.

*Radiocarbon dates for context 7302*

*(i) 2630 to 2470 cal BC: cattle phalanx, in articulation*

(ii) *2870 to 2570 cal BC: sheep vertebra, in articulation*

### Infill to kiln, Structure 10

Contexts examined**:**

- 9006, 9016, 9017, 9019: infill for linear feature, possibly flue
- 9009: collapsed superstructure associated with possible flue
- 9010: fill of west end of kiln
- 9059, 9061 and 9062: walls defining edge of kiln

Contexts adjacent to the articulated red deer deposit in Structure 10, associated with a later kiln structure in Area 5 and underlying midden spreads. The kiln/flue infill material was examined to determine if other red deer bones were deposited in this area.

*Radiocarbon dates for contexts 9009 and 9016*

*(i) 2890 to 2660 cal BC: sheep vertebra part of articulated sequence*
*(ii) 2860 to 2490 cal BC: cattle calcaneus, part of articulated foot*
*(iii) 2580 to 2349 cal BC: red deer femur, from articulated skeleton.*

### 6.2.6 Midden equivalent to context 7302 (a)

Contexts examined:

- 9110: midden from north of Area 5
- 9114: midden from north of Area 5
- 9126: midden below 9110
- 9128, 9129: concentrations of animal bone within 9126

These contexts were examined to compare this area with midden deposits, particularly because a bone concentration was recovered in this area.

### 6.2.7 Midden equivalent to context 7302 (b)

Contexts examined:

- 8000, 8001, 8003, 8015, 9003, 9012, 9028 and 9085 midden equivalent to 7302

The contexts were examined to determine if this collection of bones differed from those of context 7302.

Cattle and sheep dominated all collections. Small numbers of rabbit bone, four in spit 1, context 7302, and one in context 9031, shows that although rabbit burrowing is prevalent on the LON site today, rabbit activity appears to have been restricted to the looser machair soil and did not significantly contaminate the more consolidated archaeological midden material.

## 6.3 Species Distribution

### 6.3.1 General

Distribution of species and some broader taxonomic categories were examined to determine the composition of the faunal assemblage. Each area under investigation is reported separately. See *Tables 14 and 15.*

**Table 14: Distribution of LON (Links of Noltland) identified species by weight (g) (excludes ribs, shafts and red deer antler). H/B whale- humpback whale**

| LON area | Cattle | Sheep | Pig | Red deer | Dog | Fox | H/B Whale | Grey seal | Otter | Vole |
|---|---|---|---|---|---|---|---|---|---|---|
| Midden below St 9 | 3038 | 408 | 9 | 536 | | | | | | * |
| Floor St 9 | 1760 | 571 | 13 | 166 | | | | | | * |
| Wall core St 9 | 8277 | 1184 | 8 | 200 | | | | | 8 | * |
| Midden 9031 | 10100 | 4222 | 143 | 329 | 2 | | | | 7 | * |
| Midden 7302 | 38380 | 19574 | 1128 | 866 | 10 | 2 | 121 | 10 | 14 | * |
| Infill to kiln, St 10 | 4166 | 1639 | 13 | Deposit exclude | 1 | | | 6 | | * |
| Midden ~7302a | 4824 | 2064 | 12 | 15 | | | | | | * |
| Midden ~7302b | 2476 | 655 | 4 | 20 | | | | | | * |

**Table 15: Distribution of LON (Links of Noltland) NISP (excludes ribs, shafts and red deer antler). H/B whale- humpback whale**

| LON area | Cattle | Sheep | Pig | Red deer | Dog | Fox | H/B Whale | Grey seal | Otter | Vole |
|---|---|---|---|---|---|---|---|---|---|---|
| Midden below St 9 | 244 | 174 | 2 | 41 | | | | | | * |
| Floor St 9 | 142 | 153 | 5 | 18 | | | | | | * |
| Wall core St 9 | 1265 | 368 | 6 | 34 | | | | | 9 | * |
| Midden 9031 | 1023 | 1298 | 30 | 37 | 1 | | | | 6 | * |
| Midden 7302 | 3013 | 4953 | 202 | 48 | 7 | 1 | 2 | 2 | 3 | * |
| Infill to kiln, St 10 | 268 | 355 | 3 | Deposit exclude | 1 | | | 1 | | * |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Midden ~7302a | 202 | 189 | 2 | 2 | | | | | | * |
| Midden ~7302b | 175 | 153 | 3 | 2 | | | | | | * |

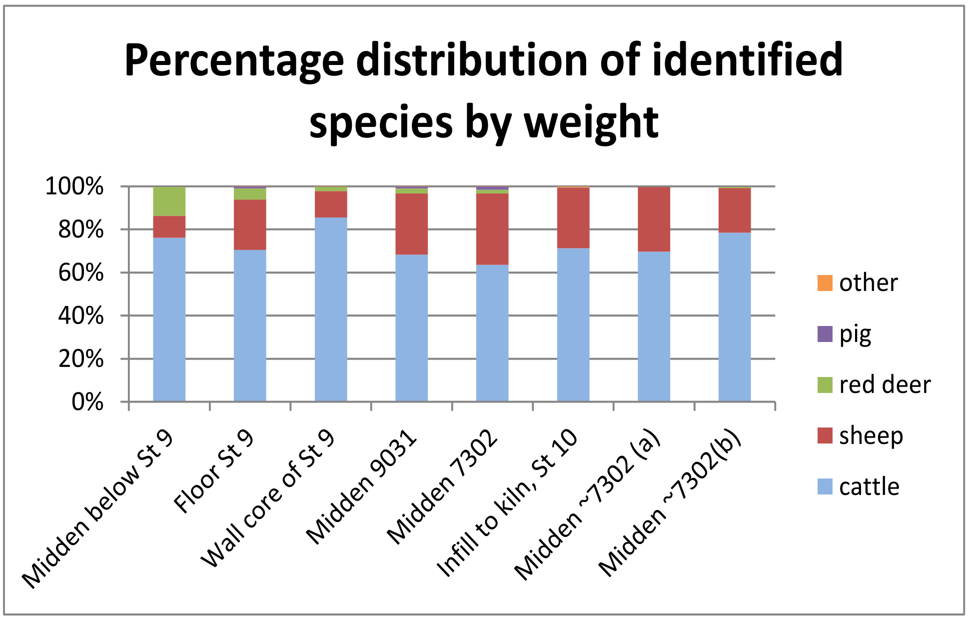
## 6.3.2 Results

Details of NISP; weight of bone identified to species: percentage of total weight of bone recovered identified to species is in *Table 16.* The percentage of unidentified bone, by weight, that could not be allocated to species or even to size category (e.g. large mammal, medium size mammal, small mammal) varied from 5% to less than 1%. See *Table 16*.

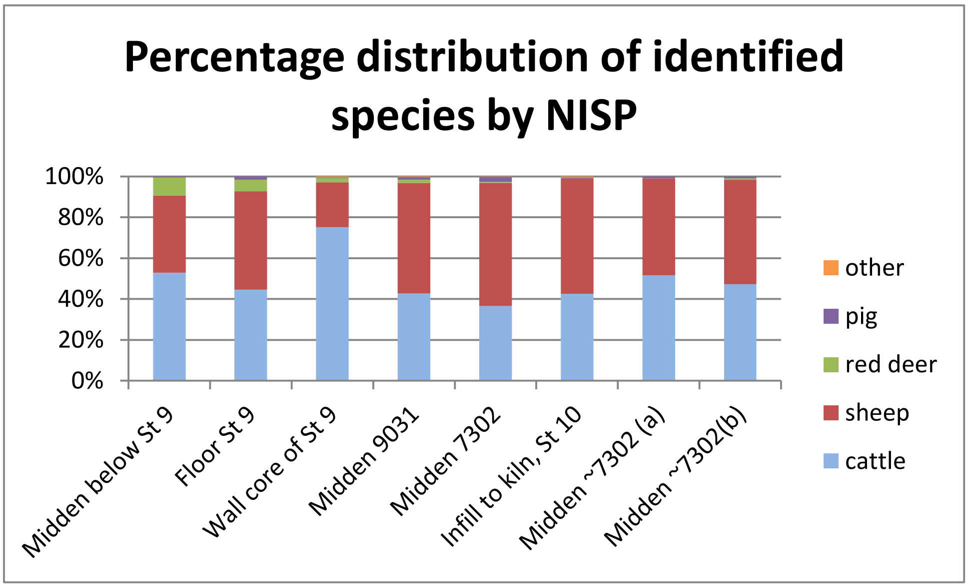
**Table 16: Percentage identified by weight for eight LON areas studied. Voles and red deer deposit in in kiln, Area 5 not included.**

| LON area | Wt ID (kg) | %Wt ID |
|---|---|---|
| Midden below St 9 | 4.0 | 55% |
| Floor of St 9 | 2.5 | 60% |
| Wall core of St 9 | 9.7 | 77% |
| Midden above St 9 | 14.8 | 68% |
| Midden 7302 | 60.0 | 73% |
| Infill to kiln, St 10 | 5.8 | 72% |
| Midden ˜ 7302 (a) | 6.9 | 94% |
| Midden ˜ 7302 (b) | 3.2 | 87% |

Proportions of mammal species weight/NISP are displayed in *Graphs 7 and 8.* The red deer deposit from kiln, Structure 10 was not included since these bones were predominately associated with an articulated skeleton. This red deer deposit weighed 4.04kg. In all areas cattle bones were ranked 1st and sheep 2nd by weight apart from the midden area below Structure 9, where although cattle are still ranked 1st, red deer bone weight was ranked higher than sheep bones. For NISP, sheep were ranked 1st, cattle 2nd in five areas, cattle ranked 1st and sheep 2nd in three areas.



**Graph 7: Percentage distribution of cattle, sheep, red deer, pig and other species in eight areas studied at LON (Links of Noltland) by weight (g). Red deer deposit in kiln, Area 5, excluded**



**Graph 8: percentage distribution of cattle, sheep, red deer, pig and other species in eight areas studied at LON (Links of Noltland) by NISP Red deer special deposit in kiln, Area 5, excluded**

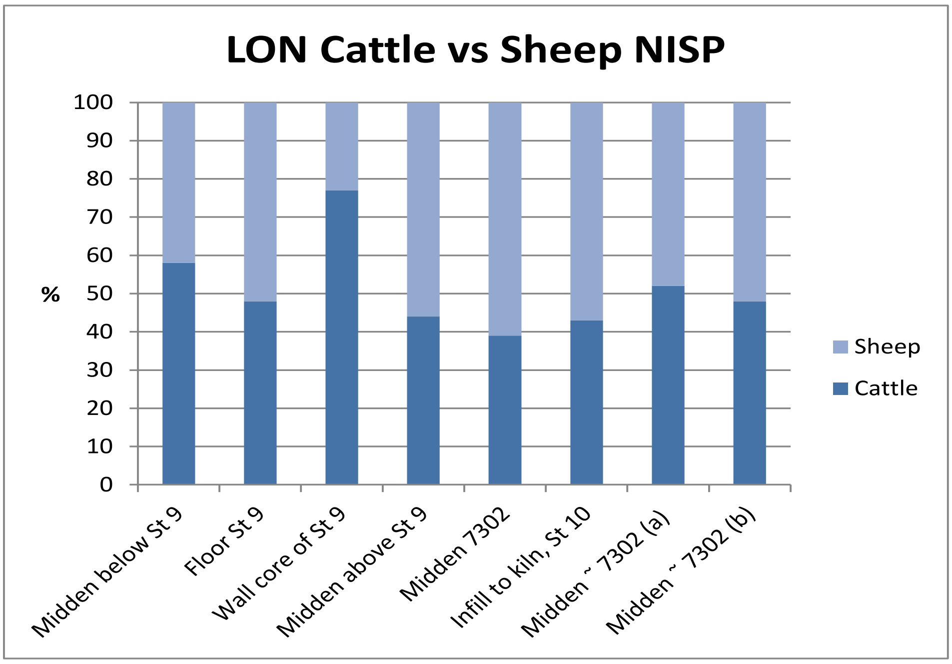
In addition, spits 1-8 from midden context 7302 were examined (with spits 7 and 8 amalgamated because of low bone numbers). The results throughout the midden were consistent, with cattle always dominant by weight, sheep dominant by NISP and pig third in both NISP and weight categories except for spits 7/8 where the presence of three red deer bones altered the weight ranking, making red deer 3rd by weight. These red deer bones comprised a right patella, distal tibia and distal femur from an adult red deer. The femur and tibias diaphyses had spiral breaks and cut marks adjacent to the articulation of the distal tibia, suggesting these bones, although possibly from one animal, were not from an unbutchered articulated limb bone.

Ranking results illustrate that cattle and sheep dominated all mammals identified to species in all LON areas examined. Combined percentages of cattle and sheep NISP/weight from total NISP/ weight were tabulated to demonstrate how few bone fragments from other mammal species were present. See *Table 17.*

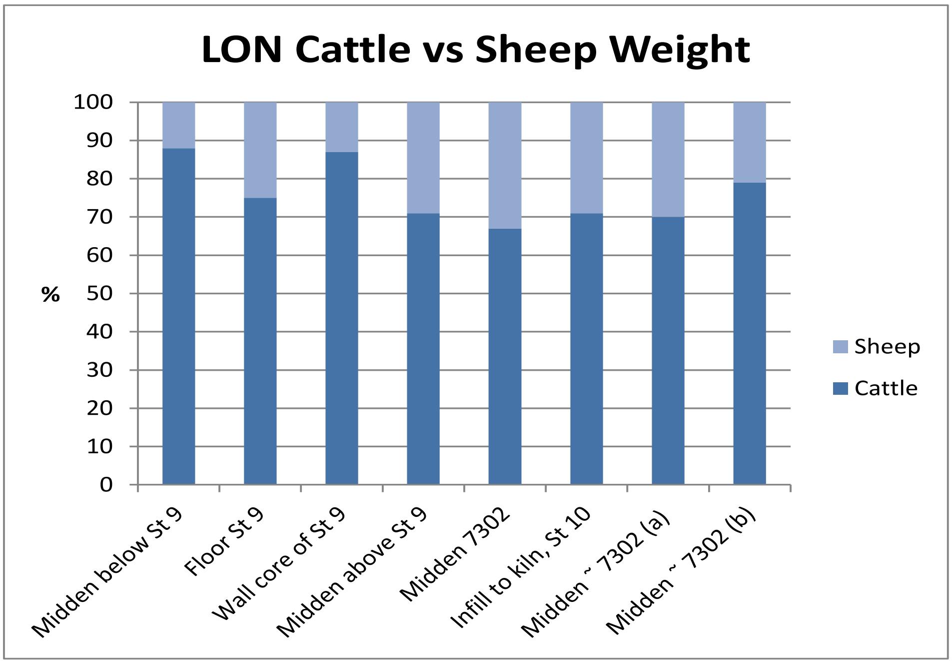
**Table 17: Percentage cattle and sheep in bone fragment counts and weight from eight LON areas studied (Red deer deposit in kiln, Area 5, excluded)**

| LON area | NISP cattle/ sheep | NISP total | NISP % cattle/ Sheep | Wt cattle/ sheep (g) | Wt total species identified (g) | Wt % cattle/ Sheep |
|---|---|---|---|---|---|---|
| Midden below St 9 | 418 | 461 | 91% | 3446 | 3991 | 86% |
| Floor St 9 | 295 | 318 | 93% | 2331 | 2511 | 93% |
| Wall core St 9 | 1633 | 1682 | 97% | 9461 | 9677 | 98% |
| Midden 9031 | 2321 | 2395 | 97% | 14322 | 14803 | 97% |
| Midden 7302 | 7966 | 8231 | 97% | 57954 | 60012 | 96% |
| Infill to kiln, St 10 | 623 | 628 | 99% | 5805 | 5827 | 99% |
| Midden ~7302a | 391 | 395 | 99% | 6888 | 6915 | 99% |
| Midden ~7302b | 333 | 338 | 98% | 3131 | 3155 | 99% |

Percentages of cattle and sheep combined were in excess of 90% of all mammals identified at species level, apart from weight of bone in midden below Structure 9, due to greater abundance of red deer bone fragments. The ratio of sheep and cattle, by NISP and by weight are for all eight areas are presented in *Graphs 9 and 10* and *Appendix 13.*

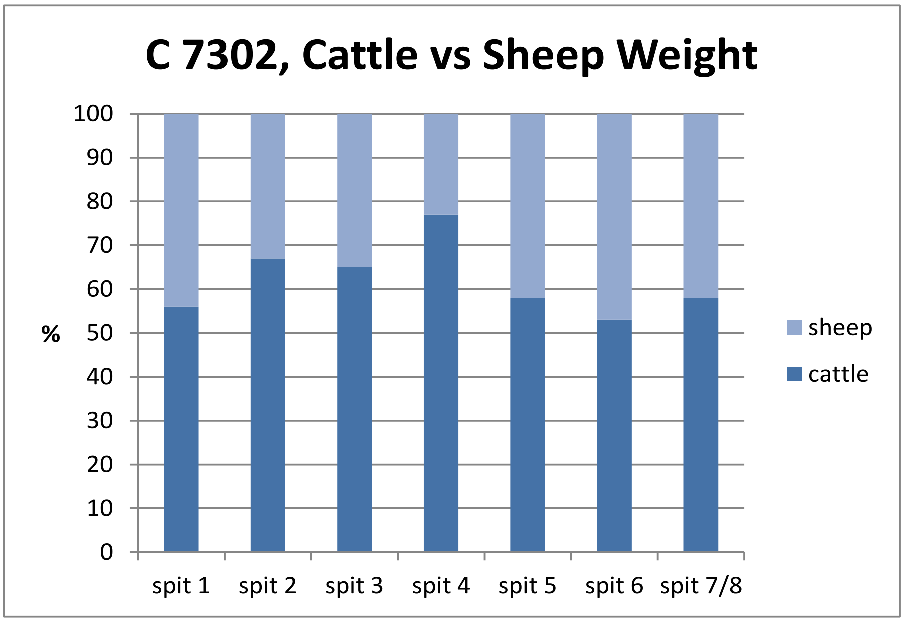


**Graph 9: Percentage cattle and sheep in eight LON (Links of Noltland) areas under study, NISP**



**Graph 10: Percentage cattle and sheep in eight LON (Links of Noltland) areas under study, weight (g)**

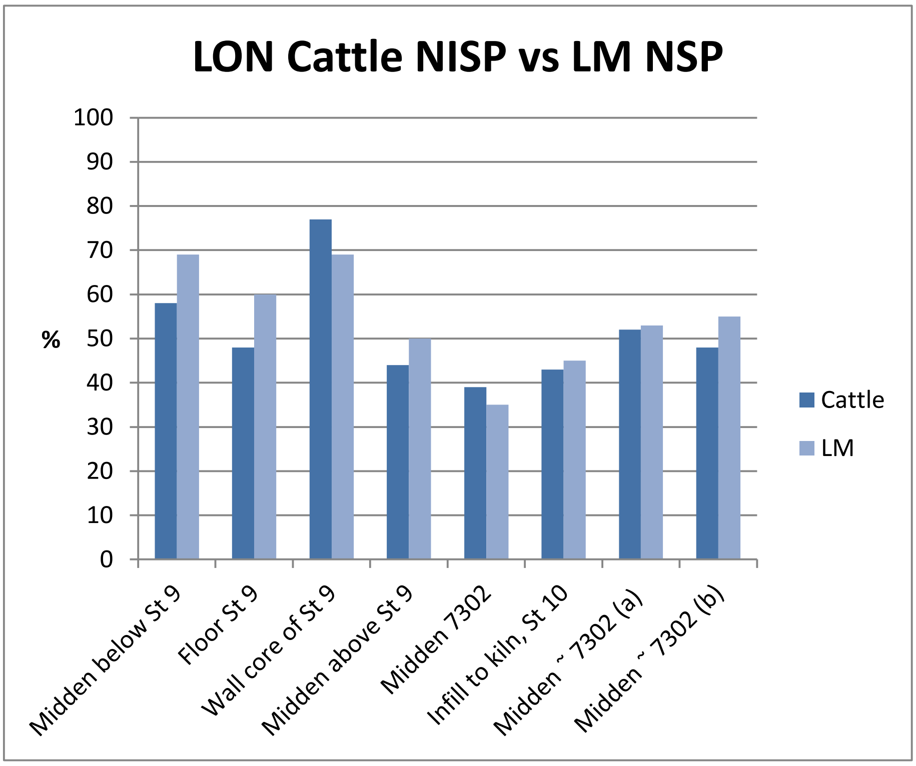
In addition, the proportion of cattle to sheep was examined for spit by spit for midden 7302 to determine if there was any evidence of change over the period when the midden was deposited. See *Graph 11* and *Appendix 14.*



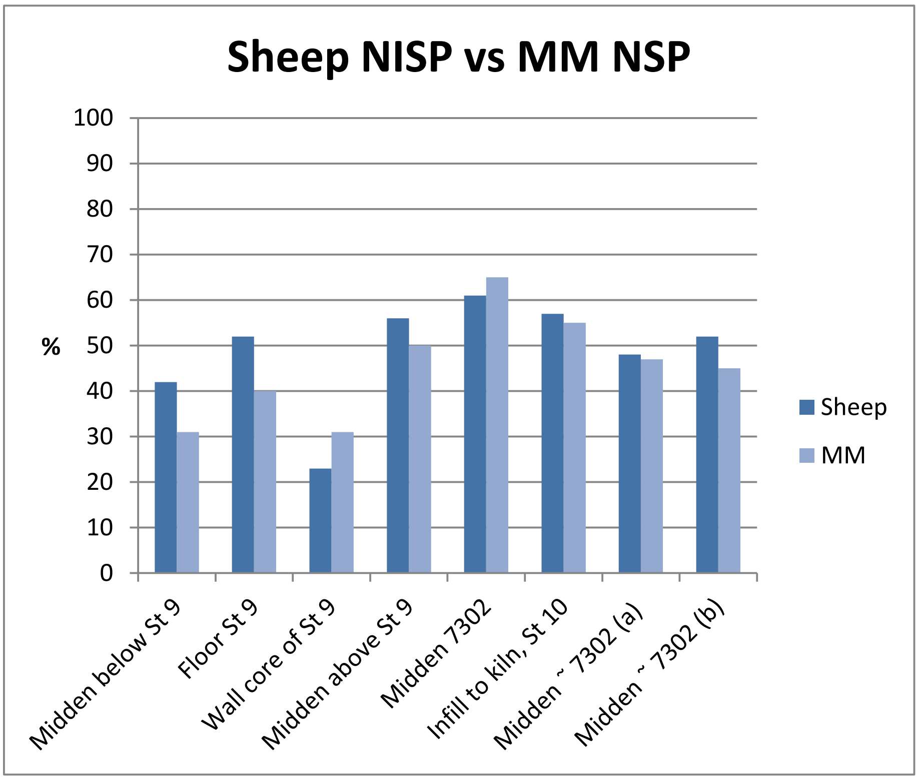
**Graph 11: Percentage cattle and sheep in midden context LON (Links of Noltland) 7302 spits, weight (g)**

The results indicate some variation in proportions of the two species, but no evidence that there was an increase in sheep representation during the later stages of this late Neolithic midden formation.

To check whether most large mammal and medium size mammal bones were from the main two species, cattle and sheep, and removal of ribs and shaft fragments from NISP and species weights did not distort results, the percentage cattle versus percentage large mammal (including those identified to cattle and red deer bones) and percentage sheep versus percentage medium sized mammals (including those identified to sheep, pig and dog) were examined. The large mammal and medium sized mammal graphs demonstrated similar distributions to those for cattle and sheep. See *Graphs 12 and 13.*



Graph 12: Percentage cattle NISP distribution compared with large mammal (LM) NSP distribution in eight LON (Links of Noltland) areas under study



Graph 13: Percentage sheep NISP distribution compared with medium sized mammal (MM) NSP distribution in eight LON (Links of Noltland) areas under study

The LON mammal distribution, dominated by cattle and sheep, aligned with observations from other Late Neolithic Orcadian settlement site of Skara Brae (Clarke, 1998, pp14-15, Clarke and Sharples, 1985, p75, Noddle, 1979, p288, table 2, Watson, 1931, pp198-203). Also, at D. Clarke's earlier excavation at LON, Trench D, sheep were numerically the most abundant species, by NISP followed by cattle with pigs being rare. If bone weight is used cattle bones weight exceeded those of sheep (Armour-Chelu, 1992, p111).

At the Mid Neolithic Orcadian settlement at Knap of Howar, Papa Westray, cattle and sheep were also the dominant species, with other mammal species rare (Noddle, 1983, p93). There is therefore no evidence that pig husbandry was important to earlier generations and suffered a decline between the Mid and Late Neolithic (Noddle, 1983, p95).

NISP ratios of cattle: sheep at Knap of Howar:

- 55%: 45% (Phase 2)
- 45%: 55% (Phase 1)
- 44%: 56% (topsoil)

At Pool settlement, Sanday cattle and sheep also dominated Neolithic contexts with pig red deer and whale bone rarely encountered (Bond 2007, p210, table 7.2.1).

NISP ratios of cattle: sheep at Pool:

- 57%: 43% (phase 1)
- 50%: 50% (phase 2)
- 64%: 36% (phase 3)

At Tofts Ness, Sanday Neolithic and Early Bronze Age assemblages were amalgamated, with cattle and sheep again dominating the assemblages while pig, red deer, otter and whale bones rare (Nicholson and Davies, 2007, p174, table 6.3.1.3).

NISP ratios of cattle: sheep at Tofts Ness:

- 45%: 55%,

By the Iron Age period in Orkney at Skaill, Mainland, Site 5 (13,080 NISP) cattle and sheep were still dominant but over one-fifth NISP were allocated to other species, including 10% to pig. The NISP ratio for cattle: sheep, however, was 52%: 48%, similar to results from Orcadian Neolithic settlements (Noddle, 1997, p237, table 17.1a).

A larger proportion of pig bones was also noted at four other Orcadian Iron Age sites (i) Pool, Sanday, phase 5 (Late Iron Age) (ii) Pierowall Quarry, Westray (Iron Age structure built over a Neolithic cairn) (iii) Early, Mid and Late Iron Age at Howe, Mainland (iv) Brest Ness, Westray (Bond, 2007, p210, table 7.2.1, Fraser unpublished, MacCormick, 1984, Smith 1994, p139). At all these Iron Age sites cattle and sheep bones NISP still dominated the assemblage.

The cattle: sheep bone weight ratios, and the large mammal: medium size mammal weight ratios indicate that the LON midden below Structure 9, and the wall core of Structure 9 (which may have been sourced from adjacent midden) have a lower proportion of sheep than the other six areas examined, and these results are analysed in more detail later in this chapter to determine whether this difference was due to taphonomic or cultural factors.

Since LON cattle: sheep and large mammal: medium size mammal weight ratios were similar, removing shafts and rib fragments from identified species weights does not seem to have had a significant impact on reporting the representation of cattle and sheep at this particular site with its limited taxonomic mammal diversity. However, when the NSP ratios are examined, there are slightly greater differences between the ratios and in two instances there is a reversal of the most abundant species between cattle: sheep and large mammal: medium size mammal. This demonstrates the sensitivity of NISP to decisions as to what to include/exclude in counts and the degree of fragmentation of bones.

### 6.3.3 Summary

Cattle and sheep dominated the mammal bone fragments from the eight LON areas studied. Red deer bones made the next most important contribution to the assemblage, with low representation from pig. This pattern is reflected at other Mid and Late Neolithic Orcadian sites, but by the Iron Age pig representation increased although relative proportions between cattle and sheep NISP remained similar. At Neolithic sites in southern England cattle are also the best represented mammal in bone collections, but pig contribute more, sheep less. In addition, red deer bones are more numerous at LON than sites in southern England. Presence of sea mammal bones is negligible at both the Orcadian and southern English sites, apart from structural elements in buildings or as containers/artefacts in Orkney.

## 6.4 Fragmentation

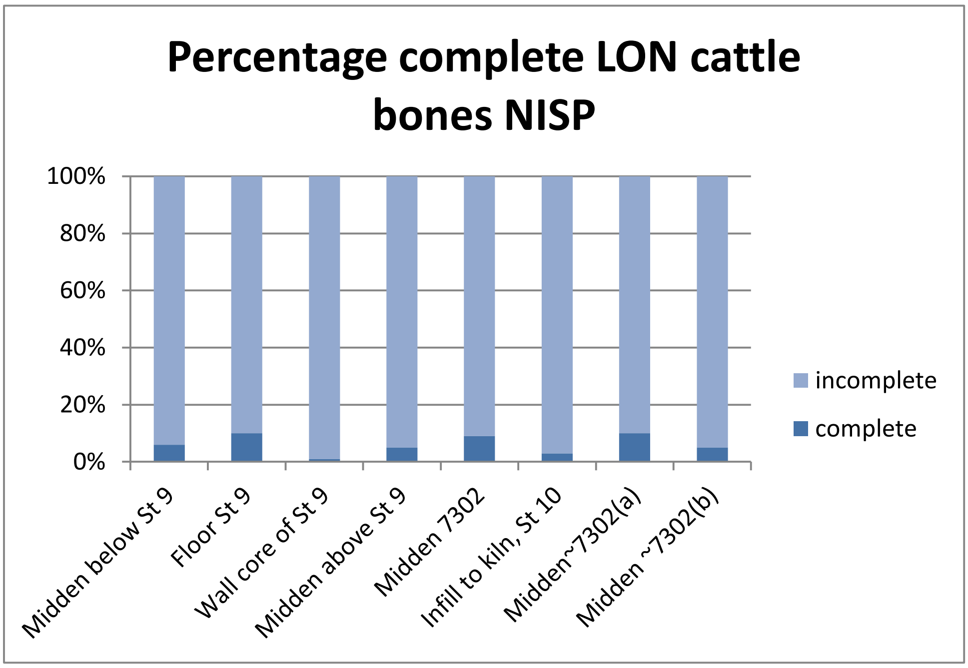
### 6.4.1 General

Fragmentation of bones was reviewed for each of the eight LON areas under study. The extent of fragmentation (the proportion of NISP made up by complete bones) and intensity of fragmentation (the mean weight of fragments) was examined (Lyman, 1994, p333). Fragmentation depends on which bone elements are present, on taphonomic factors such as trampling, exposure to weathering, bird and mammal scavenging, condition at excavation, as well as mesh size of sieves, but gives some indication of patterns across the LON eight areas excavated. Observations of methods of bone breakage methods are also reported.

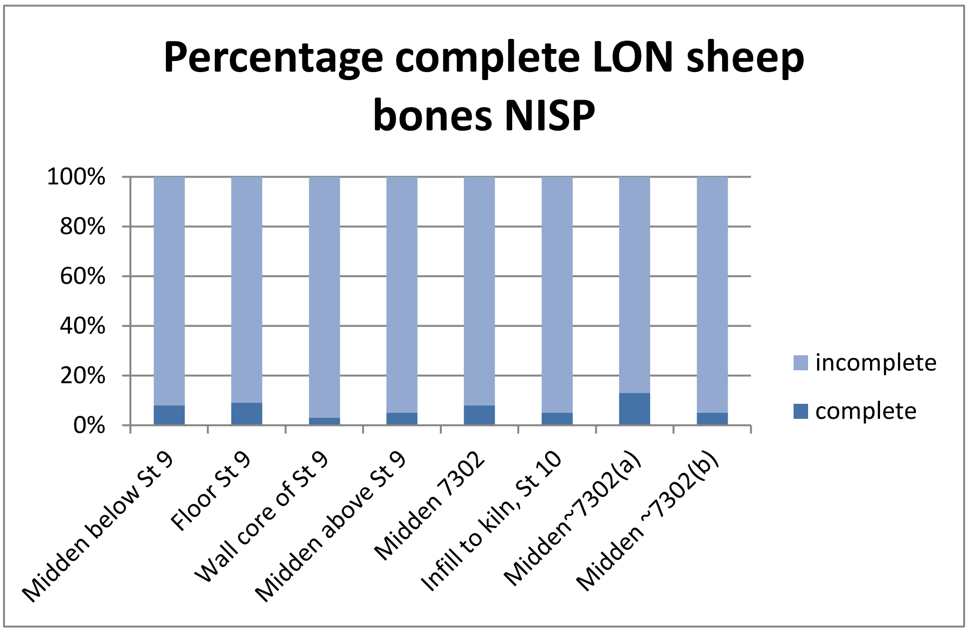
Bones broken during excavation can often be recognised because breaks are angular and have a different colour and present opportunities for retrofitting. However, early breaks from dismemberment, cooking and use of bones for tool material may often result in bones from the same animal being deposited at different times in different locations at the settlement (Schiffer, 1983, 1996) and in these cases, it is unlikely that cross-matches will be recognised during identification. During cooking, if meat and bones were boiled in a pot over a fire; or in a trough heated by fire-stones (Wilson, 1973, p64) bones have to be reduced to “pot-sized” portions, so roasted bones may suffer less breakage.

### 6.4.2 Results

Complete bones from cattle, sheep, pig and red deer, excluding those from neo-natal mammals and loose teeth were investigated. Less than ten percent of cattle or sheep bones recovered were complete (or broken but retrofitted), apart from sheep in Midden ~7302a, predominately carpal and foot bones See *Graphs 14 and 15 and Appendix 15.*



**Graph 14: Percentage complete cattle bones in eight LON (Links of Noltland) areas under study (by NISP)**

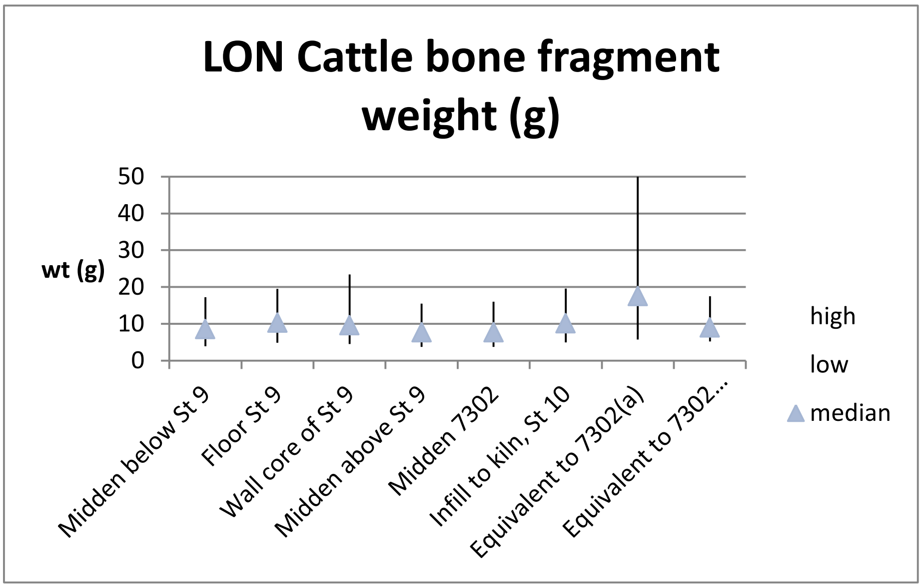


**Graph 15: Percentage complete sheep bones in eight LON (Links of Noltland) areas under study (by NISP)**

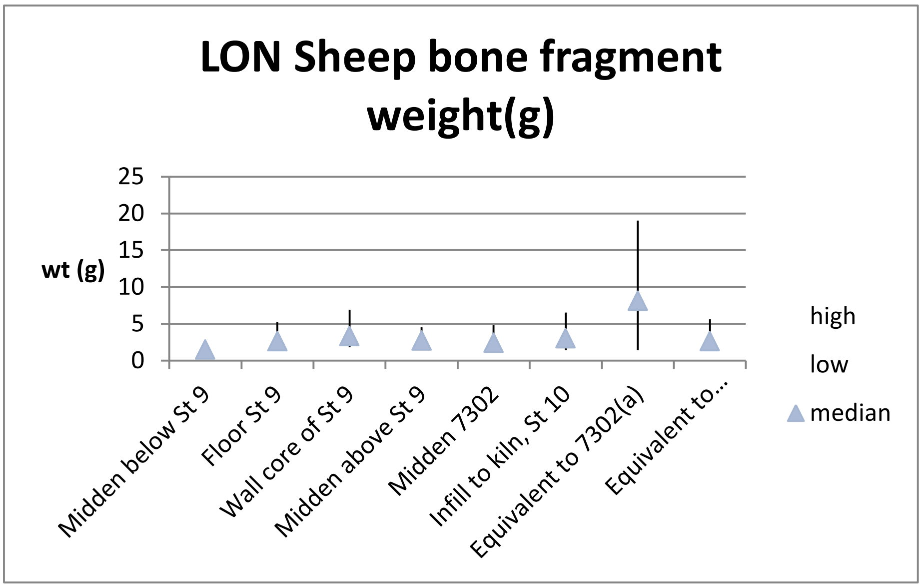
In cattle only “forefeet” and “hindfeet” bones (phalanges, carpals and tarsals) were complete. For sheep, in addition to bones from these categories, a number of mandibles were complete, as were some vertebrae and a few radii, femora, tibiae and metapodials. The unusual nature of the cattle pelvis deposit in the foundation course, Structure 9 is emphasised by the higher level of fragmentation of pelves in other LON areas, none more than 30% complete.

A few pig and red deer complete bones were also recovered (in addition to the red deer articulated skeleton deposits). However, the only complete bones from both species were "forefeet" and "hindfeet", apart from one fragmented but retrofitted red deer radius (dry breaks) in articulation with four carpals from context 9098, north extension of context 9031.

Median and upper/lower quartiles of weights of cattle and sheep bone fragments were calculated for the eight LON areas under study See *Graphs 16 and 17.*



**Graph 16: Cattle bone fragment median and 25% (low) and 75% (high) quartile range from eight LON (Links of Noltland) areas under study, weight (g)**



**Graph 17: Sheep bone fragment medium and 25% (low) and 75% (high) quartile range from eight LON (Links of Noltland) study areas, weight (g)**

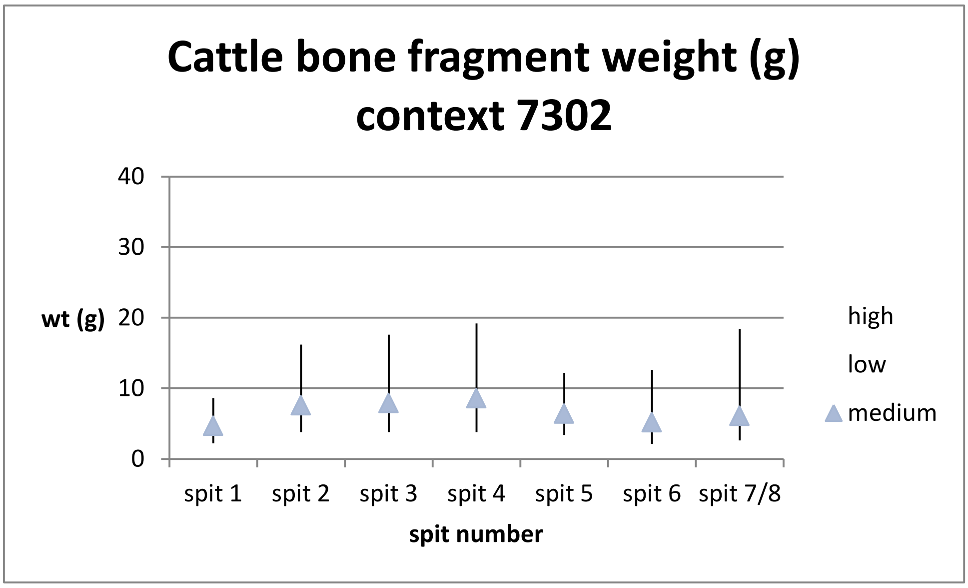
The higher medium weight from midden “equivalent to context 7302 (a)” were due to deposits of sheep and cattle mandibles and maxilla in this area plus a section of articulated cattle vertebrae, perhaps indicating an area particularly associated with primary butchery. These graphs demonstrate a high level of fragmentation of bones from the eight LON areas.

It was noted that young cattle were processed. For example, two cattle skull frontals with undeveloped horn-core buds displayed long thin cut marks, and one cattle axis fragment appeared to have chop marks. Two cattle mandibles, with 1st molars ($M_1$) only erupted to bone line had cut marks on the horizontal rami, and another mandible of similar age had cut marks on its buccal side below the condyle. Cut marks were also noted on the following calf bones:

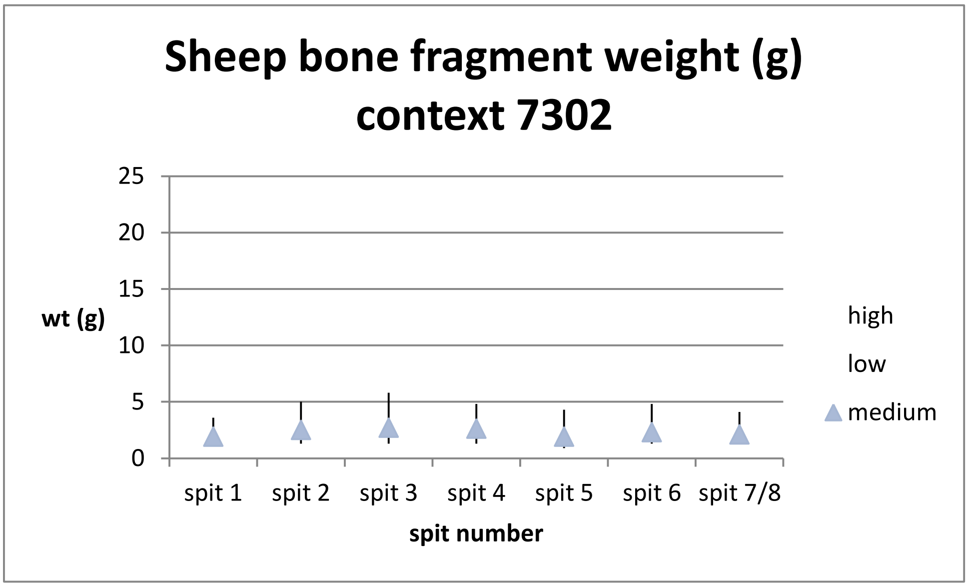
- five metapodial bones
- three humeri diaphysis
- three radii
- two femora
- one tibia
- two pelves

Use of calf skins may have been important for manufacturing clothing. Additionally, rennet from the stomach of a recently born calf would have been essential for cheese production if this occurred at LON.

Weights of cattle and sheep bone fragments were also examined for separate spits in context 7302. See *Graphs 18 and 19.*



**Graph 18: Cattle bone fragment median and 25% (low) and 75% (high) quartile range in LON (Links of Noltland) context 7302 by weight (g)**



**Graph 19: Sheep bone fragment median and 25% (low) and 75% (high) quartile range in LON (Links of Noltland) context 7302 by weight (g)**

Spit 1, the uppermost spit, has a slightly lower cattle and sheep fragment weights than other spits but perhaps not as much as might be expected since this spit might have been subjected to more recent trampling or exposure to weathering. All spits demonstrate a high level of fragmentation of bone.

### 6.4.3 Comparison with complete bones

Over ninety percent of cattle, sheep, red deer and pig bones recovered from the eight LON areas under study were incomplete. Complete bones were predominately phalanges, carpals and tarsals. No meat bearing cattle bones were complete, but some sheep long bones and mandibles remained intact. These medium bone weights for cattle and sheep in each area were low compared with the weights of complete bones. For example, the Shetland cow skeleton in the NMS Collection Centre (Z.1905.46) has a left radius weighing 436.1g, a left humerus 568.9g and the left femur 690.7g, whereas in all contexts the medium weight of cattle bone fragments was 10.0g or less (the exception being “equivalent to context 7302 (a)”). Most cattle and sheep long bones had spiral breaks in the diaphysis, indicating they may have been broken just after the animals’ deaths either for cooking purposes, marrow extraction and/or produce blanks for manufacturing.

## 6.5 Other Modifications

### 6.5.1 General

Bone gnawing was examined in order to determine if this activity was a major source of bone loss at LON and indirect evidence of presence or absence of dogs on the site. Root etching highlighted whether the bone deposits had been close enough to vegetation at any time to impact on their surface texture. Proportions of burnt bone were calculated in order to determine the impact of this potentially destructive force on bones, and whether patterns of burning varied between areas.

### 6.5.2 Carnivore gnawing

Carnivore gnawing was defined as obvious signs of depressions caused by canine teeth. Using these criteria, mammal bones from most areas under study displayed evidence of gnawing on 1% or less of the bones examined (NISP minus loose teeth, ribs and shafts). A few bones had proximal and distal portions gnawed. See *Table 18.*

**Table 18: Percentage evidence of carnivore gnawing on identified mammal bones (cattle, sheep, pig, red deer NISP) (minus ribs, shafts and loose teeth) from eight LON (Links of Noltland) areas under study**

| % | Cattle | Sheep | Pig | Red deer |
|---|---|---|---|---|
| Midden below St 9 | 0 | 0 | n/a | 0 |
| Floor St 9 | <1 | 1 | 0 | 0 |
| Wall core St 9 | 0 | 4 | n/a | n/a |
| Midden above St 9 | <1 | 3 | 0 | 0 |
| Midden 7302 | 1 | 1 | 6 | 0 |
| Infill to kiln, St 10 | 0 | 2 | n/a | n/a |
| Equivalent 7302 (a) | <1 | 0 | n/a | n/a |
| Equivalent 7302 (b) | <1 | <1 | 0 | 0 |

Only a few bones had the smooth, undulating appearance of acid digestion caused by passage through the carnivore intestine, for example a medium mammal rib fragment from midden context 8000 et al “equivalent to context 7302 (b)”. Small splinters of bone created by crunching by carnivores were not identified (Payne and Munson, 1985). Nine pig bones from context 7302, fragments from pelves, long bone and phalanx were gnawed, 6% of all pig bones.

Carnivore gnawing results from LON are consistent with those from the earlier excavation at LON when 2% of all bone fragments were recorded as modified by gnawing (Armour-Chelu, 1992, p94, table 3). In addition, at the Neolithic settlements at Tofts Ness, Sanday it was noted that “gnawing was never common-place” (Nicholson and Davies, 2007, p173) and at Pool, Sanday “only a small proportion of bone showed gnawing or puncture marks” (Bond, 2007, p209). The carnivore gnawing marks at LON were probably the result of dog activity.

### 6.5.3 Non-carnivore gnawing

Little evidence of non-carnivore gnawing was noted. Some herbivores also gnaw bones and this physiological osteophagia may be linked to phosphorus deficiency. For example, gnaw marks on modern bones in North Ronaldsay, Orkney, were attributed the island’s feral sheep (Brothwell, 1976, O’Connor, 2000, p49) but no evidence of this type of gnawing was noted. See *Table 19.*

**Table 19: Percentage evidence of non-carnivore gnawing on identified mammal bones (cattle, sheep, pig, red deer) (minus ribs, shafts and loose teeth) from eight LON (Links of Noltland) areas under study**

| % | Cattle | Sheep | Pig | Red deer |
|---|---|---|---|---|
| Midden below St 9 | 0 | 0 | n/a | 0 |
| Floor St 9 | <1 | <1 | 0 | 0 |
| Wall core St 9 | 0 | 0 | n/a | n/a |
| Midden above St 9 | 0 | <1 | 0 | 0 |
| Midden 7302 | <1 | 2 | 0 | 0 |
| Infill to kiln, St 10 | 0 | 0 | n/a | n/a |
| Equivalent 7302 (a) | 0 | 2 | n/a | n/a |
| Equivalent 7302 (b) | 0 | <1 | 0 | 0 |

### 6.5.4 Root etching

All areas under study had significant levels of root etching on identified mammal bones (NISP), a factor that might have affected survival and fragmentation of LON mammal bone. See *Table 20.*

**Table 20: Percentage root etching on identified mammal bones (cattle, sheep, pig, red deer) (minus ribs, shafts and loose teeth) from eight LON (Links of Noltland) areas under study**

| % | Cattle | Sheep | Pig | Red deer |
|---|---|---|---|---|
| Midden below St 9 | 23 | 45 | n/a | 37 |
| Floor St 9 | 30 | 36 | 40 | 40 |
| Wall core St 9 | 18 | 42 | n/a | n/a |
| Midden above St 9 | 46 | 54 | 22 | 59 |
| Midden 7302 | 44 | 48 | 34 | 50 |
| Infill to kiln, St 10 | 30 | 31 | n/a | n/a |
| Equivalent 7302 (a) | 54 | 58 | n/a | n/a |
| Equivalent 7302 (b) | 29 | 16 | 0 | 0% |

Root etching is caused by plant roots secreting humic acid, or acid secreted by fungi associated with the decay of plant roots (Lyman, 1994, p375). Some LON specimens had root etching on both interior and exterior faces of the bone, suggesting root etching occurred after breakage (for example a cattle tibia fragment from midden 9031 and a cattle metacarpal diaphysis fragment from context 7302).

### 6.5.5 Burning

#### 6.5.5.1 General

Human induced burning includes:

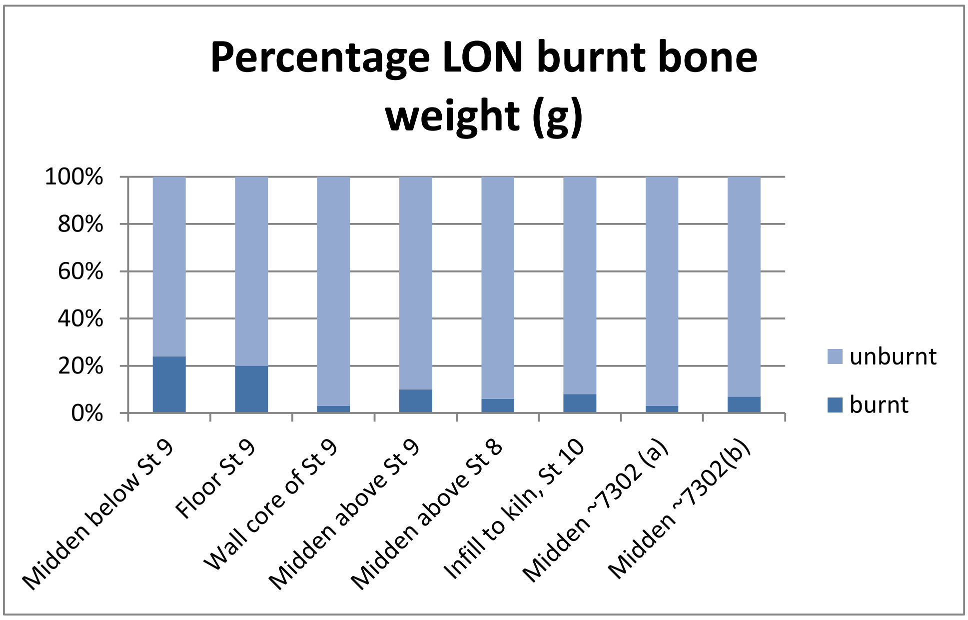
- Cooking
- Waste disposal

- Use as fuel
- Cremation/ritual disposal
- Deposition adjacent or below camp fire
- Proximity to hot ash deposits

(Costamagno et al., 2005, Gifford-Gonzalez, 1989b, Lymen 1994, pp384-392, McKinley and Bond, 2001, Whyte, 2001)

### 6.5.5.2 Results

Percentage of burnt: unburnt weight of bones for areas of LON under investigation is shown in *Graph 20* and *Appendix 16*



**Graph 20: Percentage burnt bone on eight LON (Links of Noltland) areas under study, weight (g)**

These graphs include all bones (identified and unidentified) by weight, the preferred measure because of burnt bone's potential to fragment. Results demonstrate that less than ten percent of total bone fragments had indirect or direct exposure to fire apart from bone fragments below Structure 9 and floor area of Structure 9 (which included heath fill and ashy deposits). The greatest proportion of burnt bones were diaphysis fragments, some of which were burnt on both the exterior and interior faces, perhaps indicating contact with fire once meat had been removed and bones fractured.

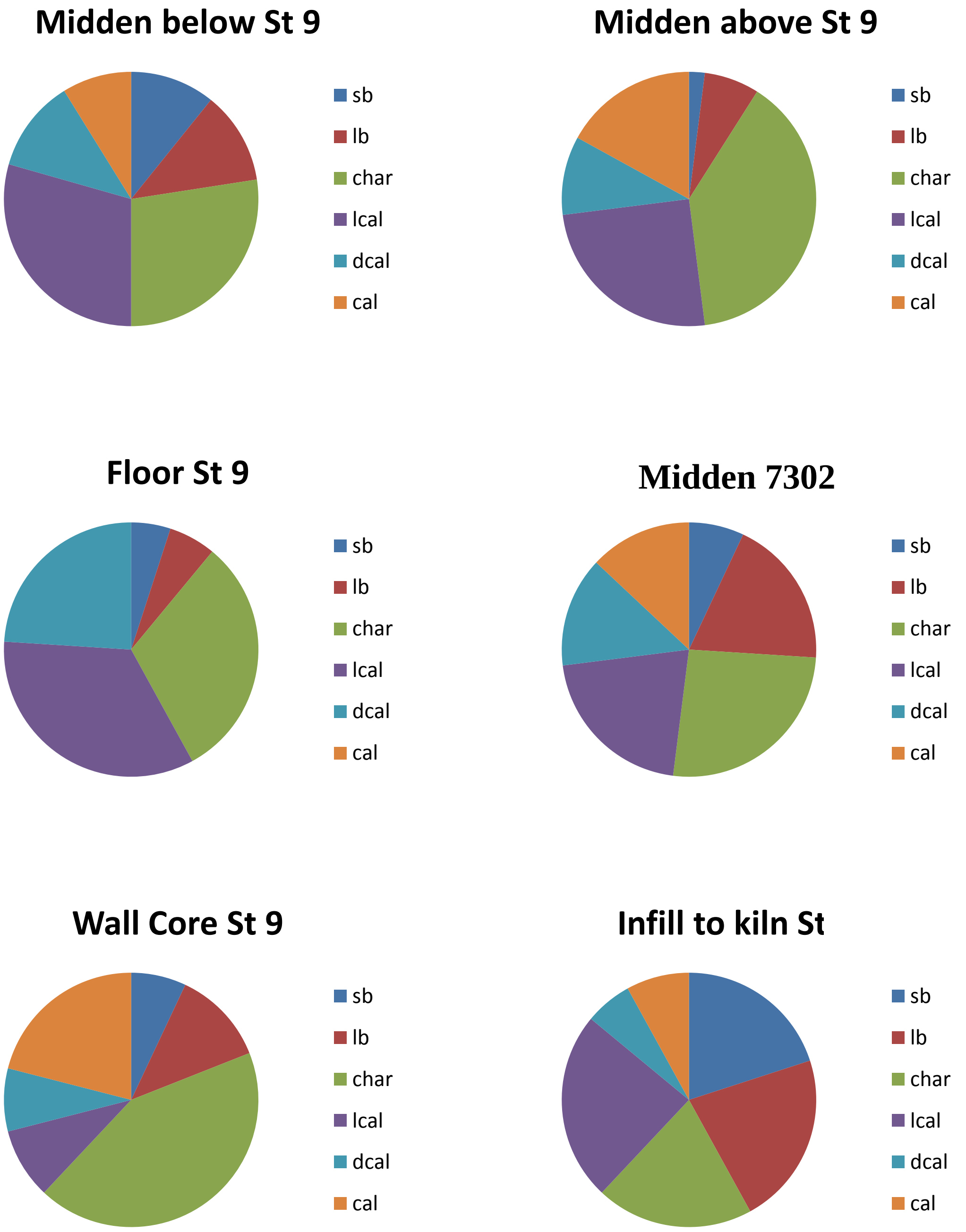
If weights of all cattle/large mammal bone fragments and all sheep/medium size mammal fragments are examined, cattle/large mammal bone fragments show a consistently higher proportion of burning than sheep/medium mammal. This difference was most marked in contexts below Structure 9.

A series of pie-charts illustrates the level of burning by weight with the majority of bones falling within the slight burn, light burn and fully charred categories. The two areas with a higher percentage of burnt bone, midden below Structure 9 and floor of Structure 9, display the same patterns of graduated burning. See *Graph 21* and *Appendix 17.*

The burning results indicate that cremation or ritual burning of animal bones did not occur at LON because a greater proportion of fully calcined bone fragments would be expected if this activity took place. There was also no robust evidence that roasting was the prime method of cooking beef since burning was not predominately associated with articular ends of long bones. The larger proportion of cattle/large mammal burnt bone fragments may however be due to different cooking and disposal of these bones (Bond, 1996, p79).

### 6.5.6 Modification evidence

Incidence of gnawing of LON bones is low and may not have been a major factor in bone loss at the site. A larger proportion of bones were root-etched, indicating that middens, wall core, infill deposits and wall core material were close to vegetation during part of their deposition history and that acid etching may have been a factor in deterioration of deposited bone. Intensive burning was not observed, so there is no evidence that mammals were cremated or bone consistently placed in camp-fires, but approximately 10% of bones had been in some contact with fire or a heat source such as ashes.



Midden below St 9

Midden above St 9

Floor St 9

Midden 7302

Wall Core St 9

Infill to kiln St

Graph 21: Levels of burning in six LON (Links of Noltland) areas under study by weight (g). Key sb: slight burn, lb: light burn, char: blackened, lcal: locally calcined, dcal: dominantly calcined, cal: fully calcined.

## 6.6 Overview

Cattle and sheep dominated the bone collections at LON, with red deer and pigs present in low numbers and dog, otter and sea mammals rare. Evidence of fragmentation and modifications indicate carcasses were intensively exploited. Carnivore gnawing levels on bones were low, perhaps providing additional evidence that dogs were not numerous at LON. Many bones were root-etched, so close to vegetation at some point in their depositional history. Approximately 10% of bones had been in contact with heat/fire, but there is no evidence of cremation or intensive burning.

## 6.7 Wall Core Structure 9 mammal bones

### 6.7.1 Introduction

More detailed investigation was undertaken to determine whether bones from Wall core, Structure 9 (contexts 9116/9123, *4590 NSP*) (where cattle and sheep skulls were deposited) varied from LON general midden deposits. The question was whether the selection of cattle foundation/wall core post-cranial bone deposits differed from general midden waste, perhaps by over-representation of high value meat-bearing bones in addition to pelves already identified. Contexts used for comparison were:

- contexts 9681/9690, midden below Structure 9
- context 9031, midden lying above Structure 9
- context 7032, all spits midden overlying Area 5

Cranial fragments were removed from calculations relating to species/element because skull fragments within foundation course, Structure 9, may have distorted comparisons. The analysis was an adaptation of a framework for taphonomy and interpretation set out by D. Orton, which was, in turn, developed from earlier studies by processual archaeologists (e.g. Binford, 1981, Schiffer, 1976, 1983) and the more recent work by social zooarchaeologists (e.g. Marciniak, 2005) (Orton, 2012). It is noted that “measuring post-depositional attrition is a more complicated endeavour than had been anticipated” (Lam and Pearson, 2005, p107).

### 6.7.2 Possible excavation, curation and recovery bias

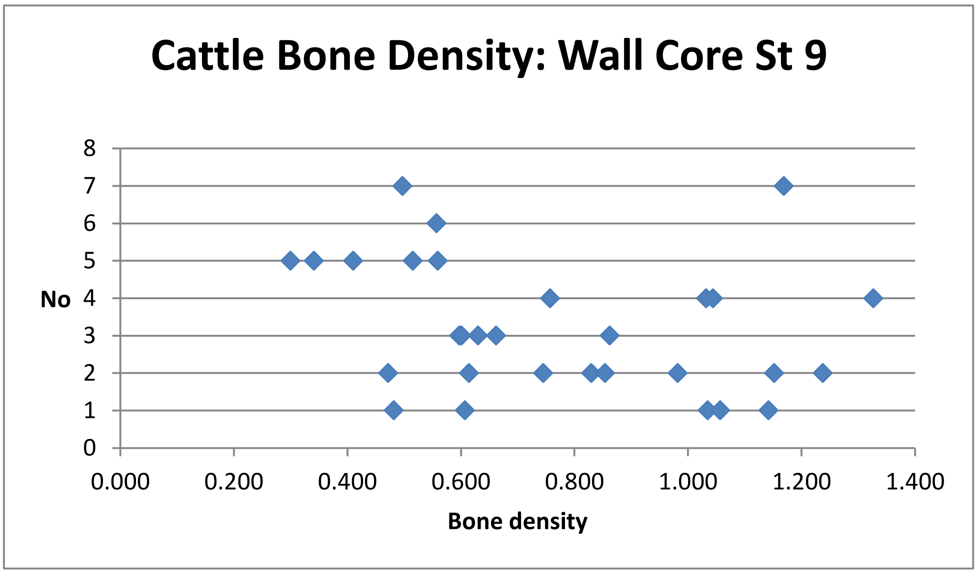
The midden below Structure 9 (contexts 9681/9690) was excavated by two people, including the author but only a small proportion of the midden under this building was investigated. The wall core, Structure 9 (contexts 9116/9123) was excavated by EASE archaeologists and the author, and contexts 7302 and 9031 by EASE archaeologists. More time was taken during the excavation of the foundation/wall core, in order to ensure that skulls suffered no further damage and this may have improved recovery rates of bones less than 10mm.

However trowelling methods, hand-extraction and sieving through 10mm, curation and handling bones during identification was similar for all four areas.

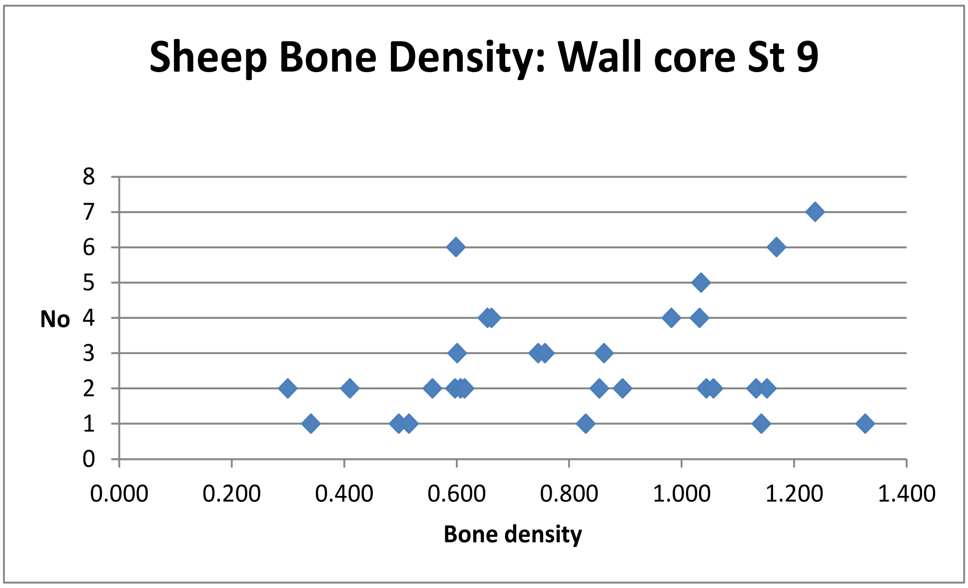
### 6.7.3 Density-mediated attrition

The probability of a bone surviving various taphonomic processes at an archaeological site and retaining sufficient integrity to allow identification to element and/or species is at least partly related to the bone's structural density (equivalent to volume of bulk density) (Grayson, 1989, Klein and Cruz-Uribe, 1984, p73, Kreutzer, 1992, Lyman, 1985, 1994, Marciniak, 2005, p105, Marean and Cleghorn, 2003, p34, Lam and Pearson, 2005, Lam et al., 2003, Symmons, 2005). If there is a relationship between abundance of a skeletal elements and density then caution must be applied to any assumptions on human mediated distribution of these skeletal elements (Lam et al., 2003, p1703).

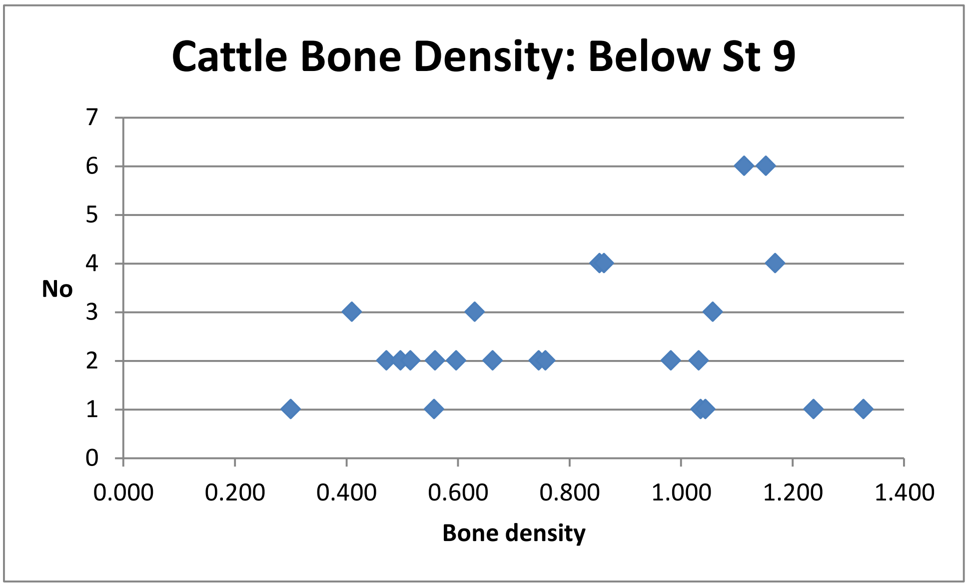
Details of density measurement protocols are given in *Appendix 18* highlighting variability and on-going debates on optimal methods. For this examination of the animal bones the case for CT scanning appeared persuasive, although species range and sample size used to produce this data was small. Results for caprine long bones (Lam et al., 1998) were applied to both sheep and cattle bone fragments, despite the fact that the correlation between these two different species may not be as close as claimed. The alternative of using different bone density measurements for different species would appear to introduce more variability. The strength of the ranked correlation between bone portion and number of occurrences was calculated using Pearson's r (Spearman's rank correlation is equivalent to Pearson's r calculated on ranking) to give $r_s$ (Drennan, 2009, p227). See *Graphs 22 to 29.*



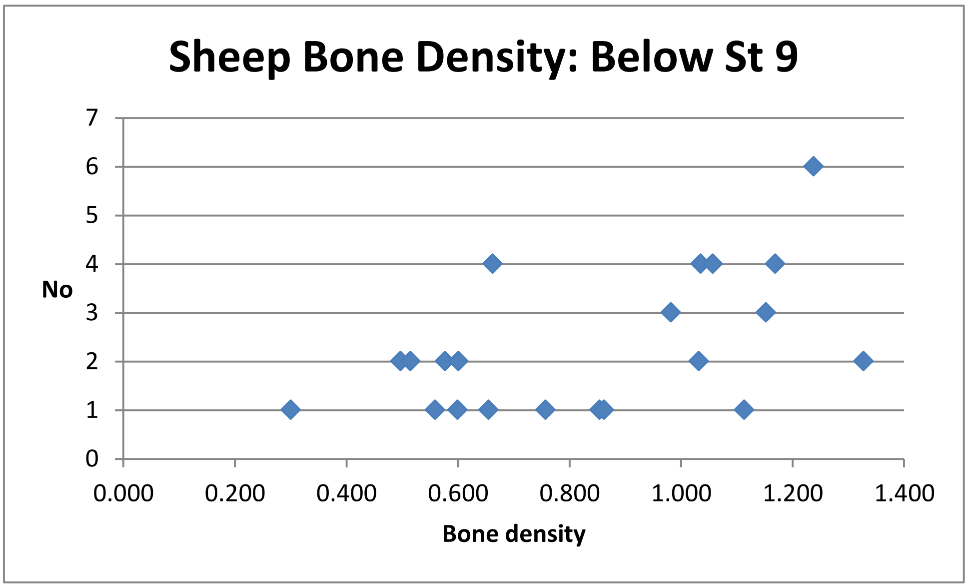
**Graph 22: Cattle Bone Density, LON (Links of Noltland) Wall core St 9. Rs -0.28.Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis**



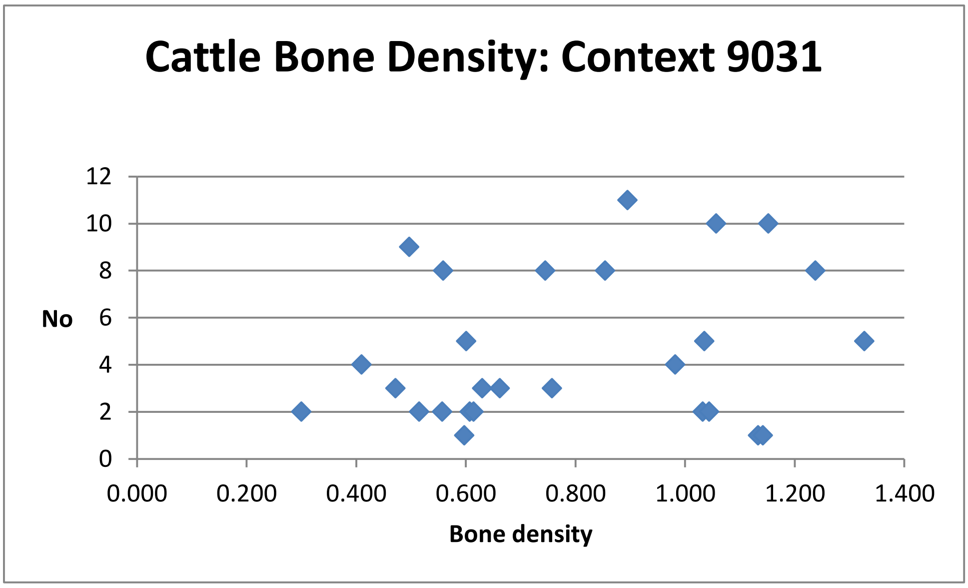
Graph 23: Sheep Bone Density, LON (Links of Noltland) Wall core St 9. Rs 0.27



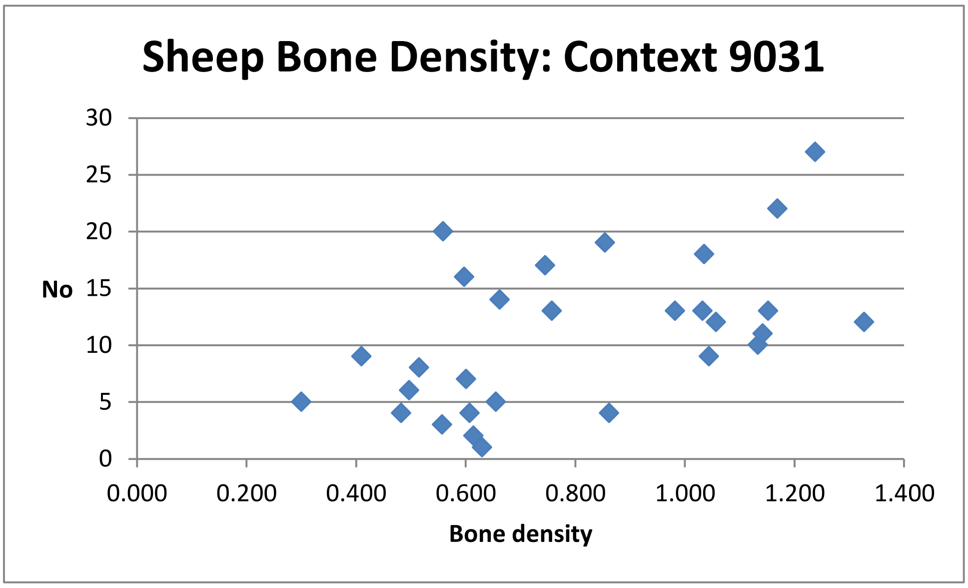
Graph 24: Cattle bone density, LON (Links of Noltland) Below St 9. Rs 0.25. Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis



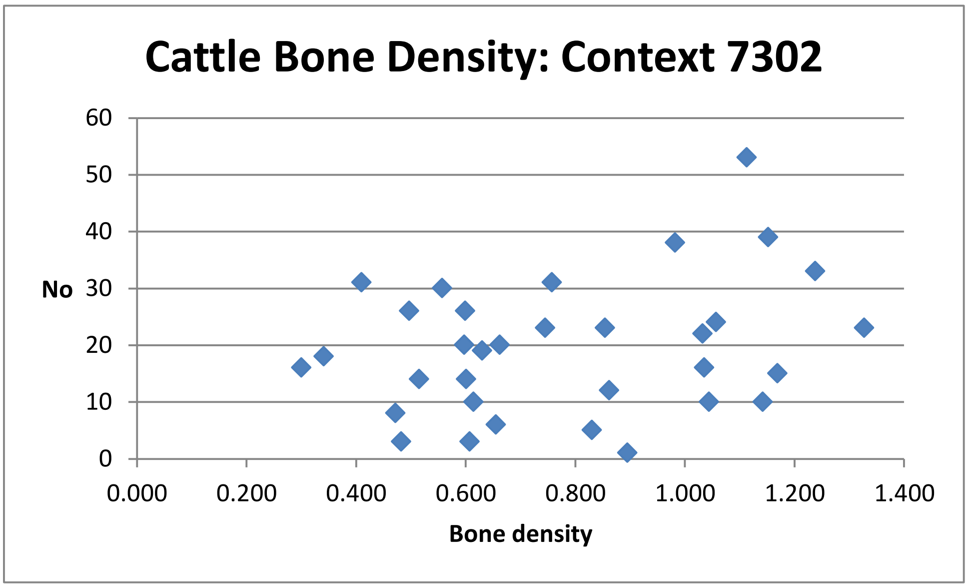
Graph 25: Sheep Bone Density, LON (Links of Noltland) Below St 9. Rs 0.51.Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis



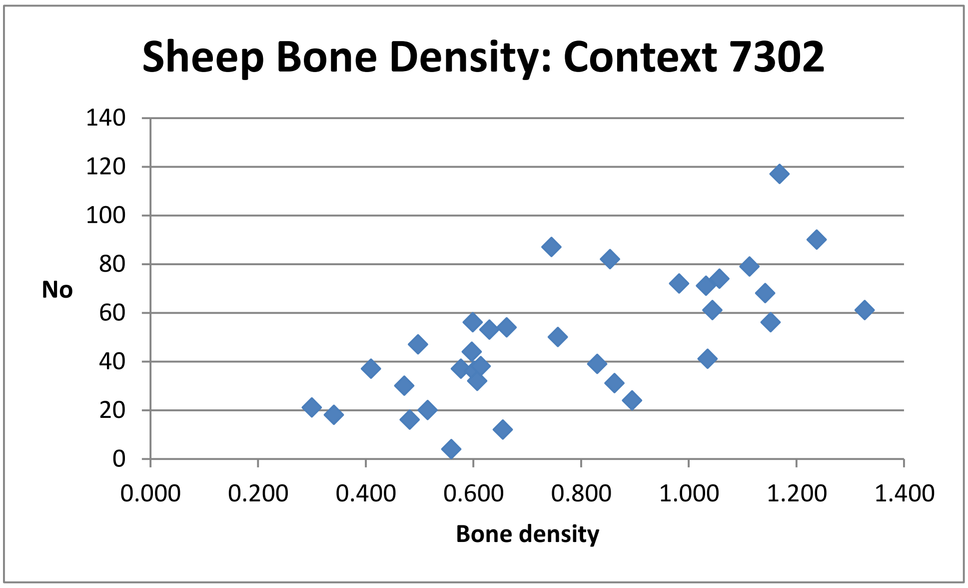
Graph 26: Cattle Bone Density, LON (Links of Noltland) Context 9031 Rs 0.23. Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis



Graph 27: Sheep Bone Density, LON (Links of Noltland) Context 9031. Rs 0.52.Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis



Graph 28: Cattle Bone Density, LON (Links of Noltland) Context 7302. Rs 0.28

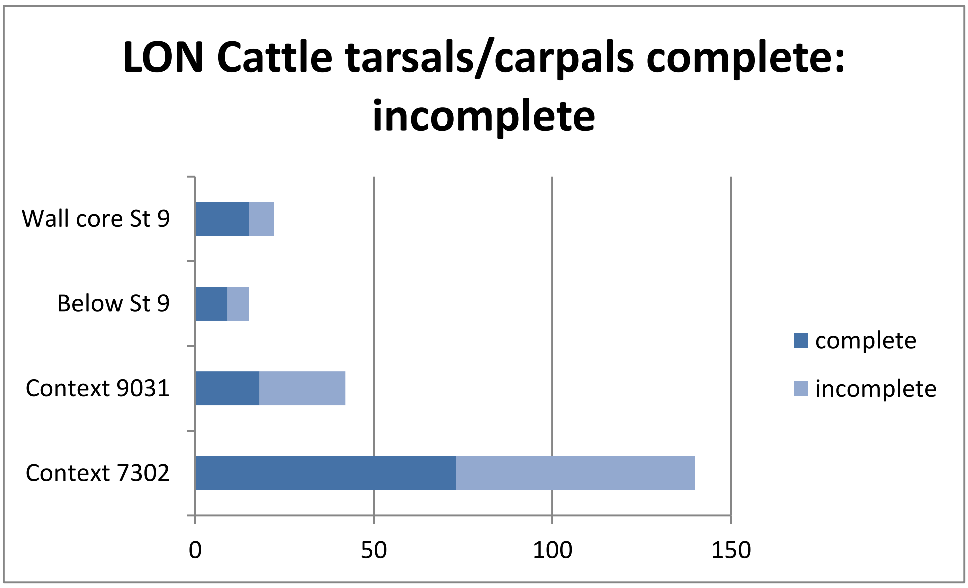


**Graph 29: Sheep Bone Density, LON (Links of Noltland) Context 7302. Rs 0.69. Vertical axis represents the number of bones having the bone density illustrated on the horizontal axis**

The graphs of sheep and cattle bone density from Wall core, Structure 9 demonstrate better survival of lower density limb bones. Cattle, in particular, demonstrated a good survival rate for lower density bones (negative $r_{s)}$. In the other three contexts areas used for comparison, cattle bone survival had a small positive correlation between bone density and survival.

Sheep bones had a low positive correlation between bone density and survival for Wall core, Structure 9 but slightly higher correlations for the other three midden areas, particularly context 7032 which had an $r_s = 0.69$ value, indicating that higher density bones appeared to have a better survival rate in these three comparative areas.

Another method of considering bone survival is the examination of low food value bones such as carpals and tarsals (Marean and Cleghorn, 2003). If these bones display a high level of fragmentation this may be due to post-depositional processes since they are rarely or never broken by humans or carnivores (Marean, 1991). If cattle complete: incomplete ratios of tarsals (astragalus, calcaneus, and navicular-cuboid, cunieform and os malleore) and carpals (trapezium, hamate, lunate, scaphoid and ulnare) are compared, Wall core, Structure 9 (contexts 9116/9123) has the highest percentage of complete bones, confirming the results from CT bone density calculations (calcaneus with unfused proximal *tuber calcanei* was counted as complete, even if the missing epiphysis was not recovered). However, it is noted that only a small number of these bones were recovered from this area. See *Graph 30.*



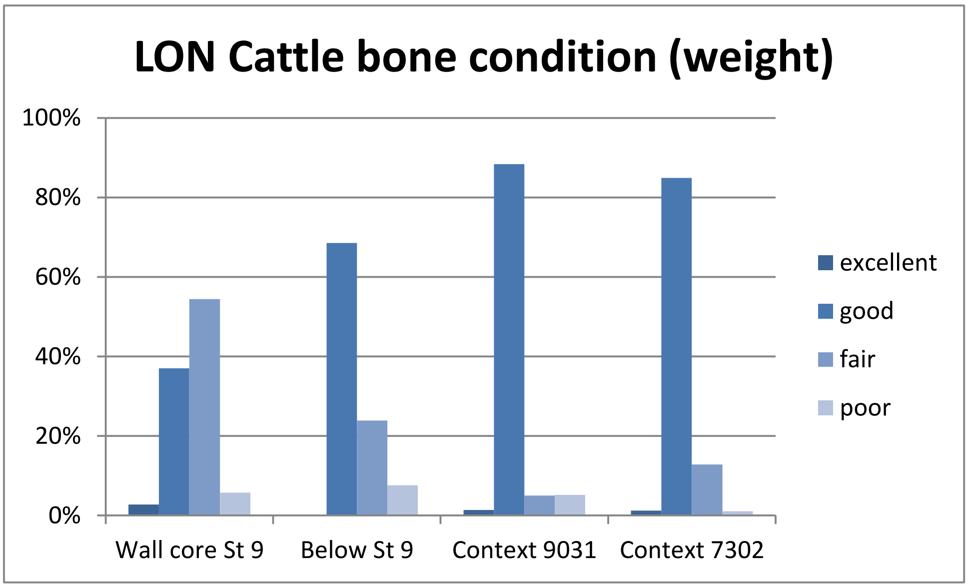
**Graph 30: Ratio of Complete: Incomplete cattle tarsals/carpals from four LON areas**

When complete 1st and 2nd cattle phalanges, fused, or with/without their unfused proximal epiphysis, were considered, the greatest percentage of complete bones was from context 7302 at 84%. Wall core, Structure 9 (contexts 9116/9123) had 62% complete 1st and 2nd phalanges. The other two study areas (contexts 9031, and 9681/9690) had lower percentages at 48% and 35% respectively.

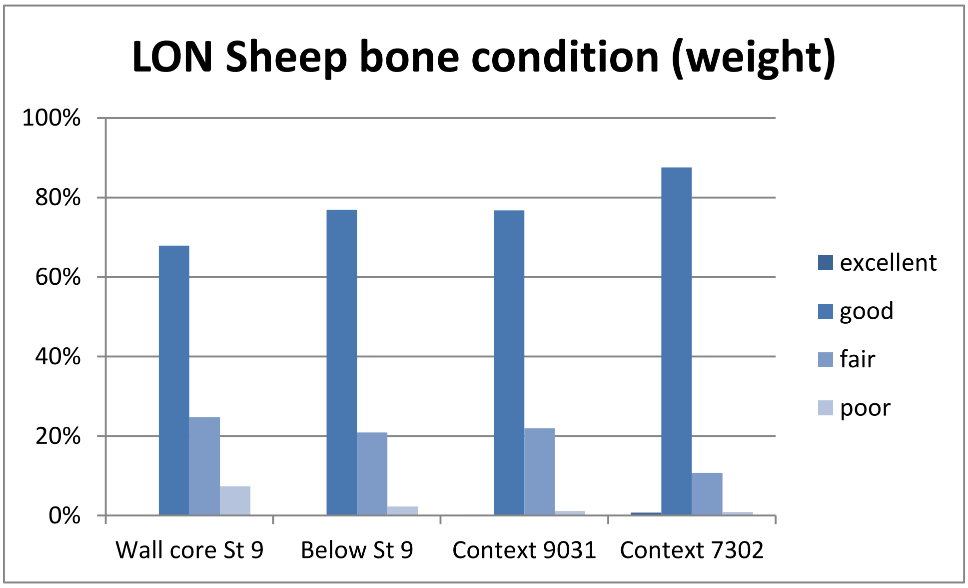
### 6.7.4 Peri-depositional damage

All study areas produced evidence of root etching. In midden context 7302 just over half of bone fragments by weight were root-etched; in the other three areas this figure was approximately one-quarter. These results reveal that many bones from all study areas were close enough to the surface at some point in their taphonomic history to have been modified by roots. Ard marks on stones adjacent to Structure 9 (H. Moore pers. comm.) indicate there may have been deliberate cultivation of middens as well as natural colonisation on midden surfaces. Incidence of carnivore gnawing and rodent gnawing (by weight), was low, indicating that Wall core, Structure 9 (contexts 9116/9123), midden below Structure 9 (contexts 9681/9690) and middens 7302 and 9031 may have been protected from scavenging rapidly after deposition.

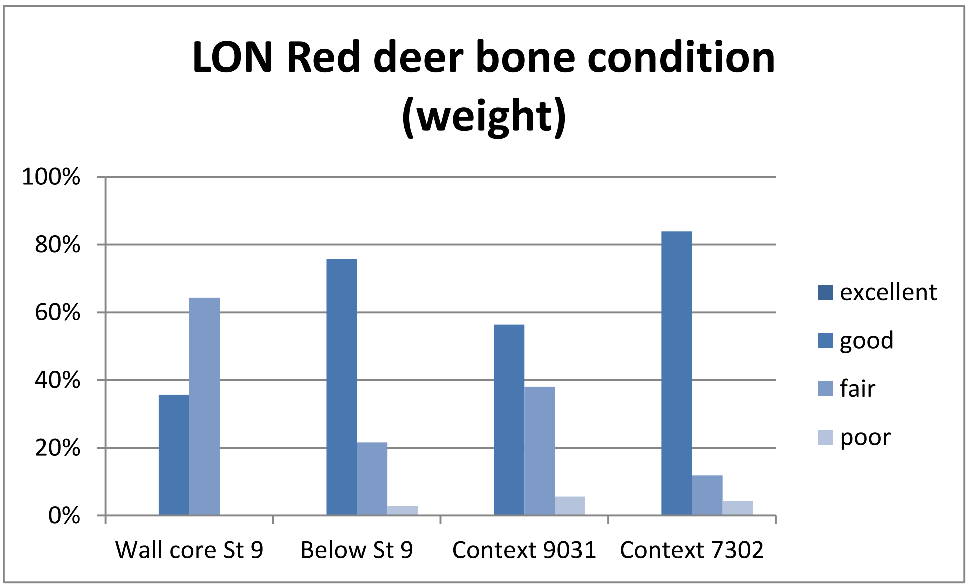
Weathering stages were examined for identified bone fragments (loose teeth, antlers, horn cores and vertebra excluded) by weight. Very few bones were in “excellent” condition. Predominately bones from cattle, sheep, red deer and pig from all four areas were dominated by bones in the second category, “good”. The exception was cattle and red deer bones from Wall core, Structure 9 (contexts 9116/9123) where the majority of bone fragments were in "fair condition" This may imply careful excavation around the skulls resulted in a larger proportion of identifiable "fair" condition bones being recovered or that the foundation stones and Wall core reduced trampling and fragmentation of bone fragments. A small number of fragments were in "poor" condition, but to a certain extent this may be associated with the difficulty of allocating bones to element and species in this category. These calculations exclude loose teeth. See *Graphs 31 to 33 and Appendix 19.*



**Graph 31: Surface condition of LON (Links of Noltland) bone fragments for cattle by weight (g)**



**Graph 32: Surface condition of LON (Links of Noltland) bone fragments for sheep by weight (g)**



**Graph 33: Surface condition of LON (Links of Noltland) bone fragments for red deer by weight (g)**

### 6.7.5 Breakage and fragmentation

The proportion of complete cattle bones (all skeletal elements) recovered was approximately 10% for both the midden context 7302 and Wall core, Structure 9 (contexts 9116/9123). The other two study areas had lower percentages. The pattern for sheep was similar to cattle but red deer from the three midden areas had a greater percentage of complete bones.

Context 7032 had the longest cattle bone fragments of humerus and tibia, Wall core, Structure 9 (contexts 9116/9123) the longest femur and radius fragments. Maximum lengths of cattle bone fragments in Wall core, Structure 9 (9116/9123) were:

- 141mm (femur)
- 169mm (humerus)
- 180mm (radius)
- 139mm (tibia)

A similar pattern of maximum length of fragment is noted from middens contexts 7203 and 9301 and below Structure 9 (contexts 9681/9690).

Average weight of cattle femur, humerus, and radius and tibia fragments was also calculated to gauge intensity of fragmentation (Lyman, 1994, p334). The wall core Structure 9 (context 9116/9123) had the greatest average fragment weight for all four long bones, particularly marked for femur and humerus. This pattern was not repeated for sheep and red deer.

However, levels of fragmentation supports the butchery evidence that cattle bones recovered from Wall core, Structure 9, were processed to maximise food extraction and there is no evidence of wasteful consumption which might be associated with feasting (Thomas 2013, p123).

### 6.7.6 Visible human modification

Weight of burnt bone (all categories of burning combined) was measured as a percentage of all bone. Wall core, Structure 9 (context 9116/9123) contained very little burnt bone, 3.3% for all bones, 1.4% for cattle bones. Middens from contexts 7302 and 9031 both had approximately 10% of bone fragments with some evidence of burning on them, and the midden below Structure 9 (contexts 9681/9690) 24% burnt bone.

### 6.7.7 Assessment of element representation

Weights of all bone fragments (identified and unidentified) allocated to large mammal (cattle, red deer, possibly mature pig) and medium size mammal (sheep, dog and pig) indicated that large mammal bones dominated all four areas under review. However in contexts 7302 and 9031, the ratios are approximately 2:1, whereas for Structure 9 Wall core (contexts 9116/9123) and the midden below Structure 9 (contexts 9681/9690) the ratio was higher.

In Wall core, Structure 9 (contexts 9116/9123) 79% of the bones, by weight, could be identified to species. This percentage was higher than for the three other middens; 68%, 69% and 51% for contexts 7302, 9031 and contexts 9681/9690 respectively. Distribution of bones identified to species is similar to large mammal: medium size mammal ratios. Cattle and sheep dominate all contexts, but there appears to be more red deer bones in Structure 9 foundation deposits (9116/9123) and the midden below Structure 9 (contexts 9681/9690) whereas there are more pig bones in midden contexts 7302 and 9031. See *Graphs 34 to 37* and *Appendix 20.*

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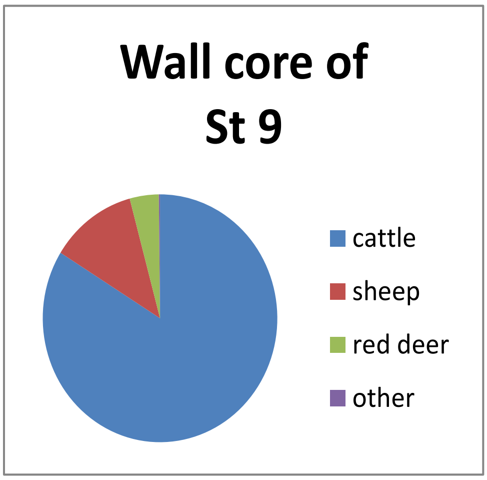
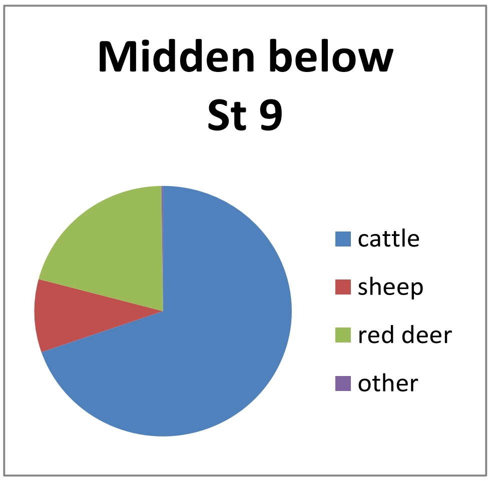
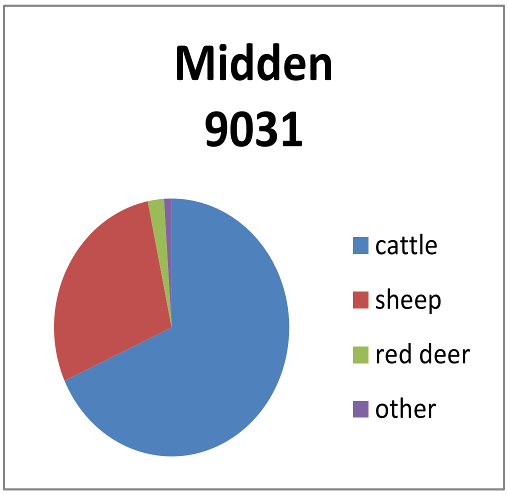


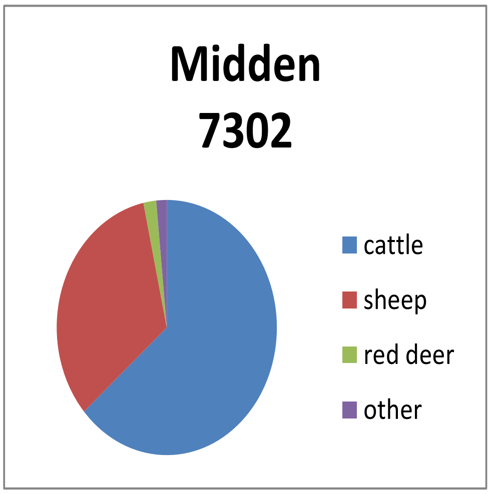
Graph 34: LON Wall core St 9: percentage species distribution by weight (g)



Graph 36: Below LON St 9: percentage species distribution by weight (g)

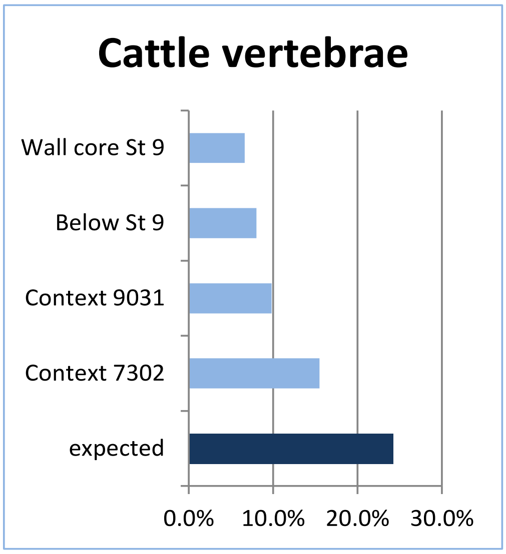


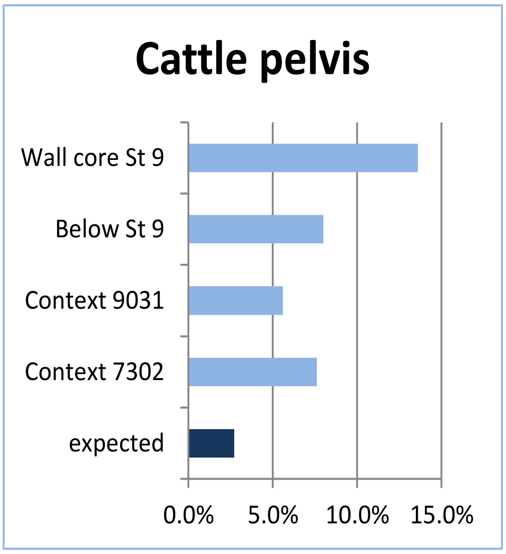
Graph 35: Above LON St 9, 9031: percentage species distribution by weight (g)

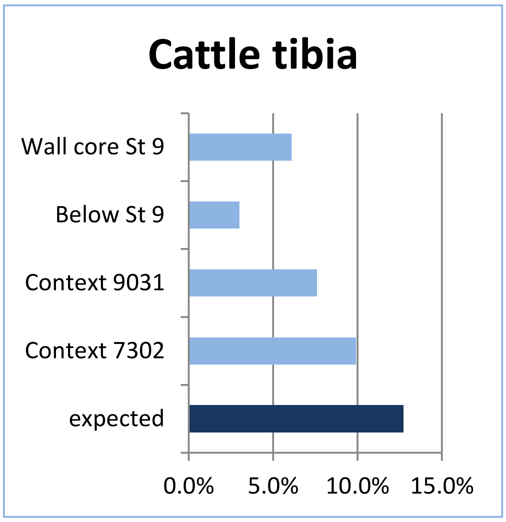


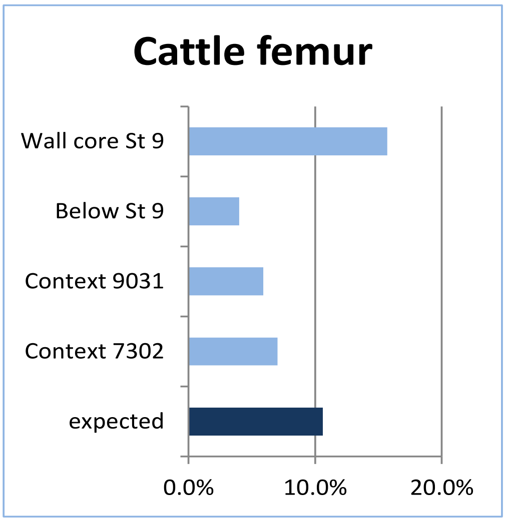
Graph 37: LON Midden 7032: percentage species distribution by weigh (g)

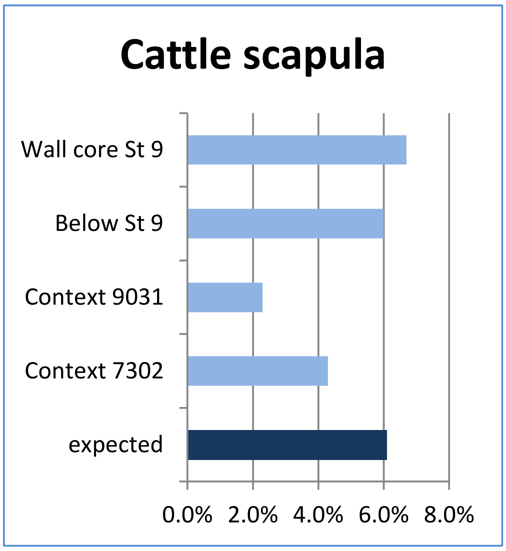
Weights of cattle and sheep mandible, vertebra, and forequarter (scapula, humerus, radii/ulna), hindquarter (pelvis, femur, tibia) and foot bones (basipodium, metapodial bones and phalanges) were calculated. Skulls, loose teeth, ribs and non-allocated diaphysis fragments were excluded. Rates from full skeletons of these species were adapted from Reichstien (1984) in order to illustrate actual: expected ratios of individual bones. See *Graphs 38-39.*

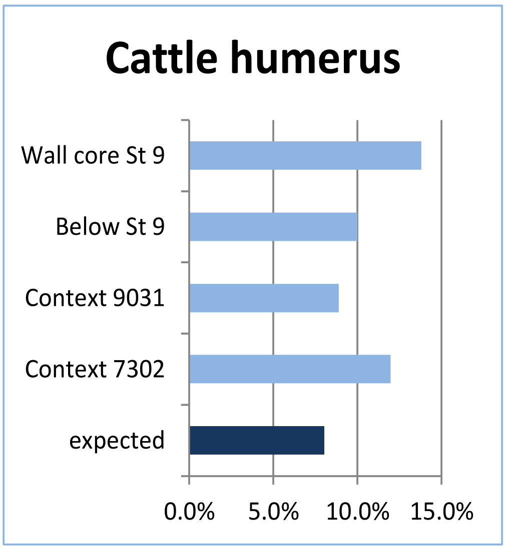

Cattle vertebrae
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
10.0%
20.0%
30.0%

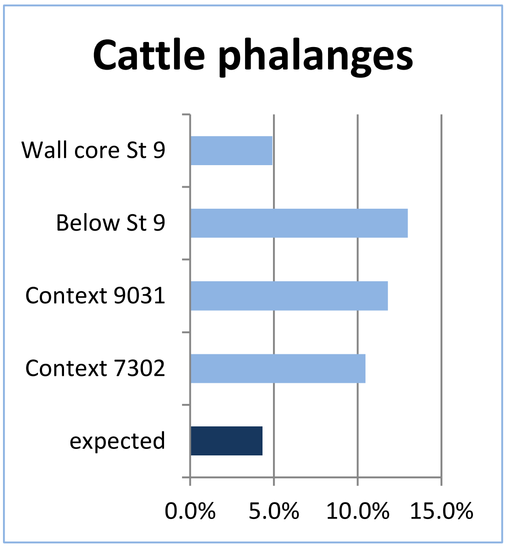

Cattle pelvis
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%

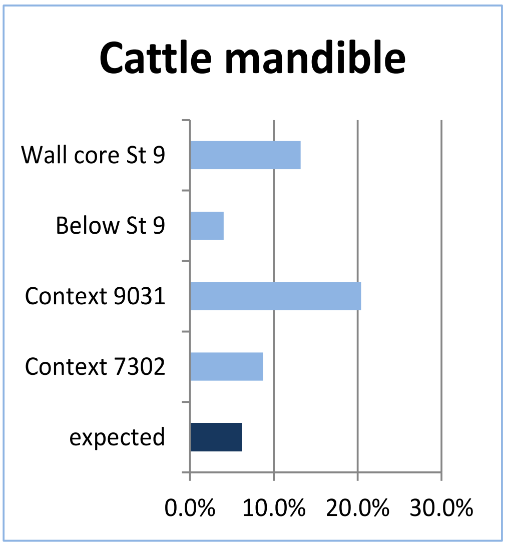

Cattle tibia
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%

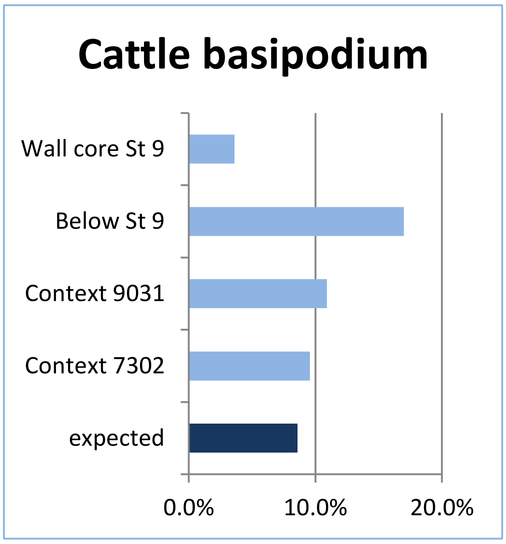

Cattle femur
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
10.0%
20.0%

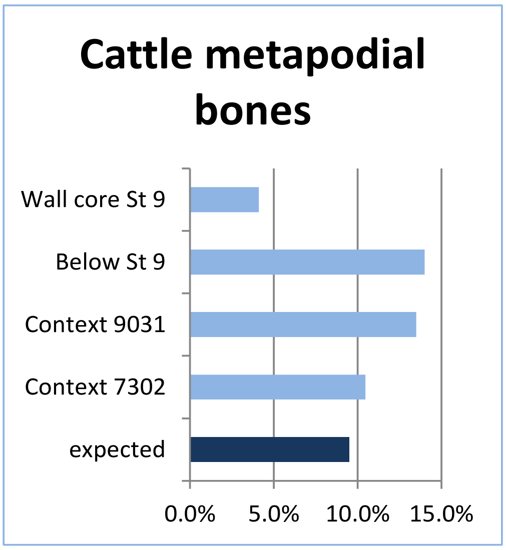

Cattle scapula
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
2.0%
4.0%
6.0%
8.0%

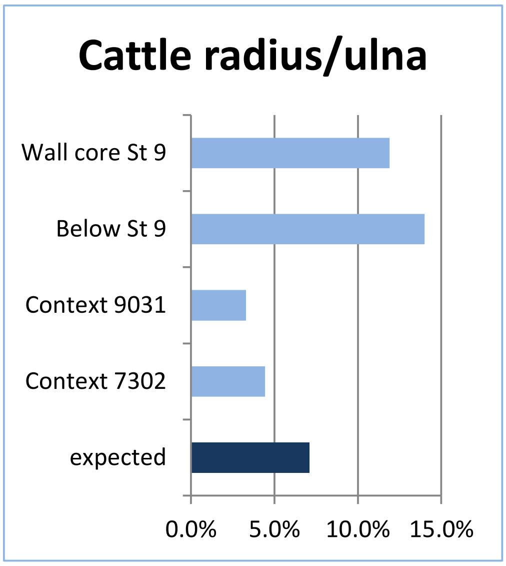

Cattle humerus
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%



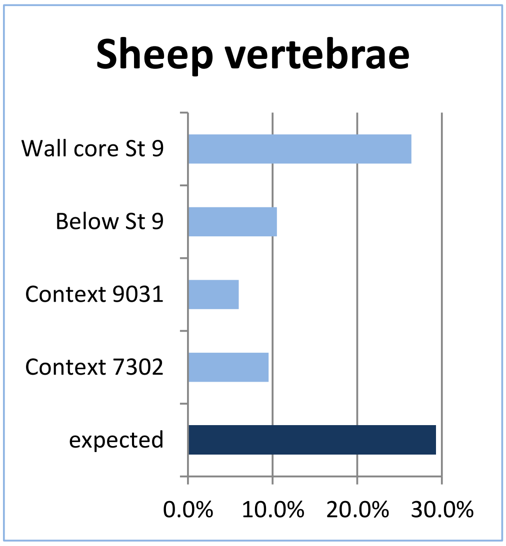


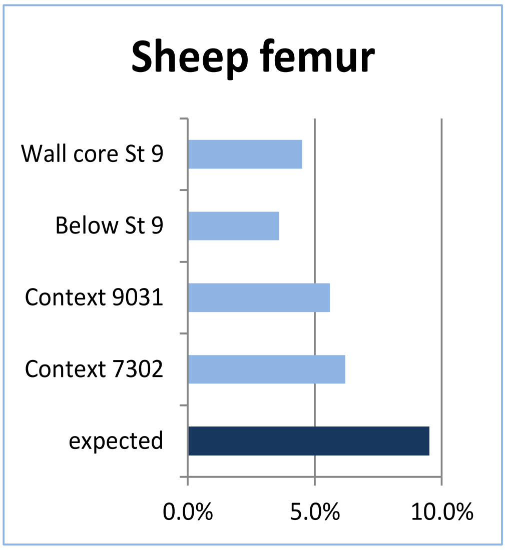


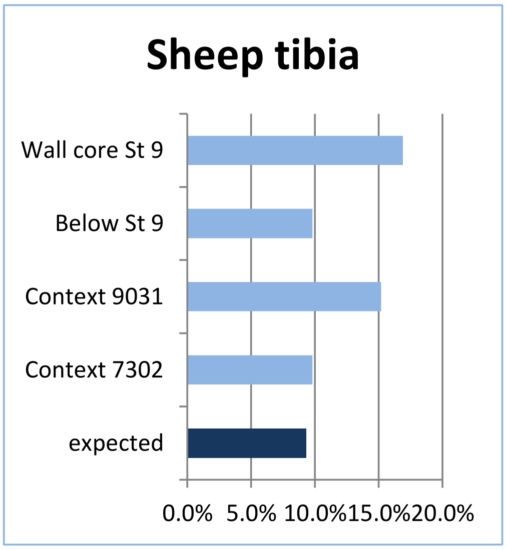


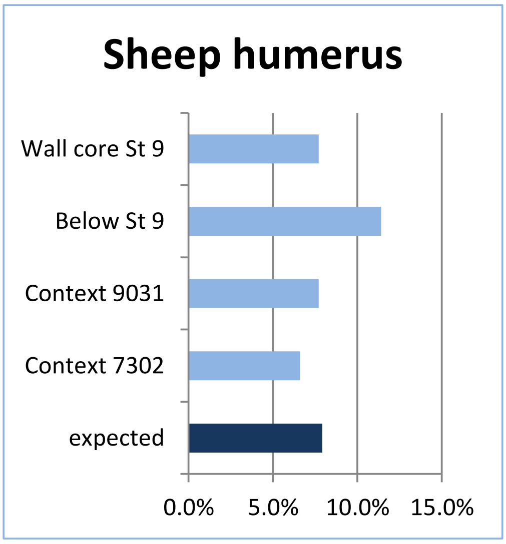


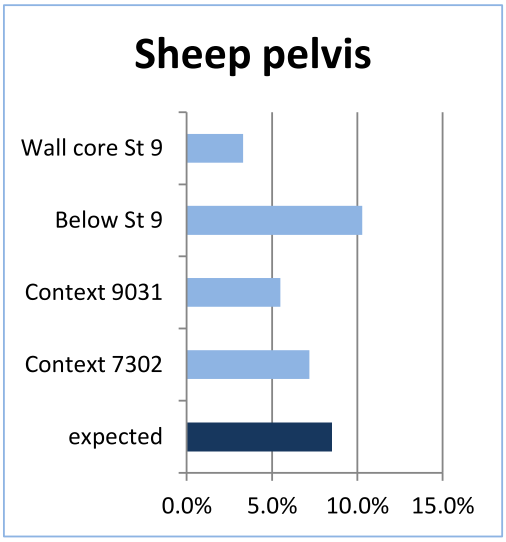
**Graph 38: Cattle bone weights, actual: expected (adapted from Reichstien, 1984) for four LON (Links of Noltland) areas**

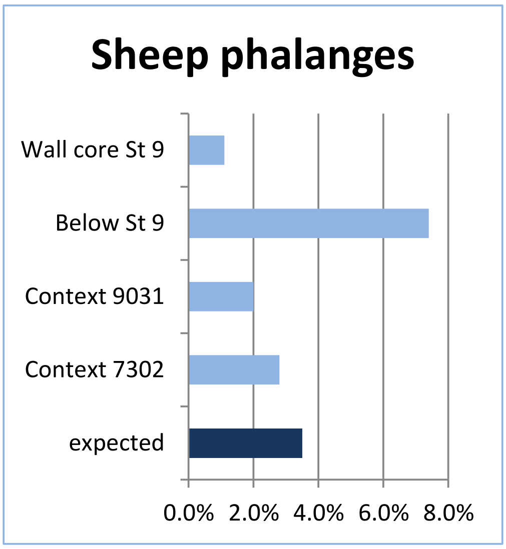

Sheep vertebrae
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
10.0%
20.0%
30.0%

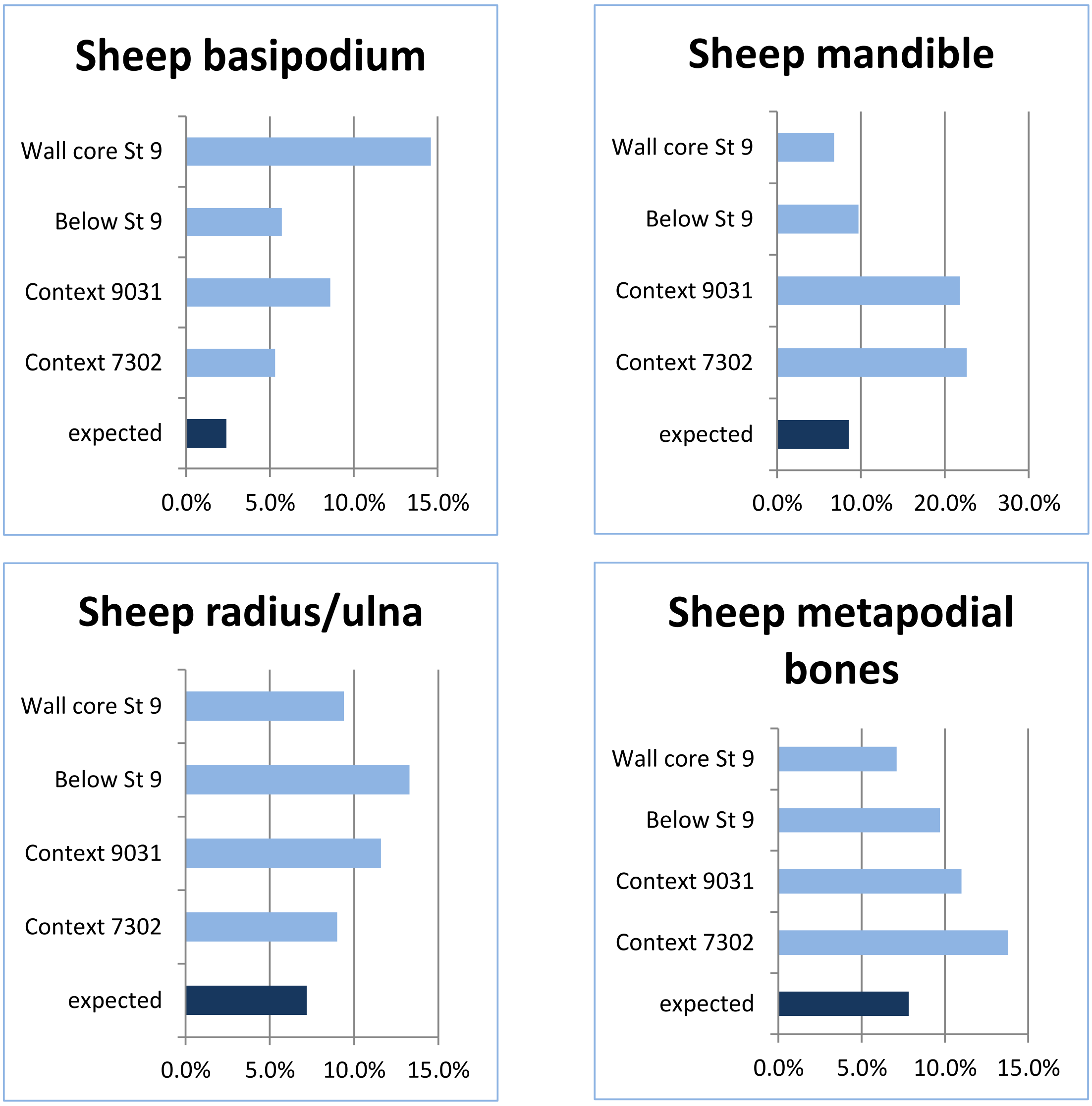

Sheep femur
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%


Sheep tibia
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%
20.0%


Sheep humerus
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%


Sheep pelvis
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
5.0%
10.0%
15.0%


Sheep phalanges
Wall core St 9
Below St 9
Context 9031
Context 7302
expected
0.0%
2.0%
4.0%
6.0%
8.0%



**Graph 39: sheep bone weights actual: expected (adapted from Reichstien, 1984) for four LON (Links of Noltland) areas**

All four study areas had smaller weights of vertebral bones than expected from complete post-cranial skeletons, apart from sheep bones in Wall core, Structure 9 (contexts 9116/9123) and this is associated with the recovery of an articulated and well preserved articulated section of vertebrae. Vertebrae have the lowest density bones in the skeleton and this may explain the low representation. In general, only articular or spinous process fragments are recovered, the centrum having fragmented beyond identification. Foot bones were over-represented, perhaps because they were discarded early during butchery and are easily identifiable.

Wall core, Structure 9 (9116/9123) had a greater proportion, by weight, of cattle scapula, humerus, radius/ulna, femur and pelvis than expected and less basipodium and metapodials. Pelvis weights in this area would have been even higher if the complete pelvis recovered with cattle skulls had been included. Levels of preservation for cattle bones from this context, based on the bone density survival graphs and completeness levels of carpals, tarsals and phalanges, was good, so the results imply that the deposition in this foundation course was biased towards meat-bearing bones, that feet bones had not become unidentifiable due to taphonomic processes. The same deposition pattern was not noted in sheep in Wall core, Structure 9 although tibia and radius/ulna, bones that may not have been meat-bearing in the primitive breed LON sheep, were over-represented.

### 6.7.8 Overview

Secondary analysis indicates that a higher proportion of cattle meat bearing bones were deposited in Wall core, Structure 9 adjacent and above the cattle skull deposit (contexts 9116/9123) than in the extensive LON overlying middens. These bones had been butchered and processed to maximise food exploitation. There is no evidence that complete bones, apart from pelves, were deposited with cattle and sheep skulls, but meat-bearing bones may have been sourced from an area designated for the preparation and/or consumption of beef. The midden directly below Structure 9 (9681/9690) had a greater proportion of red deer than the overlying midden deposits.

## 6.8 Floor deposits in Structure 9

### 6.8.1 Introduction

Contexts from the floor/hearth of Structure 9, and rubble above, were examined individually to investigate whether there were any unusual patterns of deposition, or evidence of special activities taking place within this structure. Quantities of bone from each context were low and, in the case of the hearths, particularly the upper hearth, few species were identified.

### 6.8.2 Possible excavation, curation or recovery bias

All contexts were excavated by EASE archaeologists with consistent trowelling, sieving and removal of samples for flotation. Curation and examination of bones also followed identical procedures. Flotation samples were not examined.

### 6.8.3 Factors influencing bone survival

These contexts will not reflect the full herds or flocks culled at LON, they represent residual bones not cleared from floors, remains of bones in heaths exposed to fire, with associated distortion and fragmentation and possible infill deposits after abandonment. No analysis is therefore carried out to establish fragmentation or density related survival, only observations on which bones remained in these contexts. Results summarised in *Table 21.*

**Table 21: Summary of LON (Links of Noltland) Structure 9 floor and hearth deposits LM-large mammal, MM-medium mammal**

| Context | Description | % LM (wt) | species identified | % burnt LM (wt) | % burnt MM (wt) |
|---|---|---|---|---|---|
| 9117 | upper hearth | 90% | cattle, sheep | 80% | 7% |
| 9125 | lower heath | 95% | cattle, sheep, red deer | 50% | 10% |
| 9111/ 9121 | ashy deposits adjacent to hearth | 72% | cattle, sheep, unidentified sea mammal | 38% | 14% |
| 9173 | central floor ashy deposits | 87% | cattle, sheep, pig | 39% | 62% |
| 9118/ 9166 | east floor deposits | 75% | cattle, sheep | 17% | 79% |
| 9119 | west floor deposits | 70% | cattle, sheep, pig, red deer | 20% | 16% |
| 9120/ 9189 | south floor deposits | 82% | cattle, sheep, pig, red deer | 12% | 5% |

### 6.8.4 Structure 9 Hearth/Ashy Deposits

#### 6.8.4.1 Results

*Context 9117 (upper hearth)*

- Two bones identified to species; calf's left unfused acetabulum fragment and sheep left tibia diaphysis, both unburnt
- Ratio of large mammal: medium size mammal 86:14 (NSP), 90:10 (weight)
- 80% (by weight) of the cattle/large mammal bone burnt, most partially or fully charred (lb and fc), only 4% calcined
- 93% sheep and medium size mammal bone fragments (by weight) unburnt or lightly burnt, remainder fully calcined

*Context 9125 (lower hearth)*

- Cattle, sheep and red deer identified, with cattle and sheep dominant
- Mature red deer complete astragalus, calcaneus and distal tibia (may have been articulated). Break in tibia diaphysis recent but cut marks on distal lateral face of astragalus, possibly caused during disarticulation
- Ratio of large mammal: medium size mammal 88:12 (NSP) 95:5 (weight) similar to hearth context 9117
- Cattle 2nd phalanx only complete cattle bone (proximal epiphysis fusion still visible, indicating juvenile). Bone stained but not obviously burnt
- Unburnt partial mandible from a new-born calf ($dp_3$ and $dp_4$ not yet in wear). One maxillary adult cattle $P^3$
- Approximately half cattle/large mammal bones unburnt (by weight), 19.5% partially or fully charred, the rest partially calcined. Burnt cattle bones include foot bones and a distal radius
- One sheep bone, an ulna, locally calcined, remainder unburnt

*Contexts 9111 and 9121 (ashy deposits adjacent to the hearth)*

- Cattle, sheep and one sea mammal fragment identified
- Ratio of large mammals: medium size mammals less biased towards large mammals than two hearth contexts (see above) at 59:41 (NSP) and 72:28 (weight)
- One cattle complete bone recovered, an unburnt cattle 3rd phalanx
- Two sheep complete bones recovered an unburnt sheep astragalus and charred fused sheep calcaneus (not articulated)
- A calf's deciduous incisor and a lamb's unworn maxillary $dp^3$ indicate presence of young animals, a sheep mandible fragment with $P_3$ and $P_4$ "*in situ*" a mature sheep
- Cattle phalanges with fused proximal epiphysis (animals older than 18 months)
- 62% cattle/large mammal bone (by weight) unburnt, remainder charred, none calcined. Burnt bones include (i) astragalus (ii) pelvis fragment (iii) carpals (iv) phalanges
- 14% sheep/medium size mammal bone (by weight) charred. Burnt bones include (i) astragalus (ii) calcaneus
- Weight of cattle femur and humerus bones higher than expected if complete skeletons were deposited, lower than expected for tibia and radius, mandible and vertebrae. Also greater than expected proportion of foot bone fragments, so it cannot be assumed that prime roasting joints were being cooked in Structure 9 hearths

*Context 9173 (ashy deposit central floor)*

- Cattle, sheep and pig present, but pig was only represented by a 1st and 2nd phalanges (one proximal epiphysis fused, one unfused). Large proportion of bone not allocated to species
- Ratio of large mammal: medium size mammal 63:37 (NSP), 87:13 (weight)
- Unfused cattle distal radius fragment, indicating an animal which had not attained maturity
- Three sheep deciduous molars (in wear) indicating a juvenile/sub adult
- Three complete phalanges, one cattle, one sheep and one pig, all unburnt.
- 61% cattle/large mammal fragments (by weight) unburnt. Most burnt bones partially or fully charred but partial calcination of a few diaphysis fragments.
- 38% of sheep/medium size mammals unburnt

#### 6.8.4.2 Summary

Unburnt bones from hearth contexts, and in particular the articulated red deer lower foot bones in context 9125, reveal some bone fragments were deposited after Structure 9 hearth went out of use, possibly associated with infill material. Cattle and large mammal dominated all contexts. Pig and red deer bone were present, as was an unidentified sea mammal fragment. A higher proportion of cattle and large mammal bones were burnt compared with sheep and medium size mammals. The few pig and red deer bones recovered were unburnt.

Little evidence of calcination of bone fragments exists, suggesting that either that fully calcined bones were no longer identifiable, or that bones had been subjected to variable exposure, perhaps due to casual disposal of bones on a fire. There is no pattern of charring on distal and proximal cattle bone fragments to suggest prime meat joints were roasted in the hearth. Structure 9 heath measured 1.1m by 0.95m (Moore and Wilson, 2011), whereas the heath at Barnhouse, Mainland, possibly used for feasting was 2.15m by 1.9m (Jones and Richards 2005, p43). There are not enough bones to produce age profiles, but newborn and juvenile sheep, pigs and cattle were recovered, as were adult sheep and cattle.

### 6.8.5 Structure 9 Floor deposits

#### 6.8.5.1 East

- Cattle and sheep identified
- Ratio of large mammal: medium size mammal 56:44 (NSP), 75:25 (weight).

- Complete cattle bones (i) astragalus (ii) two phalanges
- Complete sheep bones (i) astragalus, (ii) calcaneus (iii) three phalanges, all unburnt apart from the sheep's calcaneus, which was slightly burnt
- 83% cattle/ large mammal unburnt
- 79% sheep /medium size mammal, burnt, predominately partially or fully charred (lb, sb, fc) but some diaphysis and vertebrae fragments calcined.
- Two cattle horn core fragments (context 9166) based on measurements/ appearance, a pair. Texture indicates mature animal (Armitage 5/6) and based on (i) only beginning of perlen at base (ii) basal circumference of left horn core 150mm, female. Also small cranium fragment, possibly from occipital. Context 9166 described as dark-brown ashy soil in eastern recess of Structure 9, up to 0.4m deep, deposited during occupation (Moore and Wilson, p24, 2013). Horn cores therefore associated with occupation, or dislocated from cattle skull deposition representing an additional cattle skull to twenty-eight recovered
- Cattle phalanges with fused and unfused proximal epiphyses, indicative of at least two cattle ages (less than 18 months old, greater than 24-30 months)
- Sheep ages represented (i) unfused distal humerus and acetabulum (less than 10 months) (ii) phalanges unfused, fusing and fused proximal epiphyses (below 13 to 16 months, approximately 13 to 16 months, and older) (iii) worn dp4 teeth and unerupted permanent premolars (sub-adult) (iv) fused calcaneus (greater than 36 months) (v) proximal tibia in the process of fusing (36-42 month) (iv) distal tibia and a distal femur, fused (adults)

#### 6.8.5.2 West

- Cattle, sheep, pig and red deer identified, pig represented by only a humerus fragment and red deer a right femur distal fragment and right fused ulna
- Ratio of large: medium size mammal ratio 57:43 (NSP), 70:30 (weight).
- Complete sheep bones (i) sheep metatarsal (retrofitted) (ii) 1st phalanx
- Neonatal cattle right metacarpal as well as cattle bones from older, but undetermined ages
- Mandible of a recently born lamb and bones from sheep older than 20 to 28 months
- 80% cattle/large mammal bone unburnt (by weight)
- 84% of sheep/medium size mammal unburnt (by weight)

- Largest burnt bone proximal right cattle mandible (lightly charred with cut marks on bone)

### 6.8.5.3 South

- Cattle dominant with sheep, pig and red deer present
- Ratio of cattle/large size mammal: sheep/medium size mammal 62:38 (NSP), 82:18 (weight).
- Complete cattle bones (i) two 1st phalanx (ii) one 2nd phalanx (iii) one 3rd phalanx, epiphyses fused, unburnt
- Complete sheep bones (i) unfused left sheep metatarsal, unburnt
- Complete red deer bones (i) 1st phalanx, fused with the fusion line visible, unburnt
- Neonatal cattle unfused metapodial. Right mandibular $P_4$ Grant wear “f” represents adult cattle, along with a fused proximal ulna.
- Sheep metatarsal and proximal femur unfused, not adult
- Pig metatarsal II, fused, indicating juvenile/sub-adult/adult
- Red deer 1st phalanx, fused, indicating juvenile/sub-adult/adult
- Cattle metatarsal with chop mark at diaphysis break, 1st phalanx with cut marks below the proximal articulation, perhaps indicating skinning
- 88% cattle/large size mammal bones were unburnt
- 95% sheep/medium mammal bones unburnt

### 6.8.5.4 Summary

Cattle, sheep, red deer and pig bones were recovered from floor deposits in Structure 9. A range of ages for each species was represented, including neonatal cattle. Large mammal bones (cattle, red deer and unidentified) dominated the assemblage, both by NSP and weight. The majority of bones were unburnt.

### 6.8.6 Overview

Detailed examination of mammal remains floor and hearth deposits in Structure 9, LON, did not produce evidence of special treatment of mammals during the occupation of this building, although large mammal bones dominated, and a larger proportion of these bones burnt. All ages of cattle and sheep were represented, the collection was not dominated by older individuals.

# *7 Pathologies*

## 7.1 Introduction

LON bones from the eight areas studied were examined to investigate whether these animals displayed evidence of bone pathologies already reported for the Orcadian Neolithic and whether any other pathological symptoms were present. In addition, although there is a lack of knowledge of natural variation of lesions in wild populations (Siegel, 1976, p350) pathologies or red deer and otter are discussed.

The study of animal diseases is complex (Bartosiewicz and Gál, 2013, O’Connor, 2000, pp98-99) and this section only considers descriptive, macro-morphological changes. NMS Collection Centre does not include a reference collection of pathological specimens. However, zoo animal skeletons are curated, including wild boar from the Royal Zoological Society of Edinburgh’s Highland Wildlife Park site, so pathological features could be observed on skeletons from animals which, if roaming free, would have succumbed at an earlier age through natural death or predation. None of the pathological features from LON were as advanced as those observed on zoo specimens.

Examining bone pathology at LON will not reconstruct the complete picture of animal diseases at the site, since many signs of disease are predominately associated with soft tissues (Armour-Chelu, 1992, p225, Baker and Brothwell, 1980, p12, O’Connor, 2000, p98, Siegel, 1976, p355). Also, a proportion of cattle and sheep from the LON study areas were older adults and age itself may be a significant background factor to pathological conditions (Bartosiewicz and Gál, 2013, pp42-43, Siegel, 1976, p357).

## 7.2 Traumatic lesions

As discussed in *Chapter 4,* there appears to be some breaks, with cracks emanating from them, on the frontal bones of cattle, and these may be blows from humans. However, in the LON areas investigated no further skull fractures were noted.

Cattle and sheep had healed or unhealed breaks in ribs and misaligned fusions of epiphyses to diaphyses. Most of these traumatic lesions were not extensive and misaligned epiphyses were still securely attached to their respective diaphysis, although fusion incomplete. In addition, there were two healed perforations on the centrum of a cattle lumbar vertebra, which may be of traumatic origin. One pig metapodial bone had a proliferation of bone growth around a mid-diaphysis break and one red deer femur had some woven bone on the diaphysis adjacent to a misaligned epiphysis fusion. A red deer had a hole in an ulna, described in *Chapter 5.* An otter rib demonstrated evidence of a break followed by successful healing. At the previous excavation at LON five sheep ribs had healed fractures (Armour-Chelu, 1992, p242). At Knowe of Ramsay cairn, Rousay, a red deer scapula had a misaligned glenoid articulation.

## 7.3 Non-specific infection

Two examples were recorded, a cattle 1st phalanx from kiln flue infill in Structure 10, Area 5, and a cattle metatarsal from midden context 7302, both cases displaying bone distortion and an excess of nodular bone growth. In addition, a cattle scapula from context 7302 had a granular articular facet of the glenoid cavity and a proliferation of bone growth at the cavity margin.

## 7.4 Arthropathies (following headings in Bartosiewicz and Gál, 2013)

### 7.4.1 Osteoarthritis

Osteoarthritis is associated with degeneration of articular cartilage. Initial joint failure, in the absence of proper treatment, may result in inflammation and degeneration of the entire joint (Bartosiewicz and Gál, 2013, pp105-106, Siegel, 1976, pp361-362). Arthrodial joints which connect the major long bones are defined as arthritic if at least three of the following four inter-related symptoms are noted (i) grooving (ii) eburnation (iii) lipping (iv) small amorphous outgrowths (Baker and Brothwell, 1980, p115, Bartosiewicz and Gál, 2013, p108). Four LON cattle bones, a carpal, a distal 1st phalanx, a proximal 1st phalanx and a distal metapodial condyle displayed eburnation, and another cattle metapodial had grooving on a condyle. However, none of these bones had more than one other inter-related symptom, so identification for osteoarthritis is not secure (although some researchers consider grooving and eburnation alone can associated with the advanced stages of osteoarthritis e.g. Isaakidou, 2006, p107). The same position pertains for the two sheep bones, an os centrotarsale and an astragalus, which both displayed eburnation but did not have at least two other inter-related symptoms.

In contrast, an ulna and 3rd metacarpal of a mature otter (context 9031) displayed unambiguous evidence of osteoarthritis. The larger collection of otter bones from the Iron Age site of Brest Ness, Westray also revealed a high incidence of osteoarthritis in mature animals (Fraser, unpublished), as did the otter bones from the earlier LON excavation (Armour-Chelu, 1992, p236).

At the LON previous excavation a cattle sacrum, femur caput and pelvis acetabulum displayed eburnation, considered to be caused by osteoarthritis. In addition, a sheep radius displayed all four symptoms of osteoarthritis (Armour-Chelu, 1992, p232). In the Neolithic period at Pool, Sanday a fragment of burnt cattle pelvis acetabulum displayed eburnation and pitting and was described as arthritic (Bond, 2007, p233). At Tofts Ness, Sanday one sheep pelvis exhibited eburnation on the acetabulum and one cattle femur exhibited "*in vivo*" polish and wear on the caput (Nicholson and Davies, 2007, p177, p179).

## 7.4.2 Subchondral cystic lesions

### 7.4.2.1 General

Subchondral cystic lesions (or depressions) on articular facets, small discontinuities of various shapes, may be considered non-pathological in their incipient forms (Baker and Brothwell, 1980, p109, p111). "These lesions may be the result of *osteochrondroosis dissecans* a form of disturbed endochronal ossification of the epiphyseal cartilage in which joint surfaces fail as a result of compression" but other factors such as inheritance, sex, weight, trauma, growth and nutritional imbalance may also be associated (Bartosiewicz and Gál, 2013, p110).

At LON (i) narrow splits between distal articulations of 1st and 2nd phalanges (ii) shallow splits on articulations of 3rd phalanges and (iii) depressions on the proximal articulation of 1st and 2nd phalanges were noted on cattle and sheep phalanges. In addition, one pig 2nd phalanx had a split between the distal articulation and another pig 1st phalanx pitting on the distal articulation. Two red deer 1st phalanges also had splits on distal condyles (Baker and Brothwell, 1980, p111).

### 7.4.2.2 Cattle

Splits between distal articulation condyles in twenty-four 1st phalanges were the most commonly occurring manifestation of subchondral cystic lesions in cattle. Only two examples of splits in the articular surfaces of 3rd phalanges, illustrated for the Late Orcadian site of Skara Brae, Mainland, were noted. These splits were considered almost exclusive to the Scottish Neolithic (Baker and Brothwell, 1980, p111, fig 5) but there was an example at the Iron Age site of Brest Ness (Fraser, unpublished).Splits were noted on four bones from 3rd phalanges examined from twelve Neolithic Danish cattle (7% of sample) (Thomas and Johannsen, 2011, p52, table 6).

Prevalence of depressions on cattle 1st phalanges from the earlier LON excavation is 7%, an almost identical result to the present excavation (Armour-Chelu, 1992, p231). At the Iron Age site of Brest Ness, Westray, 6.5% of cattle 1st phalanges displayed splits between the distal condyles, again similar proportions to the Neolithic LON material (Fraser, unpublished).

In addition to phalanges, some cattle carpals, tarsals and proximal articulations of both metacarpals and metatarsals had lesions. Depressions were also present on three proximal radii and one proximal tibia articulation. Finally, two scapula glenoid cavities had whorl depressions in the centre of the articular facet.

Overall, subchondral cystic lesions were present on 1% of cattle bone fragments (NISP) at LON. An articulated partial cattle skeleton from the Neolithic midden at Tofts Ness, Sanday also exhibited depressions on carpals, proximal and distal metatarsal articulations and phalanges (Bond, 2007b, p200).

#### 7.4.2.3 Sheep

Although sheep bone fragments (NISP) were more numerous than cattle, incidence of subchondral cystic lesions was lower (0.6% of NISP). In addition, unlike cattle, only a few phalanges displayed lesions. One sheep 1st phalanx with a distal condyle split had a proximal fusion line still visible, a juvenile animal, perhaps indicating, in this case, the condition was not associated with age. Os centrotarsale sheep bones displayed the highest number of lesions and there are also more lesions on metacarpal and metatarsal proximal articulations than for cattle. In addition whorls on the articular facets of sheep scapula glenoid cavities were noted.

#### 7.4.2.4 Red deer and pig

Three red deer distal humeri, two proximal ends of radii and three distal epiphyses of tibias had small lesions on articulations. Splits in two 1st phalanges were also noted. No lesions were noted for pig bones from a 2nd phalanx distal articulation split.

### 7.4.3 Lesions of axial skeleton

No inter-ventral fusion of vertebrae was observed for any LON species. However minor exostosis was present at the margins of centra of a small number of cattle cervical and sheep cervical and thoracic vertebrae. Slight lipping was also noted on articular facets of cattle and sheep vertebrae. In addition, a few cattle skulls had slight exostoses at margins of the occipital condyles.

No cup-shaped depressions, as illustrated on the centra of cervical vertebrae from the modern population of Soay Sheep on Hirta, St, Kilda, Western Isles and thought to be related to butting behaviour of rams, were present in the LON material studied (Clutton-Brock et al., 1990, p8, p12, fig 8). However depressions were noted on the centra of two sheep lumbar vertebrae. In addition, small depressions were present on two cattle lumbar vertebrae and one cattle thoracic vertebra.

Some otter cervical, thoracic and lumbar vertebrae displayed slight exostosis at the margins of the centrum. These were also noted at the earlier LON excavation (Armour-Chelu, 1992, p236) and at Calf of Eday cairn. No axial skeleton lesions were noted on pig or red deer bones.

### 7.4.4 Lesions of scapulae and pelves

Fifteen LON cattle pelves with extensive remodelling of bone surrounding the acetabulum, predominately in the form of additional, pouched bone, although in two cases additional lipping of the articulation margins was also noted. Some acetabulum articulation facets had been remodelled to such an extent that their outline had lost definition. These were present in approximately 10% of the pelves acetabulum examined, more if calf and juvenile bones are excluded. One lesion was noted on the articular surface. See *Photograph 21*.

**Photograph 21: LON cattle pelvis**

Two cattle scapula glenoid cavities display evidence of lipping at the edge of the articulation facet and a porous area was noted on the articulation of a third, but the extensive remodelling observed for pelvic articulations was not recorded.

In comparison with cattle, no extensive remodelling was noted for sheep pelves, but two bones did display lipping at the margin of the acetabulum, three bones had slight pouching around the acetabulum and there was a pit in the medial articulation in another acetabulum. There was also lipping around the margin of glenoid articulation facets of three sheep scapulae.

No lesions were noted on pig bones but for red deer one scapula fragment had remodelling, resulting in pouching, adjacent to the glenoid cavity.

### 7.4.5 Lesions in long bones

#### 7.4.5.1 Cattle

The most extensive remodelling on cattle long bones was the distortion and overdevelopment of ulnar grooves on of six radii, most of which contained ulna fragments within the groove. The following additional lesions were noted:

- Three femur caputs with slight remodelling around fusion line
- Two distal tibiae and seven proximal tibiae with remodelling adjacent to their articulations, resulting in additional, pouched bone
- Three proximal tibiae articulations with lipping at the margins and one the medial crests of one bone
- Six humeri with slight exostoses were present at the edge of the distal articulation
- Three radii had additional remodelled bone adjacent to proximal articulations
- Two radii with lipping at the margin of the proximal articulation

#### 7.4.5.2 Sheep

No remodelling was noted for sheep femora but tibiae had additional pouched bone below two proximal articulations and above four distal articulations. A larger number of sheep forelimb bones displayed lesions, including two partially merged radius/ulna bones with exostoses. This fusion had not progressed to the extent illustrated by L. Bartosiewicz (Bartosiewicz and Gál, 2013, p119, figs 94-95). In addition, fourteen sheep radii had remodelled bone below the proximal articulation and three also had lipping at the margins. Three ulnae had lipping and remodelling at the articulation and seven humeri also had slight exostoses at either the lateral or medial edges of the distal articulation.

Two examples of sheep radii at the earlier excavation at LON were considered to display symptoms of “penning elbow” caused by channelling sheep through races or pens (Armour-Chelu, 1992, pp233-234, Baker and Brothwell, 1980, p127). However, a number of modern feral Soay sheep on St Kilda displayed similar symptoms and penning was ruled out in this instance (Clutton-Brock et al., 1990, pp8-9). At the Iron Age site at Brest Ness, Westray, four sheep radii had extensive bony growths around the radius/ulna articulation, indicating this pathology was also present in the later pre-historic period in Westray (Fraser unpublished). The fact that some sheep survived to old age may influence the incidence of these lesions. In the late 18th and 19th century the sheep population of the Orkney Islands were left to fend for themselves on common lands and foreshores for most of the year (Fenton, 1997, p446, Lovick, 2004, p1) and this may have been how sheep were managed in the Neolithic period, exposing them to rough terrain. Another possibility is that the condition is related to systemic, possibly inherited factors (Bartosiewicz and Gál, 2013, pp117-118).

#### 7.4.5.3 Red deer

In red deer lipping was noted at the margins of a radius proximal articulation and on an ulnar groove of a radius. Bone remodelling was present adjacent to distal articulations and one proximal articulation of tibia. At the earlier LON excavation one red deer, estimated to be approximately five years old, had bone remodelling and osteophytic growth around the margins of epiphyses of radii, femur and tibiae. Since the pathology was widespread the osteoarthritis may not have been of traumatic origin (Armour-Chelu, 1992, p237). A similar pattern of symptoms manifest on several bones was noted from the mature LON red deer skeleton deposited in the current excavation from the kiln infill, Area 5, perhaps indicating that this was also systemic.

Some remodelling to produce pouched bones was noted on the distal end of one pig tibia and one otter tibia.

### 7.4.6 Lesions of hock joints and phalanges

Spavin in a LON red deer has already been discussed in *Chapter 5*. Spavin is a direct result of dry tarsal joint inflammation and thought to be caused by a complex of inherited, structural and functional disorders (Bartosiewicz et al., 1997, p70, Bartosiewicz and Gál, 2013, pp125-126). The fact that six incidences of this condition have been recorded from red deer bones recovered from Neolithic and Iron Age Orkney may demonstrate that inheritance/inbreeding is a factor, particularly since spavin is rare in deer (Bartosiewicz and Gál, 2013, p125). No examples of spavin were noted in LON cattle bones, although one incidence was recorded for the Iron Age site at Howe, Mainland (Smith, 1994, table 41mf 1:E6).

A small proportion of cattle and sheep phalanges, calcanei, os centrotarsale, carpals and proximal metapodials had lipping at the margins of the articulated surfaces and some remodelling of adjacent bone. None of the cattle phalanges had progressed beyond “stage 2” in terms of exostosis or lipping, as illustrated by L. Bartosiewicz and colleagues for modern Romanian and Hungarian draught oxen (Bartosiewicz et al., 1997, pp46-57).However, some LON 2nd cattle phalanges had developed exaggerated bony hooks protruding from the proximal articulation, unlike the morphology featured in the illustrations for these modern draught oxen 2nd phalanges. Some cattle, sheep and red deer had bony sole outgrowths and distortions of the tip of 3rd phalanges. Pitting and new bone formation was present in 36% of sheep 3rd phalanges at D. Clarke’s earlier excavation of LON (Armour-Chelu, 1992, p241, fig 31), a higher proportion than identified in the current study. It was suggested that this symptom may have been associated with prolonged exposure to wet conditions (Armour-Chelu, 1992, p242).

There was slight evidence of “spread” in the distal diaphyses segment and articular condyles of cattle metapodials, a condition that may be associated with traction (Bartosiewicz et al., 1997, pp75-76, fig 53-55, Bartosiewicz and Gál, 2013, p147, fig 124). See *Photograph 22*.

**Photograph 22: LON cattle metatarsal with asymmetric distal condyles**

## 7.5 Inherited or congenital disorders

All LON cattle skulls examined had horn-cores. One, skull from the foundation deposit, Structure 9, had asymmetric horns that did not appear to be the result on manual manipulation. All cattle skulls examined from V.G. Childe's excavation at Skara Brae also had horn cores (Watson, 1931). A few sheep lacked horn cores, but no polycertia was noted, an anaomoly present in modern St Kildean, Hebridean and Jacob sheep and also recorded at a Neolithic site in Poland (Bartosiewicz and Gál, 2013, pp188-191). The presence of a small perforation in cattle skulls was discussed in *Chapter 4* but no further examples of this this phenomenon were noted.

One sheep and one cattle mandible had exaggerated depressions at the mental foramen, the anterior opening of the mandibular canal. At Skara Brae, Mainland, two cattle mandible fragments had double foramina, and one triplicated foramina (Baker and Brothwell, 1980, p35) and at the earlier LON excavation extra or enlarged foramina were noted on two cattle mandibles (Armour-Chelu, 1992, p228). These are considered to be congenital defects (Baker and Brothwell, 1980, p35).

Absence of 2nd mandibular premolars, $P_2$, has been recorded in both wild and domestic ruminants and may be pathological or simply intra-population variability (Andrews and Noddle, 1975, Bartosiewicz and Gál, 2013, pp196-197, Hillson, 2005, p281). One example was recorded from a sub-adult at the Neolithic site of Skara Brae, Mainland (Andrew and Noddle, 1975, p138) and from an animal at the Iron Age site of Howe, Mainland (Smith, 1994, table 41mf 1: E). At LON one cattle mandible also had a missing $P_2$, but another ten mandibles had $P_2$ *"in situ"* but not in wear even though these teeth were fully developed or part of a tooth row with all other teeth in wear. It is of interest that all fully developed maxillary $P^2$ examined were in wear, with dentine exposed, so perhaps these teeth occluded with the mandibular $P_3$ although malocclusions are not common in high-crowned ungulates (Hillson, 2005, p283).

No cattle mandibular $M_3$ with reduced posterior cusps were noted at LON, although the earlier excavation identified two teeth with this congenital abnormality (Armour-Chelu, 1992, p229) and one was identified from the Neolithic phase at Pool, Sanday (Bond 2007, p233). One cattle mandibular $M_3$ from the Neolithic Rowiegar cairn, Rousay was identified as missing a third cusp during examination at the NMS Collection Centre.

Some mandibular and maxillary cattle premolars, P3 and P4 had additional small pillars. This may be intra-population variation. The same pillars were noted on the bred-back aurochs, the Heck bull (a combination of numerous traditional cattle breeds) from the NMS Collection Centre.

The only inherited post-cranial disorders noted were an asymmetric foramen on a cattle atlas and an additional foramen on a sheep axis. No bifurcated spinal processes of vertebrae were noted.

## 7.6 Oral Pathology

Enamel from several cattle molar and premolar teeth and deciduous 4th molars, were covered in clearly defined cementum ridges, a feature first noted at the Neolithic phases of Pool, Sanday (Bond 2007, p233). See *Photograph 23*.

**Photograph 23: Cementum ridges of cattle maxillary molar**

Cementum holds the tooth in its socket and acts as attachment tissue for the periodontal ligament with deposition continuing throughout life. The same pattern of layered cementum was noted on one cattle mandibular $M_3$ from Rowiegar cairn, Rousay and several cattle molars from the Mid Neolithic settlement of Knap of Howar, both collections stored at the NMS Collection Centre.

When cementum is growing rapidly it is less well mineralised, when growing slowly better mineralised (Hillson, 2005, pp194-195). Cementum formation may be related to annual cycles in ruminants (Beasley et al., 1992, Bourque et al., 1978, Lieberman et al., 1990, Low and Cowan, 1963, Lowe, 1967, p144, Mitchell, 1967, Stallibrass, 1982) with depositions impacted by climate, season, diet and nutrition, sexual cycles, continued teeth eruption and location of the tooth (Pike-Tay, 1991, p63, Stallibrass, 1983, Upex et al., 2014, p81). The layered cementum at LON was not sufficiently intact to use as an estimation of age but may imply restricted growth during the winter season.

Dental caries result from continuous damage to teeth from plaque-forming bacteria. Occurrence of caries in wild ungulates is rare (Bartosiewicz and Gál, 2013, pp172-173) and this is reflected in the low incidence at LON with only one cattle maxillary $P^4$ and one sheep maxillary $M^3$ affected. However, a greater proportion of molar teeth did have calculus, mineralised plaque deposit. In addition, there was a loss of enamel at the junction of cattle maxillary $M^1/M^2$, two sheep maxillary $dp^3/dp^4$ and one sheep maxillary $M^2/M^3$.

The most commonly occurring oral disease at LON was either bone loss or pitted bone at alveolar margins. These features are a result of infection of soft tissue around the bone, progressing to involvement of alveolar bone surrounding the teeth and the periodontal membrane of each socket. Loss of bone on two adult cattle mandibles between $P_4$ and $M_1$ and around an $I_2$ tooth was noted. On eight sheep mandibles bone loss was predominately adjacent to $M_3$. Four pig mandibles suffered bones loss on the lingual side of the $M_1/M_2$ molar junction and three lingual $P_4$ and one $M_1$ roots were exposed.

The next stage of this process, the eventual loosening and loss of teeth was not noted for any species (Baker and Brothwell, 1980, pp153-154, Bartosiewicz and Gál, 2013 pp177-178, Hillson, 2005, p306). In addition, no "*intra vivum*" teeth losses, abscesses or new bone growth, reported for some Neolithic sheep at Pool, were noted (Nicholson and Davies 2007, p177).

Although cementum was not removed from teeth in this study and teeth not extracted from sockets, pitting, a form of hypoplasia (Hillson, 2005, p168) was observed on two cattle incisors, three sheep incisors and one pig incisor. Pitting was also noted on one cattle $dp_2$ and a $P_4$ tooth and four pig molars, including two $M_3$. Hypoplasia lines were also present on two pig M2 teeth.

Incidence in the LON assemblage was far lower from the systematic study of hypoplasia on sheep permanent mandibular molars from the Orcadian Neolithic sites of Knap of Howar, Skara Brae and Holm of Papa Westray North where occurrence rates for hypoplasia were 49%, 43% and 23% respectively (Upex et al., 2014).

Various asymmetric wear patterns of both maxillary and mandibular cattle and sheep teeth were present. One adult sheep maxillary bone had a palate that veered away from the tooth row, particularly at $M^2$ and $M^3$.

## 7.7 Overview

A low incidence of pathological lesions and congenital or inherited disorders was noted on LON mammal bones. The most advanced pathological symptoms were from wild mammals (otters and red deer). A few healed breaks were recorded on stock animals' bones, but not sufficient to suggest that they were living in unfavourable or overcrowded conditions.

# 8 Age

## 8.1 Introduction

Ageing techniques were employed to produce “age at death” profiles for LON species (Chaplin, 1971, pp128-129, Klein and Cruz-Uribe, 1984, pp55-57, O’Connor, 2000, p80, Reitz and Wing, 1999, pp182-185). The death assemblage is not the equivalent of a life assemblage because faster turn-over of animals dying at an early age results in older animals being under-represented (Chamberlain, 2006, p15, Johannsen, 2006, p41). In addition, importation or exportation of stock from the settlement may alter profiles. In this study the eruption and wear of teeth was the main tool used to assess “age of death”, examination of epiphyseal fusion to collaborate results.

Age profiles cannot be constructed from small samples (Klein and Cruz-Uribe, 1984, p57) so results from mandibles, maxillary rows and loose teeth from eight LON study areas were merged for analysis. In addition, separate analysis was undertaken on the sheep mandible accumulation from the midden area “equivalent to context 7302 (a)”

The discussion assumes that cattle and sheep births were restricted to spring/early summer births based on physiological and environmental constraints, for example, seasonal availability of vegetation (cattle) and day-length (sheep) (Tresset and Vigne, 2011, p186). Using stable oxygen analysis of tooth enamel, it was established that the Mid Neolithic site of Knap of Howar had a restricted period of birth for sheep and cattle but was less restricted for sheep at the Mid/Late Neolithic cairn at Holm of Papa Westray North (Balasse and Tresset, 2007, p80, p82).

## 8.2 Tooth eruption results for LON

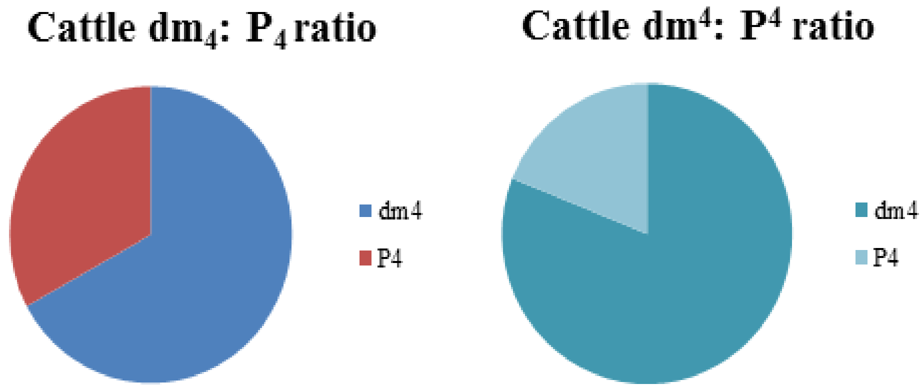
### 8.2.1 General

The first tooth eruption analysis applied to LON material was the simple method of calculating deciduous 4th premolar: 4th premolar ratios ($dp_4$: $P_4$ and $dp^4$: $P^4$) for loose teeth used by Payne to differentiate between sheep less and more than two years (Payne 1988 in Twiss, 2008). The method, using both loose and embedded teeth from cattle and sheep, is based on the premise that these two teeth occupy the same space in mandibular or maxillary arcades and cannot be in wear simultaneously. The risk is that the loose P4 are over-estimated if unworn teeth, in life still lying below the unshed dp4, are included in the calculation. This bias was reduced, but not eliminated by excluding P4 from crypts or with roots only starting to form and from obviously shed dp4. These results were compared with eruption data (Simonds, 1854).

### 8.2.2 Cattle

In cattle mandibular teeth, the ratio of dp$_4$: P$_4$ was 67%: 33% (138 teeth). If only left or right teeth were examined, the ratio remains virtually identical. These results reveal that approximately two-thirds of LON cattle were culled or died naturally in the proximity of the site before the age of 30/36 months i.e. before attaining full adult size. If examination is restricted to mandibles containing some, or all, of the tooth-row, then the dp$_4$: P$_4$ ratio is 75%: 25%, again reflecting that a large proportion of cattle did not attain adulthood.

If maxillary teeth are examined, the ratio in favour of animals culled before 30/36 months is even more marked, at 81%: 19% (90 teeth). If only left or right maxillary teeth are examined, ratios are similar. It should be noted, however, that an adult cow may have produced three of four calves in her lifetime, so the living herd profile would not be as orientated towards younger animals as the age of death profile portrays. *See Graph 40.*



**Graph 40: Ratio of LON (Links of Noltland) cattle mandibular and maxillary dp4: P4 (No 138 and 90**

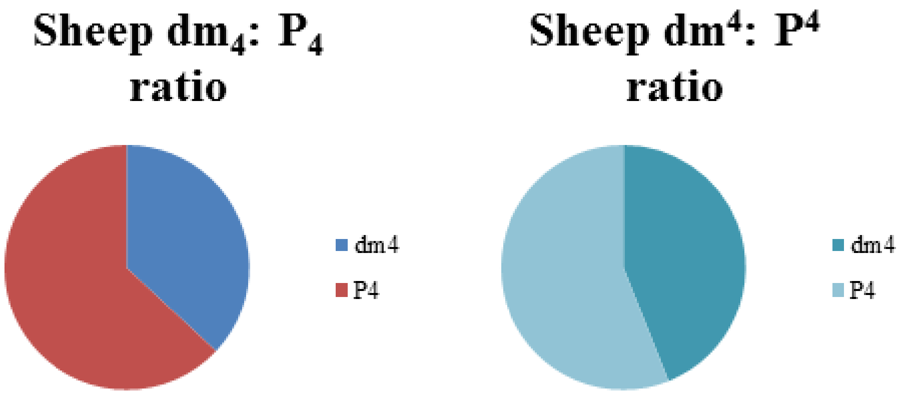
Tooth eruption data using Simonds (1854) also indicates that 13% of cattle died around the time of their birth, and a least another 39% between one and nine months. See *Table 22.*

**Table 22: LON (Links of Noltland) estimated age range of cattle mandibles based on Simonds, 1854**

| Age range | No |
|---|---|
| Neonatal | 6 |
| 1-6m | 12 |
| approx 6m | 5 |
| 6-9m | 1 |
| 9-15m | 0 |
| 15-18m | 5 |
| 18-24m | 0 |
| 24-30m | 4 |
| >30m | 13 |

### 8.2.3 Sheep

For sheep, the ratio of $dp_4$: $P_4$ is reversed from that of LON cattle, at 37%: 63% (304 teeth). The ratios of left or right teeth were similar. This demonstrates that two-thirds of the sheep had attained more than 24/ 27 months of age. The ratio of maxillary teeth $dp^4$: $P^4$ is less marked, at 44%: 56% (256 teeth). See *Graph 41*.



**Graph 41: Ratio of LON (Links of Noltland) sheep mandibular and maxillary dp4: P4 ratios (No 304 and 256)**

If sheep eruption data is restricted to mandibles containing some, or all, of the toothrow, the ratio of sheep below 24/27 months: greater than 24/27 months is similar to the $dp_4$: $P_4$ ratio, at 39%: 61% (145 left and right mandibles).

### 8.2.4 Pig

For pig, eruption from ten mandibles shows:

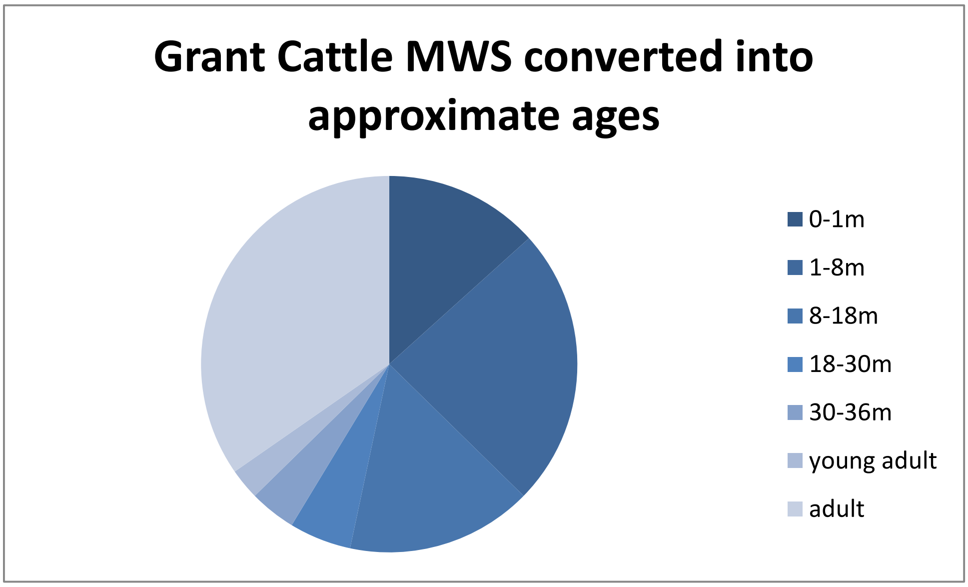
- approximately one month (one)
- 15 to 18 months (one)
- greater than 18 months (eight)

Maxilla tooth rows also indicate one piglet at one month old, one at approximately six months old, and a few greater than 18 months old at death.

## 8.3 Tooth wear results for LON

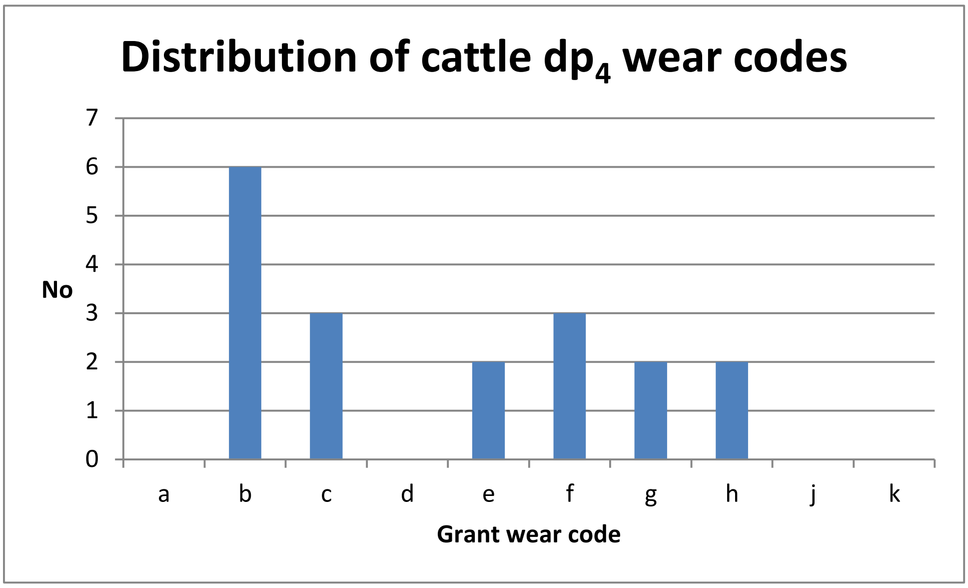
### 8.3.1 Cattle

The Grant tooth wear tables for LON cattle mandibles confirm the results from the tooth eruption analyses that 38% of cattle died within the first eight months of their lives, some as neonates. Approximately another 20% of cattle were culled as juveniles. There follows a low proportion of deaths in the sub/adult, young adult category, with most cattle that surviving the calf/juvenile stage dying as adults/older adults. This pattern does not appear to suggest that cattle husbandry was focussed on maximising meat production.  See *Graph 42.*



**Graph 42: LON (Links of Noltland) cattle estimated MWS ages (Grant, 1982)**

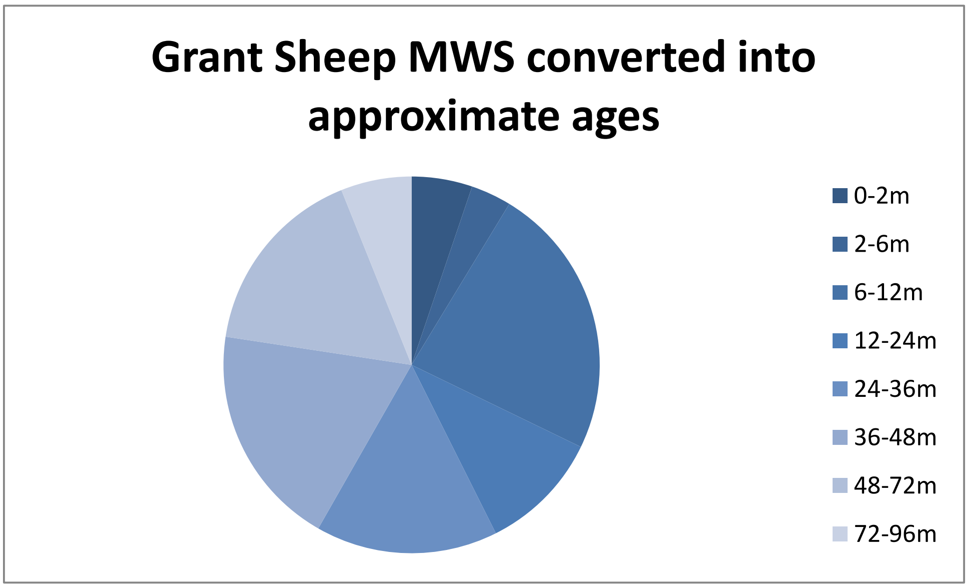
Based on $dp_4$ wear patterns these animals may have died in different months during this period and were not all “autumn/early winter cull” animals (Higgs and White, 1963). These calves may have died from natural causes or as part of a husbandry regime. See *Graph 43*.



**Graph 43: LON (Links of Noltland) cattle dp4 wear code distribution (Grant, 1982)**

### 8.3.2 Sheep

Unlike cattle, evidence from LON sheep mandibles eruption analysis reveals only low numbers of animals died or were culled in the first few months of life. This may reflect different culling decisions or alternatively sheep flocks were extensively managed and many sheep did not give birth at the settlement. A greater number of sheep died in the 6 to 12 months age range. The overall percentage of sheep dying between birth and 12 months was 37%. Most sheep mandibles “age of death” were concentrated around Grant MWS 19 to 43 (actual value or calculated from tables) estimated ages of death being from 12 to 72 months. Approximately 5% survived beyond 72 months. See *Graph 44*.



**Graph 44: LON (Links of Noltland) sheep estimated MWS ages (Grant, 1982)**

### 8.3.3 Pig

Tooth wear for pig mandibles, of which only one mandible had $M_1$, $M_2$ and $M_3$ "*in situ*" were extrapolated to give "age of death":

- zero to two months (one)
- 14 to 21 months (two)
- 21 and 27 months (five)

These figures align with the eruption data. This gives no information to the season of death since more than one litter of piglets may be produced per annum.

### 8.3.4 Tooth wear and eruption from LON contexts equivalent to 7302 (b)

In context 9110, 36 complete or partially complete sheep mandibles were present in a bone spread. The mandibles produced a MNI of eighteen (right). One left and right pair was identified but other pairs may be present. Employing Greenfield and Arnold's (2008) conversion of MWS the following ages were identified:

- Less than 5 months (one, possibly three)
- 6 to 12 months (seven)
- 12 to 24 months (two)
- Greater than 24 months (seven, predominately 4 to 6 years and 6 to 8 years, and one possibly two, attaining 8-10 years)

Other animals could not be aged because too few teeth were present in the tooth row.

Mandibles from younger animals, with permanent teeth still erupting, give the best opportunity for seasonal analysis. Age ranges for lambs indicate that, assuming they were all born within a five to six week period, it is possible, but not probable, that the 2-5 months and the 6-12 months sheep (most of which had MWS values in the lower end of the range) could be from the same cohort. The next range of ages, 12-24 months give no seasonality, but if Simonds eruption diagrams are used, there appears to be no mandibles from the 12-15 month age range, perhaps indicating that sheep in this group may have been culled between 15 and 24 months.

The results therefore suggest the possibility of a one-off cull in autumn of a minimum of eighteen sheep of different ages, as a presumed preparation for a feast, but it is also possible that this area of midden was used for repeated activity, particularly since there is also evidence of at least one new-born lamb was present in the bone spread. Skull maxilla fragments containing tooth rows from at least six individuals (six rights, four left) were all, apart from one individual, from sheep at, or above, 24 months.

### 8.3.5 Tooth wear and eruption results from other Neolithic Orkney settlements

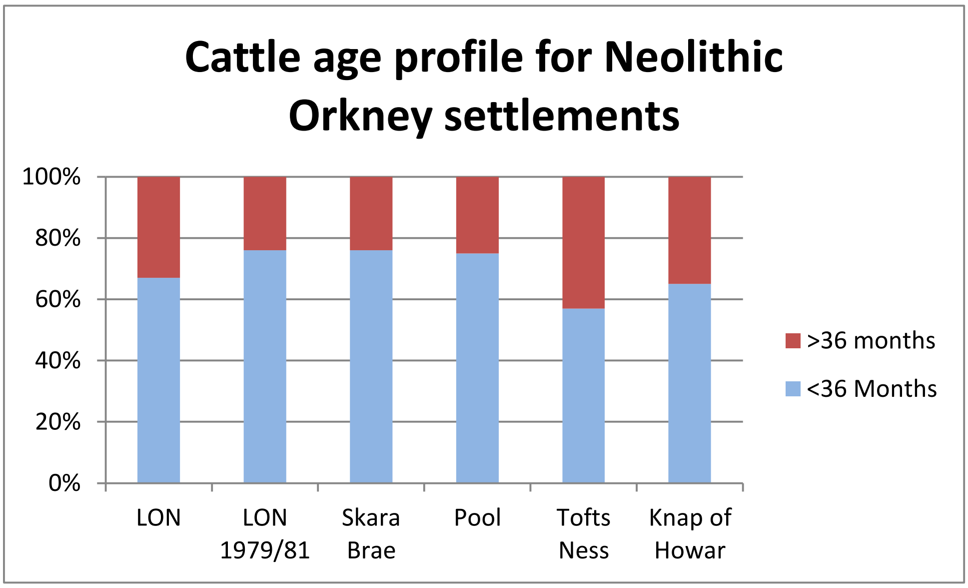
#### 8.3.5.1 Methods

Previous Neolithic Orkney animal bone reports tooth-wear measurements were as follows:

- Grant (sheep, cattle and pig): Links of Noltland (D. Clarke’s 1979/81 excavation), Isbister and Holm of Papa Westray (Armour-Chelu, 1992, Barker, 1983, Harman, 2009)
- Tooth-wear method devised by A. Legge and D. Serjeantson at the Centre for Extramural Studies, University of London 1979 (based on Payne system principles) (sheep and cattle) and eruption based on Grant’s code: Pool and Tofts Ness, Sanday (Serjeantson and Bond, 2007a and 2007b, Nicholson and Davies, 2007)

#### 8.3.5.2 Cattle

All other published data from Neolithic sites in Orkney supports the LON age of death profiles for cattle determined by tooth eruption and wear, that is, the majority of cattle died prior to attaining young adult/adult ages.  See *Graph 45.*



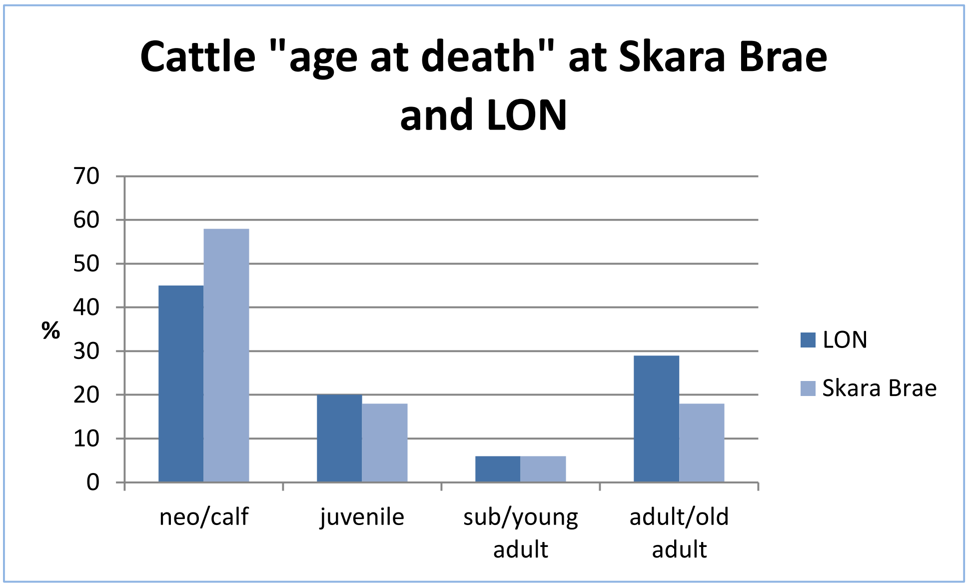
**Graph 45: Cattle age of death profile from selected Orkney Neolithic settlement sites; LON (Links of Noltland, Late Neolithic); LON 1979/81(D. Clarke's excavation, Links of Noltland, Late Neolithic); Skara Brae (Late Neolithic); Pool (Neolithic); Tofts Ness (Neolithic); Knap of Howar (Mid Neolithic)**

At D. Clarke's previous LON excavation wear stages from cattle mandibular $dp_4$ indicated most calf deaths were either as neonates or at Grant stage "j" (calves approximately six months old) (Armour-Chelu, 1992, p128, fig 7). However closer examination of the results reveals that approximately one-third of the wear stages were between neonates and 6 months old, perhaps a more graduated wear pattern. Based on mandibles and loose mandibular 3rd molars ($M_3$), it was calculated that approximately 24% of cattle survived beyond 36 months (Armour-Chelu, 1992, p131) which aligns with the present LON study.

At V.G. Childe's Skara Brae, Mainland, 17 cattle mandibles were predominately calves (Watson, 1931, pp200-201):

- neonates (two)
- 5 to 6 months (eight)
- 12 to 18 months (three)
- 30-36 months (one)
- over 3 years of age (three)

However, these age ranges have been challenged, with the "five to six months" category being possibly up to nine months old and the "twelve to eighteen months" category possibly fifteen to twenty-one months. This was on the basis that although the 1st molar ($M_1$) may have erupted between five to six months, it did not commence wear until a few months after this event (Higgs and White, 1963, p285, Simonds, 1854, p62). D.M.S. Watson's suggestion that calves killed at five to six months were the result of pre-winter culling due to the lack of winter fodder is now questioned (Clarke, 1998, p16, Higgs and White, 1963, pp284-285). At the later Skara Brae excavation by D. Clarke, details not yet published, it was stated that a large proportion of calves were slaughtered in the first year of their lives (Clarke and Sharples, 1985, p75), most at six months (Clarke, 1998, p16), although, as was highlighted above, there ae difficulties in allocating such an accurate "age of death". The Skara Brae profile is, however, similar to that of a LON results converted to suit the categories adopted by D.M.S. Watson (1931). See *Graph 46.*



**Graph 46: Percentage profile cattle "age at death" at two Orkney Late Neolithic sites, LON (Links of Noltland, No 17) and Skara Brae (No 17), (Watson, 1931)**

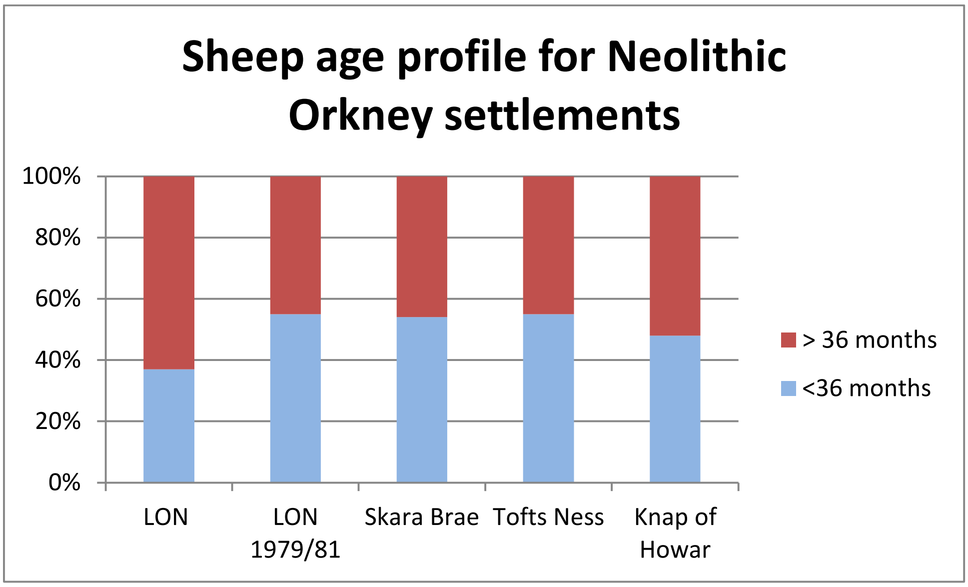
At Neolithic phases 1 and 2 at Pool, one quarter of twenty cattle mandibles examined had died at one month or less and another 20% in their first autumn/early winter (Bond, 2007, p218, pp222-223, table 7.2.4). However, from Neolithic phase 3, 76% were from adults predominately based on the examination of loose $M_3$, with the suggestion that less robust teeth and more complete mandibles had not survived (Bond 2007, p223).

At Tofts Ness, Sanday in Neolithic phases 1 and 2, 44% of calves were slaughtered before they attained approximately 6 months and, of these, half died before approximately one month when the deciduous $dp_4$ had erupted and in light wear, Grant wear stage "b". A total of 43% of cattle mandibles were from mature animals. (Serjeantson and Bond, 2007b, p205 table 6.3.3.2,).

At the earlier Neolithic site of Knap of Howar, Papa Westray, over half of cattle died in the year they were born, based on bone fusion and dentition, and just over 20% were fully mature (Noddle, 1984, p94). A high number of $dp_4$ were unworn, reflecting significant perinatal mortality (Balasse and Tresset, 2007, p82). If ratios of B. Noddle's categories of newborn, weaning and juvenile: immature and adult are taken as proxies for $dp_4$: $P_4$ then the cattle ratio for immature: adult for period 1 and 2 is 65%: 35%, very similar to those of LON (Noddle, 1983, p94, table 2).

### 8.3.5.3 Sheep

Sheep age results from other published Neolithic sites in Orkney also reflect LON sheep age profiles, of approximately half dying after attaining adulthood See *Graph 47*.



**Graph 47: Sheep age of death profiles from selected Orkney Neolithic settlement sites; LON (Links of Noltland, Late Neolithic); LON 1979/81(D. Clarke's excavation, Links of Noltland, Late Neolithic); Skara Brae (Late Neolithic); Tofts Ness (Neolithic); Knap of Howar (Mid Neolithic)**

At D. Clarke's previous LON excavation, 43% of sheep mandibles examined were estimated to have come from animals that died at less than 12 months of age a slightly higher percentage, than from the current eight LON areas under investigation. Another 45% survived beyond their third year, a similar result to the current LON excavation (Armour-Chelu, 1992, p136). At Skara Brae, Mainland 15 sheep mandibles were from:

- approximately 3 months (two)
- approximately 9 months (two)
- 12 to 18 months (four)
- adults (seven)

These results reflect those from LON, that is, not a large number of young lambs culled or dying at the settlement and a steady cull from different age-groups thereafter (Watson, 1931, p203). At Pool, Sanday twenty-eight sheep mandibles were examined and the number of lambs that died at less than a month old was 3.6%, another two died between 1 to 6 months of age (7%) and ten (36%) between 6 to 12 months, a similar profile to that observed at LON.

If ratios of B. Noddle's categories of newborn, weaning and juvenile: immature and adult at the Mid Neolithic site of Knap of Howar, Papa Westray are taken as proxies for the $dp_4$: $P_4$ then the sheep ratio (for period 1 and 2) is 48%: 52%, more evenly distributed between sheep less than 24/27 months and over this age (Noddle, 1983, p94, table 2) than at LON.

## 8.4 Epiphyseal fusion

### 8.4.1 General

In this report, the examination of epiphyseal fusion does not attempt to produce a detailed cull profile for LON but selects bones to examine the relative distribution of neonates, juveniles, sub-adult, and adult cattle and sheep. See *Tables 23 and 24.*

**Table 23: LON (Links of Noltland) cattle epiphyseal fusion (m/p -metacarpal, metatarsal and unidentified metapodial fragments (loose distal epiphysis not counted)**

| LON cattle epiphyseal fusion | Fused | Unfused | Percent fused |
|---|---|---|---|
| humerus distal | 30 | 27 | 53% |
| radius proximal | 37 | 24 | 61% |
| radius distal | 16 | 29 | 36% |
| ulna proximal | 10 | 16 | 38% |
| calcaneus proximal | 10 | 34 | 77% |
| femur proximal | 12 | 36 | 25% |
| femur distal | 8 | 31 | 21% |
| tibia proximal | 25 | 42 | 37% |
| tibia distal | 10 | 33 | 23% |
| m/p proximal | 87 | 20 | 81% |
| m/p distal | 22 | 55 | 29% |
| phal1 proximal | 126 | 137 | 48% |

**Table 24: LON (Links of Noltland) sheep epiphyseal fusion, m/p -metacarpal, metatarsal and unidentified metapodial fragments (loose distal epiphysis excluded)**

| LON sheep epiphyseal fusion | Fused | Unfused | Percent fused |
|---|---|---|---|
| humerus distal | 91 | 25 | 78% |
| radius proximal | 96 | 22 | 81% |
| radius distal | 16 | 40 | 29% |
| ulna proximal | 16 | 21 | 43% |
| calcaneus proximal | 38 | 39 | 49% |
| femur proximal | 34 | 44 | 44% |
| femur distal | 37 | 40 | 48% |
| tibia proximal | 17 | 42 | 29% |
| tibia distal | 53 | 31 | 63% |
| m/p proximal | 270 | 37 | 88% |
| m/p distal | 94 | 73 | 56% |
| phal1 proximal | 121 | 47 | 72% |

### 8.4.2 Cattle

Nineteen percent of LON cattle metapodial bone proximal articulation fragments were unfused, indicating that approximately one-fifth of the cattle died as neonates, since these bones have epiphyseal fusion approximately at birth. This reflects results from examination of LON cattle teeth eruption.

Examination of early-fusing cattle long bones (proximal radius and distal humerus with epiphyseal fusion approximately 12 and 18 months old) suggest that 39% of cattle died before 12 to 18 months (proximal radius) or 47% (distal humerus). For 1st phalanges, which fuse at approximately eighteen months 117 proximal epiphyses were unfused, one was fusing and 110 were fused, giving a ratio of fused: unfused of 48%: 52%

These cattle epiphyseal fusion results indicate that approximately half the LON cattle had been culled or died of natural causes before they reached approximately 18 months of age. Based on the $dp_4$:$P_4$ ratios, approximately two-thirds of the cattle died before approximately three years old, suggesting that the removal of animals from the herd continued into cattle's second winter and third year of life.

Examination of late fusing cattle long bones (proximal and distal femur, proximal tibia, proximal ulna and distal radius plus proximal calcaneus) reveals that only one third or one quarter of all cattle survived to adulthood. These results align with the LON cattle tooth wear and eruption data.

### 8.4.3 Sheep

Twelve percent of LON sheep metapodial proximal epiphysis was unfused, indicating a higher death rate for neonatal sheep than 4% calculated by teeth eruption data.

However, only one-fifth of sheep early fusing bones (proximal radius and distal humerus) were unfused, revealing that approximately four-fifths of the sheep survived beyond the first autumn after their birth.

Twenty-eight percent of sheep proximal 1st phalanges were unfused, and since this bone fuses between 13 to 16 months this indicates that three quarters of the sheep survived into a least their second year of life.

Examination of late fusing sheep long bones (proximal humerus, distal radius, proximal ulna, proximal and distal femur and proximal tibia, proximal calcaneus) suggests that approximately half of all sheep were culled before 30 months, (proximal ulna, proximal femur and calcaneus) and perhaps up to three-quarters by 36/42 months. This data aligns with the teeth eruption and wear data, and suggests significant removal of animals from the herd as growth rates start to decline, perhaps to maximise meat production.

## 8.5 Overview

Age of death profiles for cattle indicate high calf mortality and a herd profile for mixed out-take of resources, including milk whereas sheep age of death profile reveals a greater focus on meat production.

# 9 Measurements

## 9.1 General

Post-cranial cattle and sheep measurements from all LON study areas were assessed to determine if cattle and sheep were of similar stature to those of the Early/Mid Neolithic site of Knap of Howar (KOH), Papa Westray, or whether, in the half millennium since arrival in Westray, there had been a reduction in size. In addition comparisons were made with two Orcadian Iron Age sites (i) Brest Ness, (BNKS), Westray (Fraser unpublished) (ii) Howe, Mainland (measurements tabulated from C. Smith's identification cards, Smith 1994). It should be noted that Howe measurements are to the nearest mm, other site measurements to the nearest 0.1mm. Measurements from all four sites (Knap of Howar, LON, Howe and Brest Ness) were from a series of contexts and time periods covering several hundred years, a longer period than required to alter stature by selective breeding. Past researchers have suggested that Orcadian Iron Age cattle and sheep were smaller than Neolithic animals (Cussans et al., 2007, p244, Nicholson and Davies, 2007, p177, Noddle, 1979, p291-295, 1997, p236).

For this study, it has to be assumed that the mature bones from each site still sufficiently intact for measurement were an unbiased sub-sample of bones deposited at each site, although it is recognised that the articulated red deer skeletons from LON do not fulfil this criterion. Also bones with fused epiphysis are used for measurement, so if a community culled a large proportion of males prior to maturity, which may be possible for Neolithic cattle in Orkney, this may impact on the sexual representation of bones measured. Small bones, such as sheep carpals, although measured for this study, were not included in the present analysis. Selected LON cattle bone dimensions were also compared with measurements from Early and Late Neolithic southern English sites.

A few measurable LON pig bones were examined to investigate whether they were wild or domesticated. Red deer bone measurements were analysed to determine the relative size of Orkney red deer in the Neolithic and Iron Age. It has been previously noted that Late Neolithic Orcadian sites have smaller red deer than mainland deer (Mulville, 2010, pp48-49). A comparison of red deer measurements was also made with the Scottish island Mesolithic sites on Oronsay, Western Isles.

Individual bone measurements with approximately thirty or more results were analysed individually because they could be considered normally distributed (Drennan, 2009, p128). At LON these are predominately foot bones. For the remainder of LON mammal bone measurements, results were combined for using the “size index scaling method”. The bone dimensions included in size index scale calculations are listed in *Appendix 21*.

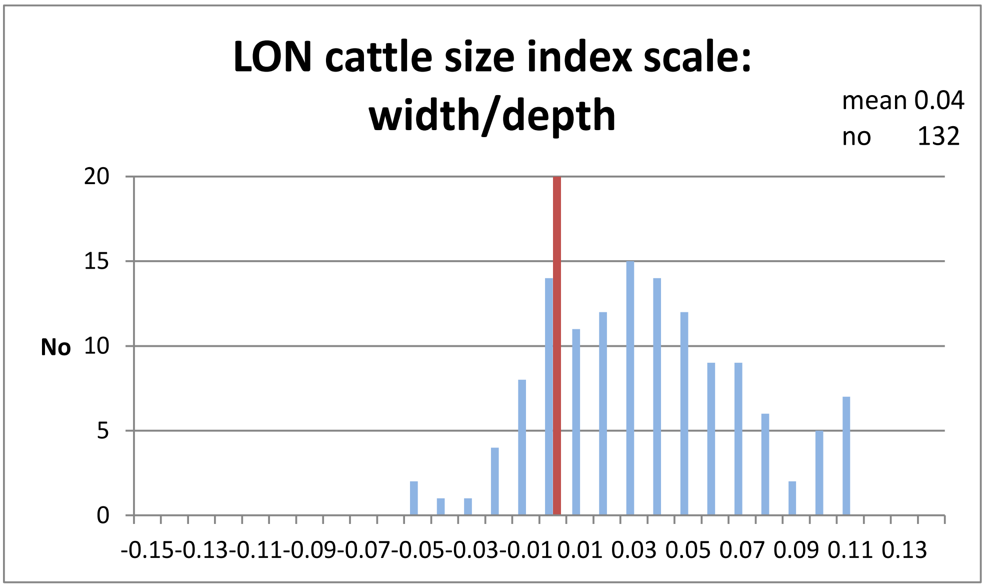
## 9.2 Cattle

### 9.2.1 Size index scale

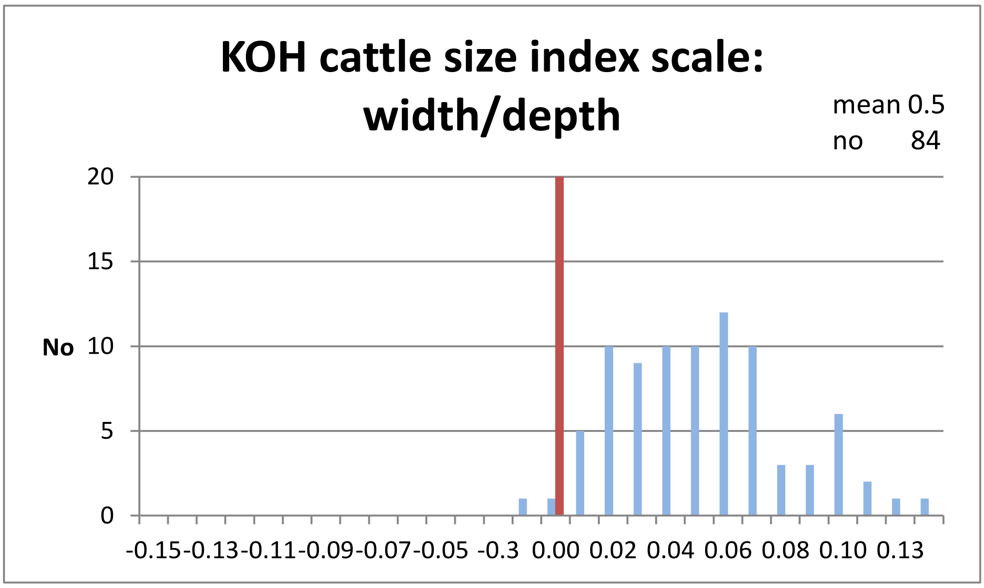
For this study the log ratio was $\log_{10}$ and the standard animals for cattle were:

- 20th century Shetland domestic cow (female) NMS Collection Centr*e Z.1905.46* selected because it was a complete skeleton and a “rare British breed” considered relatively unimproved (Fenton, 1978, p429, Hall 2004, p165, table 8.1)
- Ullerslev aurochs (female) near Nyborg, Denmark, Boreal period, because this skeleton was substantially complete (Degerbøl and Fredskild, 1970, p96), used as a “standard” by C. Grigson for the report for the Early Neolithic site of Windmill Hill (Grigson, 1999) and because the mtDNA testing raised the question of aurochs genetic material carried in Neolithic Orkney cattle

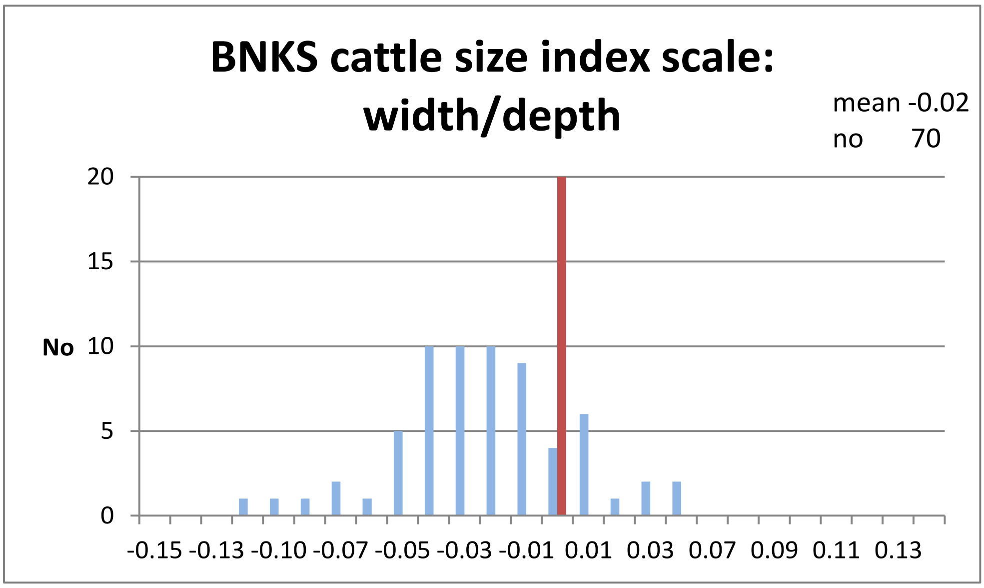
The graphs of width/depth size and length index scaling using a Shetland cow as standard confirm previous research that there was a significant decline in the stature in cattle between the Neolithic and Iron Age period in Orkney. The graphs all have similar profiles and do not indicate that change in sex representation was a major source of the observed differences between the Orkney sites Knap of Howar, Mid Neolithic (KOH) and the Iron Age sites of Howe and Brest Ness (BNKS) See *Graphs 48 to 55.*



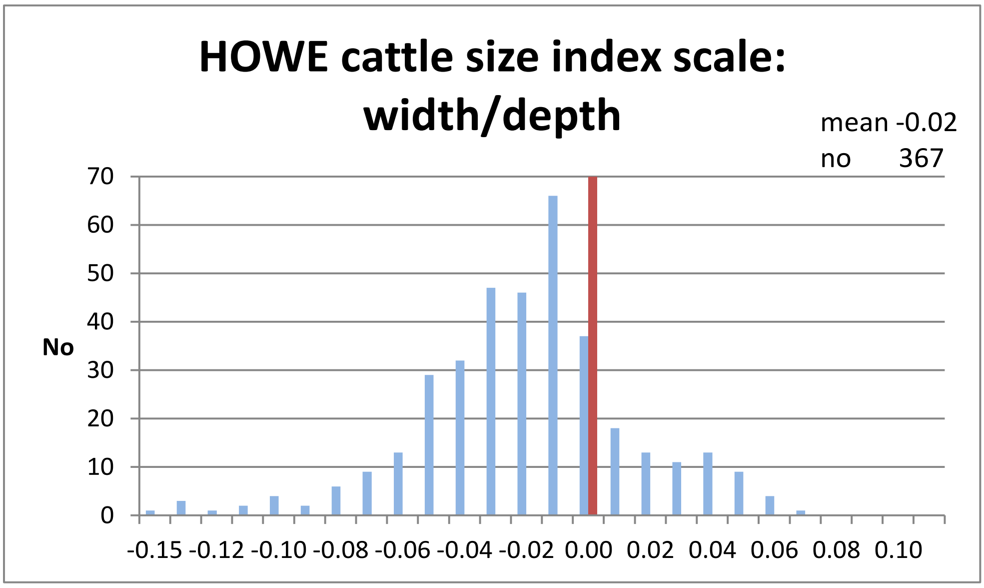
**Graph 48: Cattle size index scale: Shetland cow standard: width/depth: LON (Links of Noltland, Late Neolithic)**



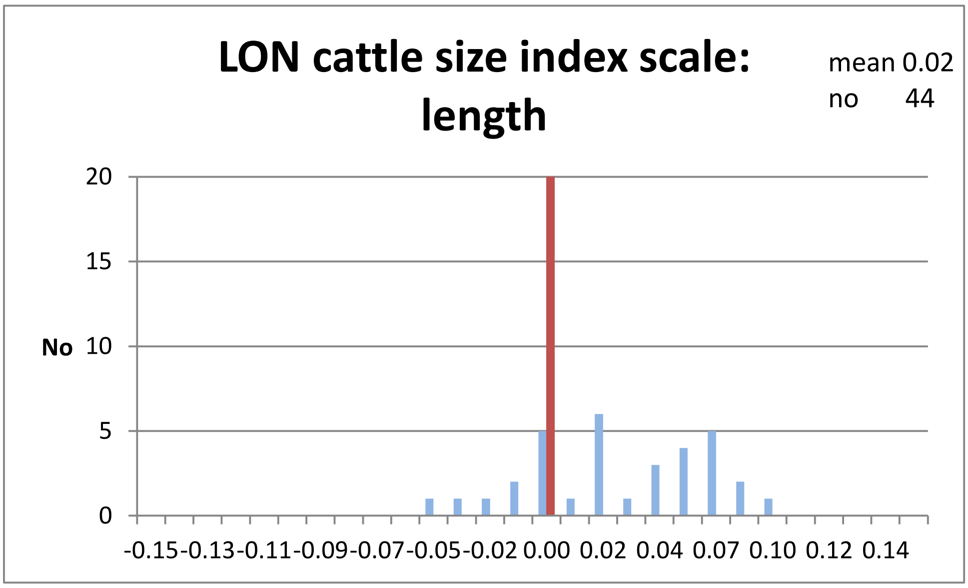
**Graph 49: Cattle size index scale: Shetland cow standard: width/depth, KOH (Knap of Howar, Mid-Neolithic)**



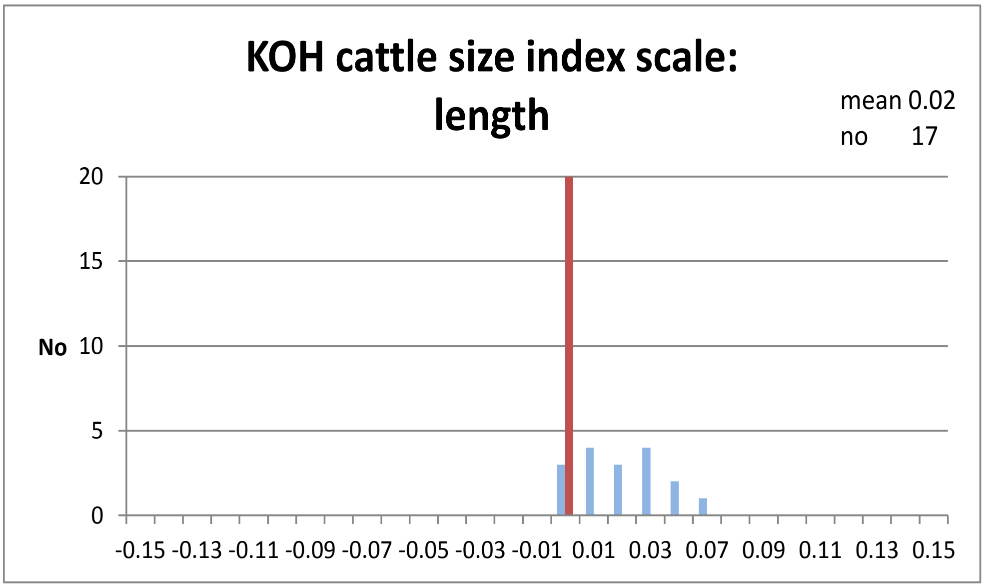
Graph 50: Cattle size index scale: Shetland cow standard: width/depth BNKS (Brest Ness, Iron Age)



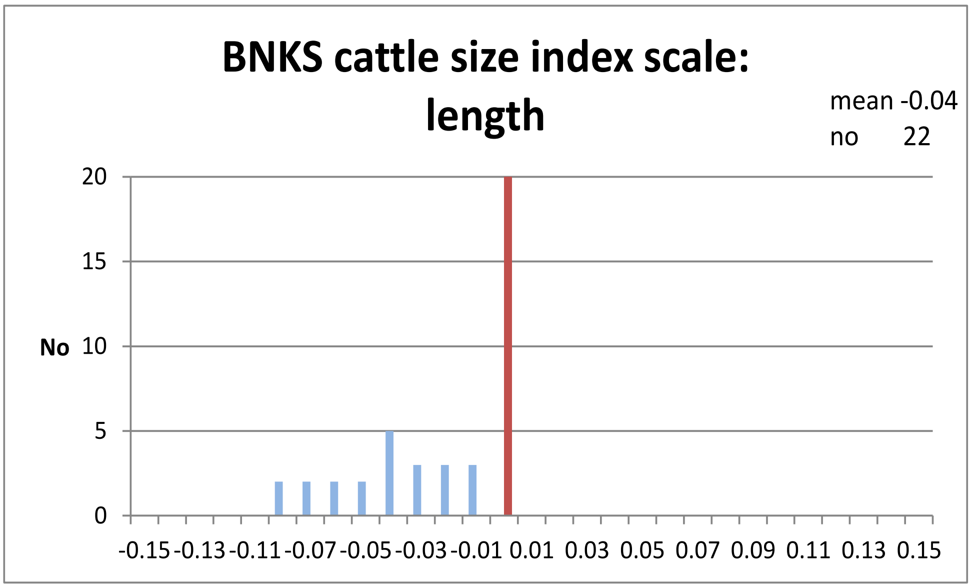
Graph 51: Cattle size index scale: Shetland cow standard: width/depth, Howe (Iron Age).The previous 3 graphs are presented in the same vertical and horizontal scale, but Howe has a greater vertical range because more measurements were available from this site



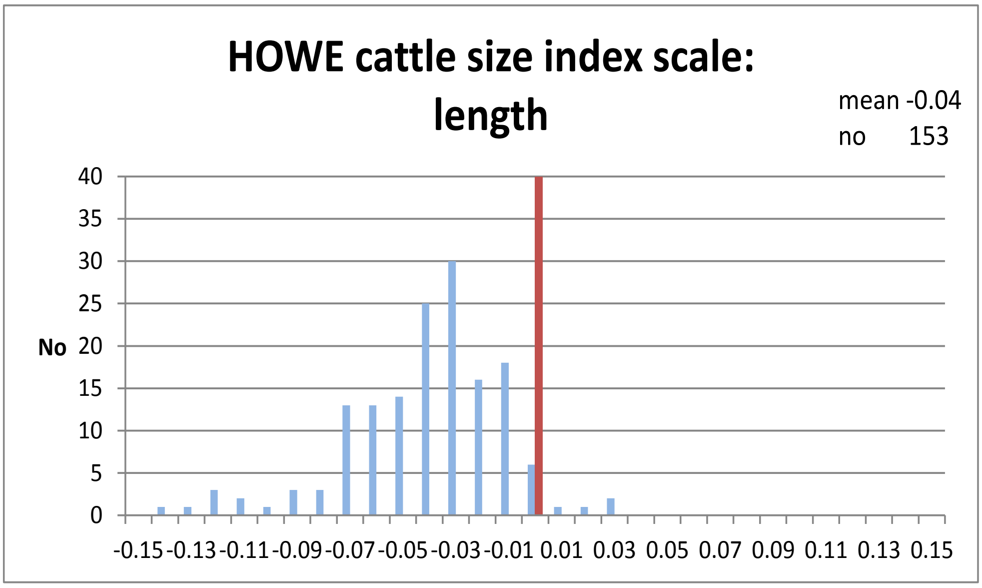
**Graph 52: Cattle size index scale: Shetland cow standard: length, LON (Links of Noltland, Late Neolithic)**



**Graph 53: Cattle size index scale: Shetland cow standard: length, KOH (Knap of Howar, Mid-Neolithic)**

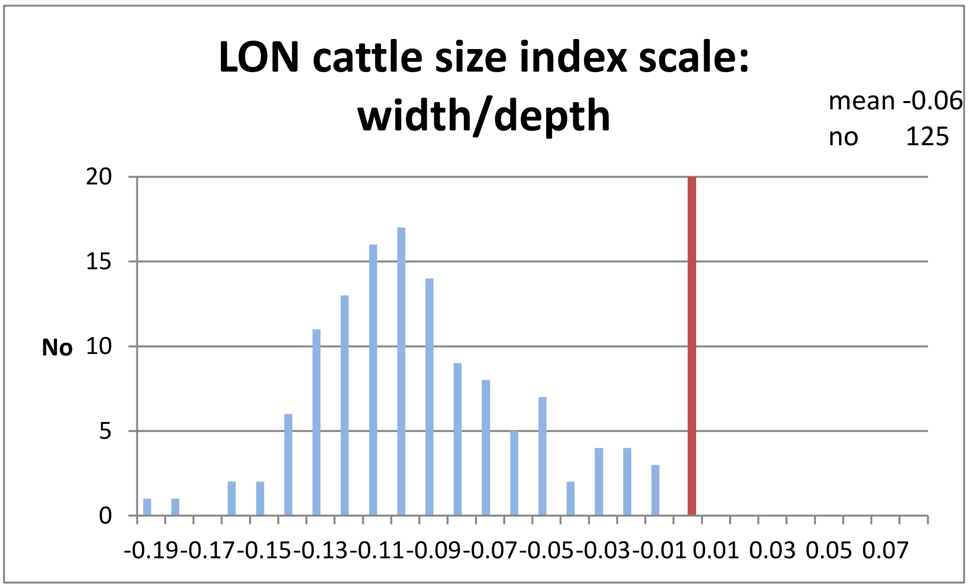


**Graph 54: Cattle size index scale: Shetland cow standard: length, BNKS (Brest Ness, Iron Age)**

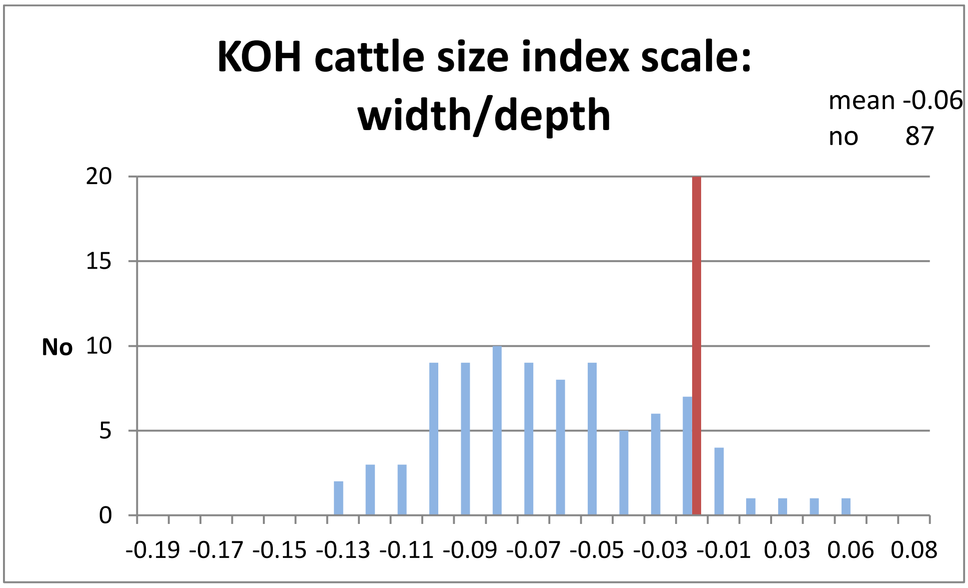


**Graph 55: Cattle size index scale: Shetland cow standard: length, Howe (Iron Age). The previous 3 graphs are presented in the same vertical and horizontal scale, but Howe has a greater vertical range because more measurements were available from this site**

Cattle size for the two Neolithic Orkney sites was also compared with a standard female aurochs. No LON bones exceeded zero and only a few Knap of Howar bones were larger than the standard. See *Graphs 56 and 57*.



**Graph 56: Cattle size index scale: Ullerslev aurochs cow standard: width/depth, LON (Links of Noltland, Late Neolithic)**



**Graph 57: Cattle size index scale: Ullerslev aurochs cow standard: width/depth, KOH (Knap of Howar, Mid-Neolithic).**

There are slight differences between the Neolithic sites. For example, at the Mid Neolithic site of Knap of Howar all length and almost all width/breadth cattle measurements were higher than the Shetland cow standard. In contrast, at LON a proportion of both width/depth and length measurements were lower than the standard. The difference between Knap of Howar and LON size index scale graphs is reflected in the mean of the width/depth graphs of 0.05 and 0.04 respectively, but not in the length graphs, where both had mean values of 0.2.

The difference between the mean of width/breadth and length graphs at LON and Knap of Howar (KOH) perhaps indicates that the Neolithic Orkney cattle were taller and much stockier than the Shetland cow.

At the Early Neolithic causewayed enclosure in southern England at Windmill Hill, Wiltshire, published cattle size index scales were also plotted against the Danish Ullerslev female aurochs the horizontal axis labels are confusing (possibly rounded to the first decimal place) but it appears that most bones were smaller than the standard Ullerslev female aurochs. Two outlying size scale indices of 0.05 and 0.07 were considered to be aurochs bulls and the intermediate group between -0.01 and 0.01 either domestic bulls or wild cows (Grigson, 1999, p216, fig 168). The higher results from Windmill Hill are similar to those at Knap of Howar.

In contrast to the Neolithic Orkney sites, the Iron Age sites of Howe and BNKS produced cattle bones smaller than the standard Shetland cow, in some cases up to -0.15 on the size index scale. No length size index scales were greater than zero for the BNKS site, suggesting that even males were smaller than the Shetland cow standard.

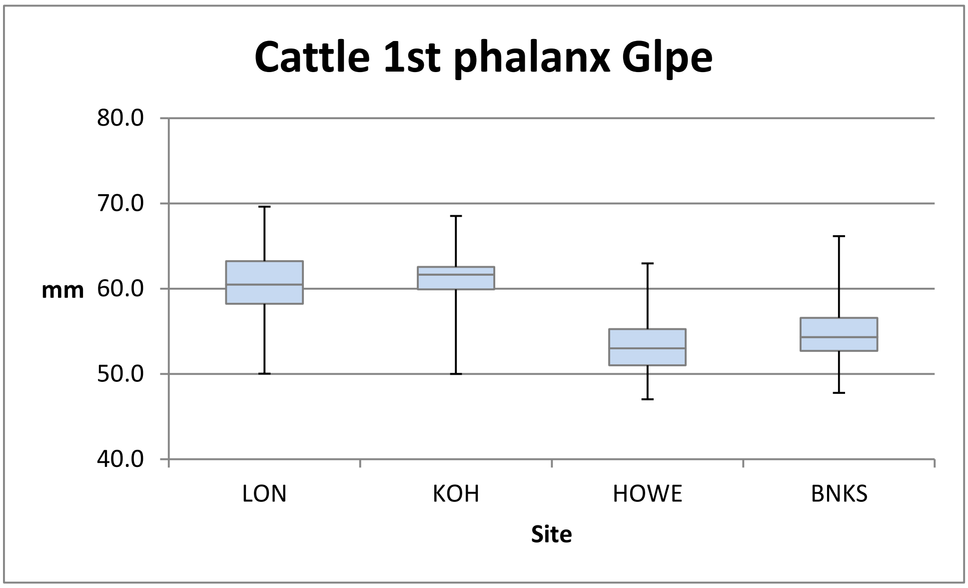
### 9.2.2 Batches of LON cattle measurable bones

#### 9.2.2.1 General

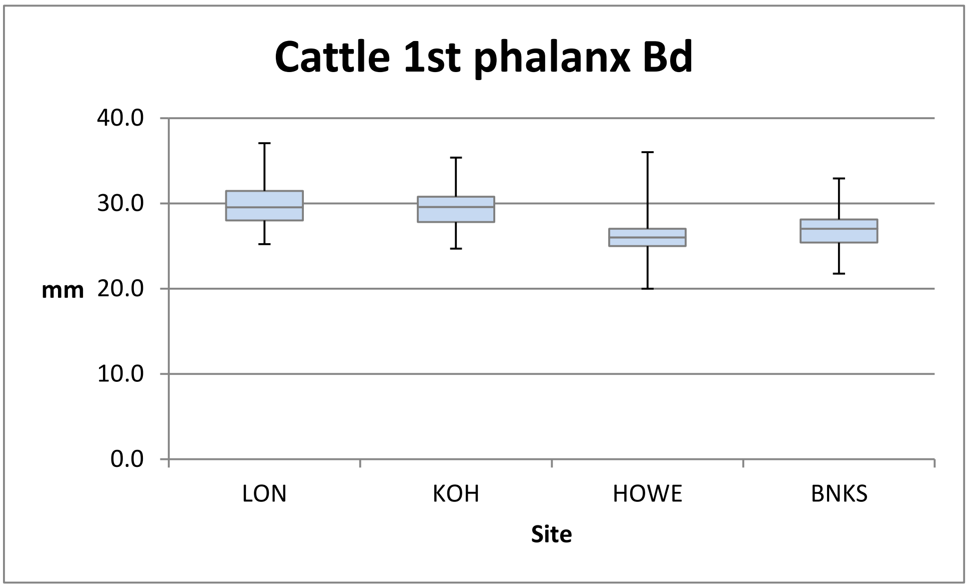
Complete cattle bones at both Neolithic Orkney and Iron Age sites suitable for individual bone analyses were predominately foot bones and teeth. By measuring metapodial bones recovered from the LON study areas and distal metapodial bones removed for tool examination as mattocks (or scrapers) another collection of measurements was produced. It is possible, however, that foot bones are of restricted value for describing full skeletal size.

#### 9.2.2.2 Neolithic Orkney and Iron Age Orkney sites

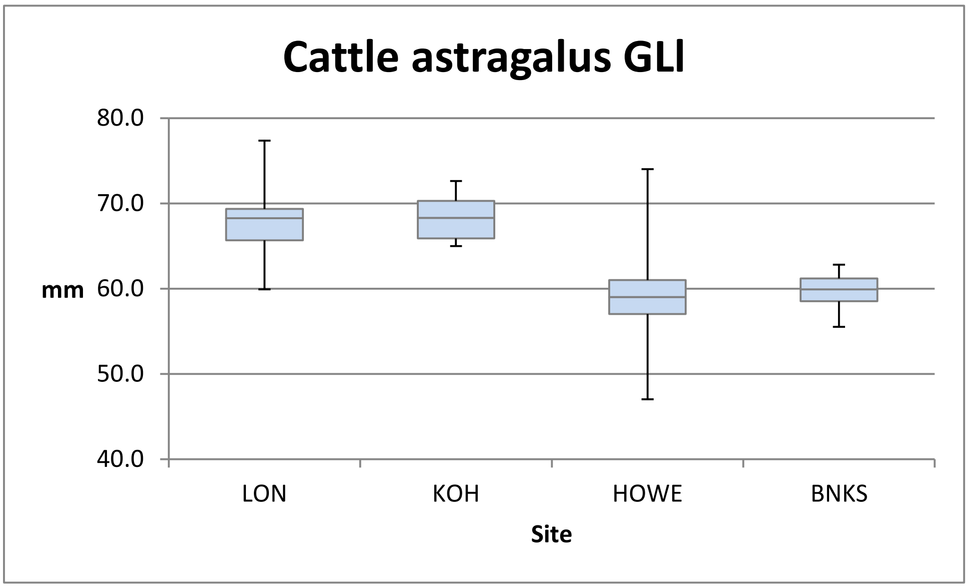
Measurements for cattle 1st phalanx, the length “GLpe” and breadth “Bp”, and astragalus “GLl” and “Bd” from four prehistoric Orkney sites were plotted on graphs using box and whisker plots that illustrated the medium, 25% and 75% quartiles and maximum range. This type of graph provides a clear indication of level and spread of the sample from each site (Drennan, 2009, p29) but would not highlight the presence of low numbers of aurochs. See *Graphs 58 to 61.*



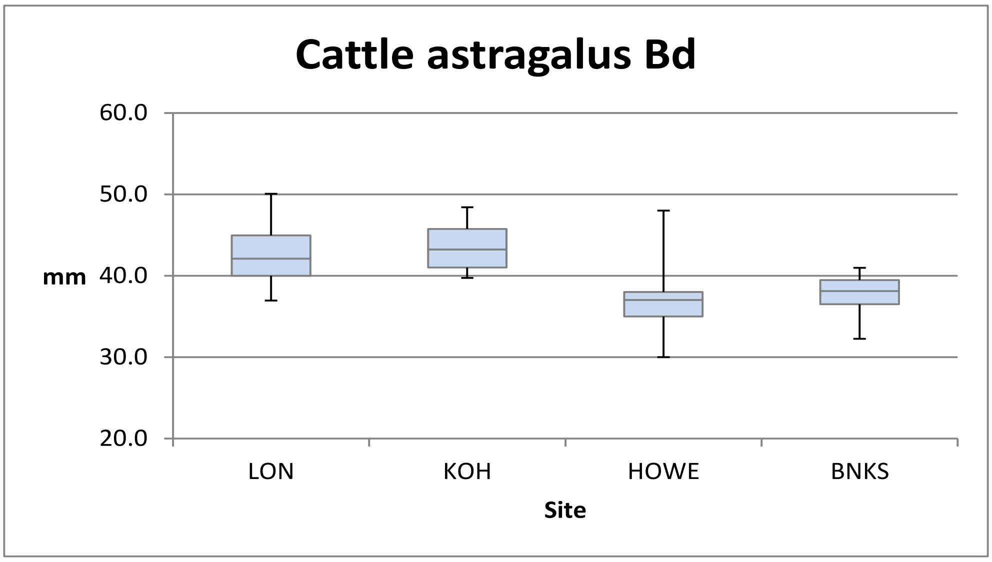
**Graph 58: Cattle 1st Phalanx GLpe midspread (mm) from four Orkney sites; LON (Links of Noltland Late Neolithic, No 84); KOH (Knap of Howar, Mid Neolithic No 20); Howe (Iron Age, No 156); BNKS (Brest Ness, Iron Age, No 67). Graph represents median, 25% and 75% quartile values and maximum range.**



**Graph 59: Cattle 1st Phalanx Bd midspread (mm) from four Orkney sites; LON (Links of Noltland Late Neolithic, No 86); KOH (Knap of Howar, Mid Neolithic No 28); Howe (Iron Age, No 100); BNKS (Brest Ness, Iron Age, No 67). Graph represents median, 25% and 75% quartile values and maximum range.**



**Graph 60: Cattle astragalus GLl midspread (mm) from four Orkney sites; LON (Links of Noltland Late Neolithic, No 36); KOH (Knap of Howar, Mid Neolithic No 9); Howe (Iron Age, No 101); BNKS (Brest Ness, Iron Age, No 13). Graph represents median, 25% and 75% quartile values and maximum range.**

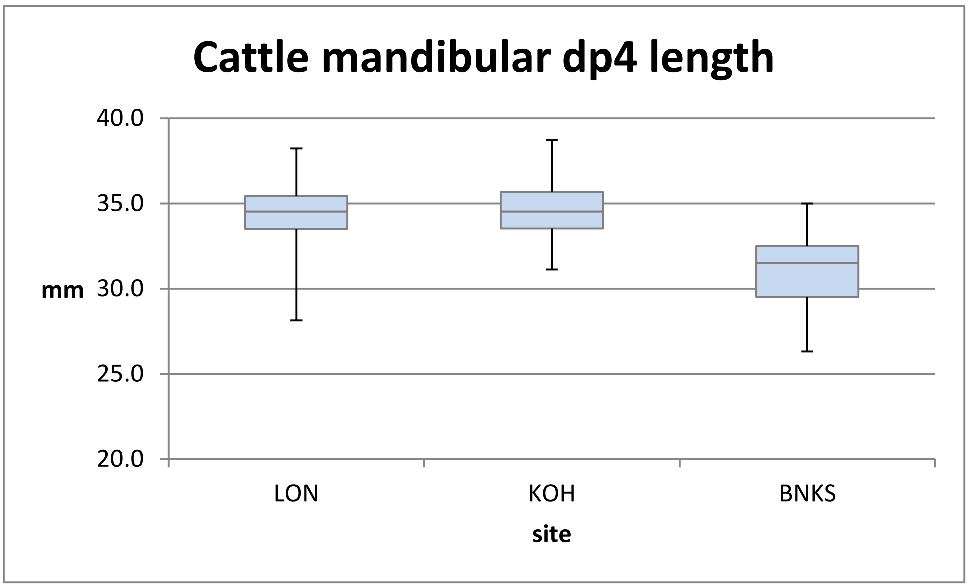


**Graph 61: Cattle astragalus Bd midspread (mm) from four Orkney sites; LON (Links of Noltland Late Neolithic, No 39); KOH (Knap of Howar, Mid Neolithic No 9); Howe (Iron Age, No 92); BNKS (Brest Ness, Iron Age, No 11). Graph represents median, 25% and 75% quartile values and maximum range.**

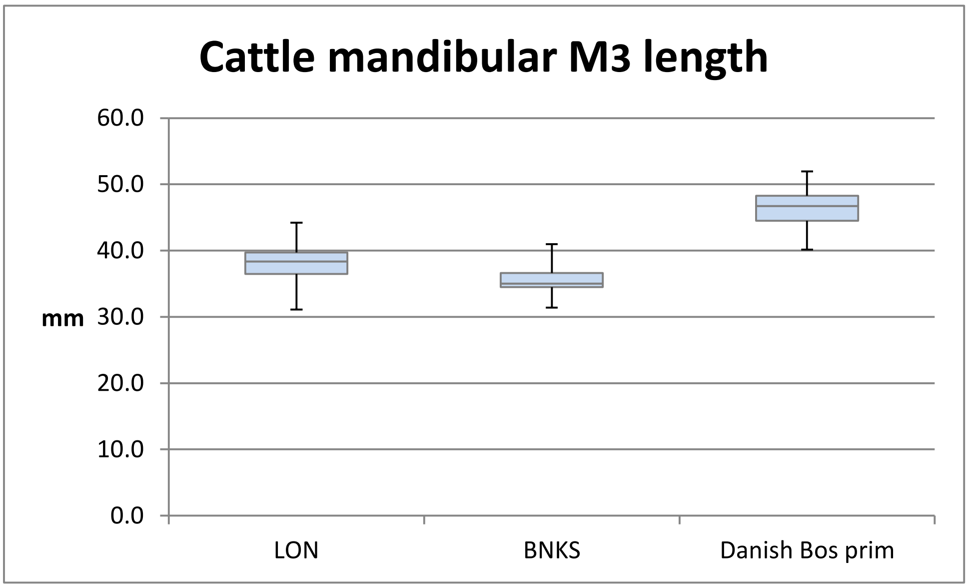
These graphs show the same pattern as the size index scale graphs i.e. cattle bones from the two Orkney Iron Age sites are smaller than those from the two Neolithic sites. The mid-ranges for the Neolithic Orkney and Iron Age sites do not overlap.

Using Students t-test for "GLl" astragalus LON (Neolithic) and Howe (Iron Age) the difference of the mean values of 67.6mm and 58.4mm is significant at greater than 99% confidence levels. Similarly, for "Bd" astragalus measurements from LON and Howe, the difference of mean values of 42.8mm and 36.9mm is also significant at greater than 99% confidence levels. This statistical method of examining data supports the medium/quartile ranges in highlighting diminution of cattle stature between the Neolithic and Iron Age in Orkney.

There were no tooth measurements available from Howe, but comparing the length of deciduous mandibular cattle tooth $dp_4$ from the Late Neolithic settlement, LON, the Mid Neolithic settlement, KOH (Knap of Howar) and the Iron Age site, BNKS (Brest Ness) and the permanent mandibular tooth $M_3$ from LON and BNKS indicates that mandibular tooth lengths also show a reduction between the Neolithic and Iron Age period similar to those of limb bones. It is also noted that the published ranges for aurochs $M_3$ "length at lower half", a non-identical measurement locus from those of LON and BNKS, may indicate that aurochs teeth had a greater length than Neolithic domesticates (Degerbøl and Fredskild, 1970). See *Graphs 62 and 63* and *Appendix 22*.



**Graph 62: Cattle mandibular $dp_4$ length midspread (mm) from three Orkney sites; LON (Links of Noltland Late Neolithic, No 72); KOH (Knap of Howar, Mid Neolithic No 55); BNKS (Brest Ness, Iron Age, No 21). Graph represents median, 25% and 75% quartile values and maximum range**



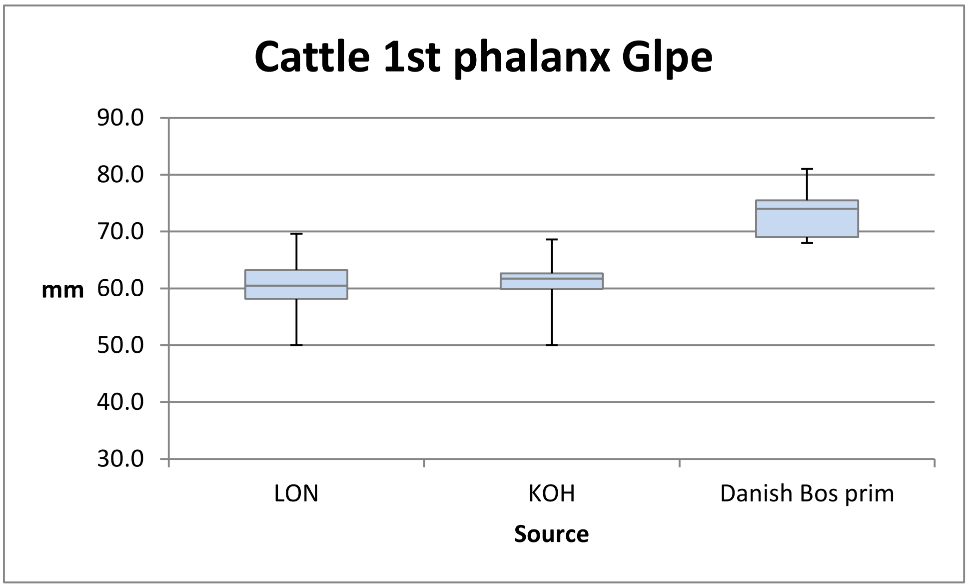
**Graph 63: Cattle mandibular $M_3$ length midspread (mm) from two Orkney sites; LON (Links of Noltland Late Neolithic, No 36); BNKS (Brest Ness, Iron Age, No 10) and published Danish male and female aurochs' $M_3$ "length at lower half" (No 47). Graph represents median, 25% and 75% quartile values and maximum range**

### 9.2.2.3 Published mean/ range measurements for cattle from Orkney Neolithic sites

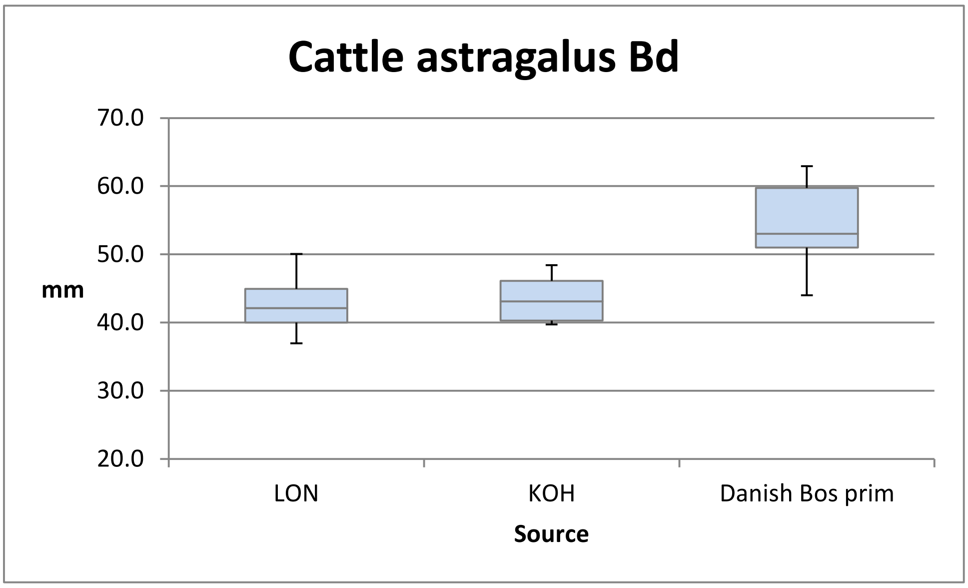
Mean and range of LON cattle bones was calculated to allow comparison with some other Orkney published cattle measurements. See *Appendix 23*. The problem with reporting only mean and range of bone dimensions is that results may not be resistant because values can be affected by outliers or asymmetric distribution (Drennan, 2009, p34). Notwithstanding, this examination demonstrated that cattle astragalus "GLl" measurements from the Neolithic sites of Pool, Sanday, Skara Brae, Mainland and the previous excavation at LON, were consistent with data from LON, whereas results from the Late Bronze Age site of Bay of Skaill, Mainland, were similar to the Iron Age measurements from Howe, Mainland (Armour-Chelu, 1992, p319, Bond, 2007a, p244, table 7.2.8, Nicholson and Davies, 2007, p192, table 6.3.1.16, Noodle, 1997, p242, table 17.4b).

### 9.2.2.4 Comparison with Orkney Neolithic cattle and Danish aurochs

Selected measurements for LON (Late Neolithic) and Knap of Howar (Mid Neolithic) cattle were plotted in order to compare them with published measurements from Danish male and female aurochs (Degerbøl and Fredskild, 1970). The Danish aurochs are larger than the Neolithic cattle with no overlap in the 25-75% quartiles for 1st phalanx GLpe and astragalus GLl and Bd. See *Graphs 64 to 65 and Appendix 24.*

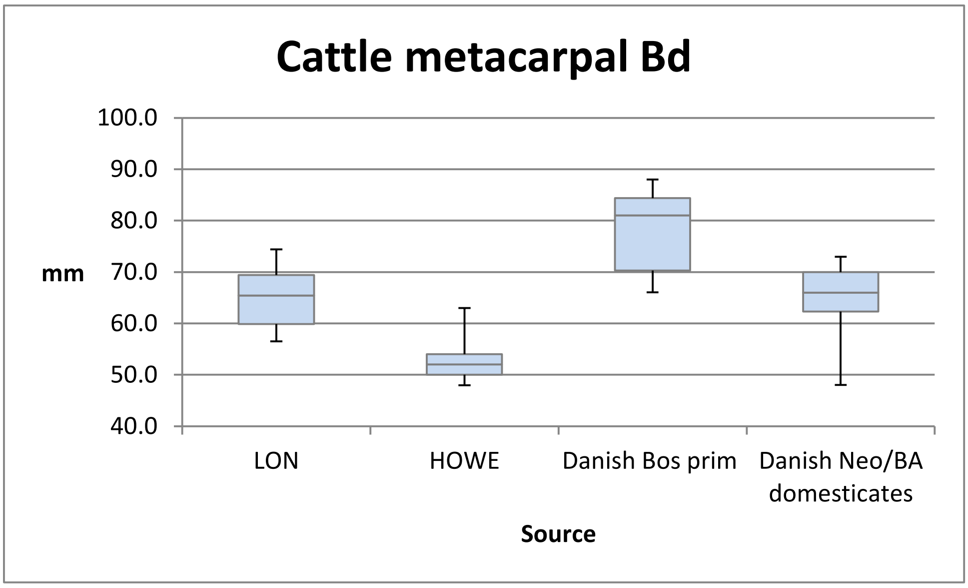


**Graph 64: Cattle 1st phalanx GLpe midspread (mm) from two Neolithic Orkney sites: LON, (Links of Noltland, Late Neolithic, No 36) and KOH (Knap of Howar, Mid Neolithic No 20) and Danish male and female aurochs (No 11). Graph represents median, 25% and 75% quartile values and maximum range**



**Graph 65: Cattle astragalus Bd midspread (mm) from two Neolithic Orkney sites: LON, (Links of Noltland, Late Neolithic, No 39) and KOH (Knap of Howar, Mid Neolithic, No 9) and Danish male and female aurochs (No 78). Graph represents median, 25% and 75% quartile values and maximum range**

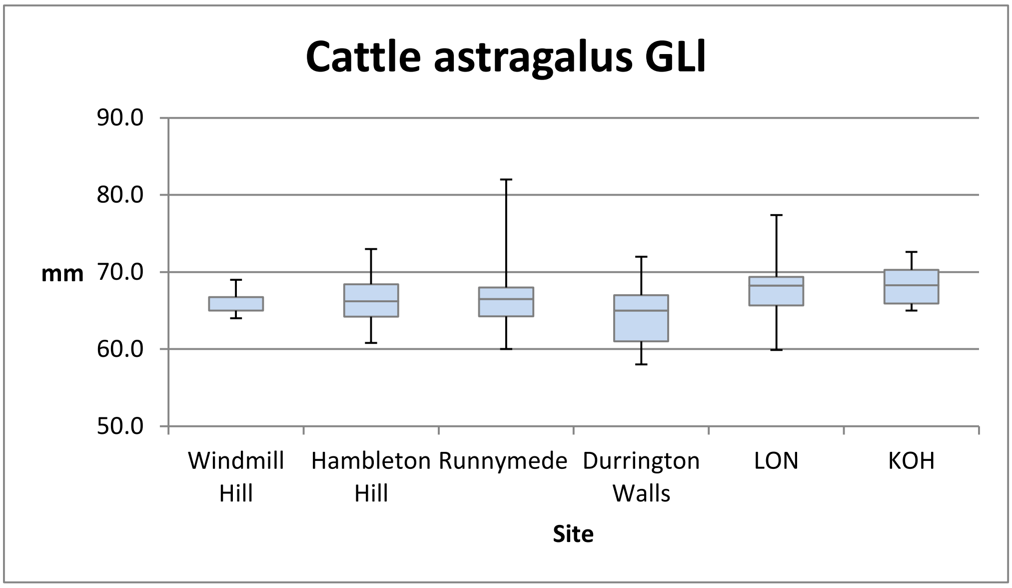
When metacarpal bone “Bd” dimensions are examined, the results again suggest that cattle stature diminished in Orkney between the Neolithic and Iron Age period, and that Danish aurochs measurements were larger than those of LON Neolithic cattle but the range for Orkney and Danish Neolithic domesticated cattle is similar. See *Graph 66.*



**Graph 66: Cattle metacarpal Bd midspread (mm) from two Orkney sites: LON, (Links of Noltland, Late Neolithic, No 25; Howe (Iron Age No,32) and Danish male and female aurochs (No 38) and Danish male and female domesticates (No 23). Graph represents median, 25% and 75% quartile values and maximum range**

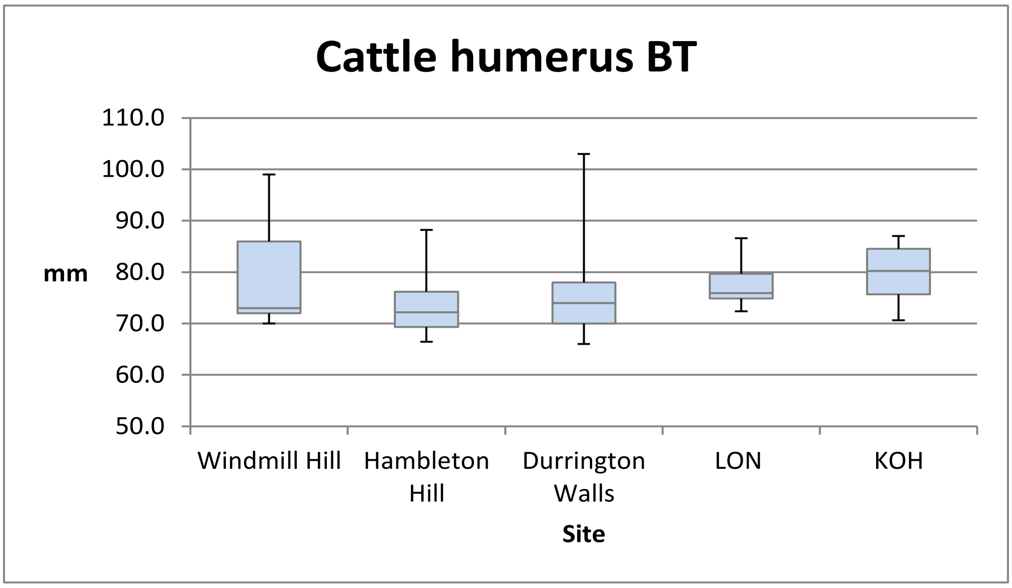
### 9.2.2.5 South of England Neolithic sites

Measurements from Neolithic cattle were also compared with astragalus and humerus measurements from Orkney and southern England sites, measurements that may have been available from cattle that died as juveniles/sub-adults/adults. See *Graphs 67 and 68* and *Appendix 25.*



**Graph 67: Cattle Astragalus GLl midspread (mm) from two Orkney Neolithic sites LON, (Links of Noltland, Late Neolithic, No 36); KOH (Knap of Howar, Mid Neolithic, No 9) and southern English sites of Windmill Hill (No 22, Early Neolithic); Hambleton Hill (No 13, Late Neolithic); Runneymede (No 14); Durrington Walls (no 13, Late Neolithic), sources Cleal et al, 1995,**

**Grigson, 1999, Viner-Daniels, 2014. Graph represents median, 25% and 75% quartile values and maximum range**



**Graph 68: Cattle humerus BT midspread (mm) from two Orkney Neolithic sites LON, (Links of Noltland, Late Neolithic, No 15); KOH (Knap of Howar, Mid Neolithic, No 10) and southern English sites of Windmill Hill (Early Neolithic, No 35); Hambleton Hill (Early Neolithic No 54); Durrington Walls Late Neolithic, No 66), sources Grigson, 1999, Viner-Daniels, 2014. Graph represents median, 25% and 75% quartile values and maximum range**

The two Neolithic Orkney sites astragalus “GLl” measurements were also compared with southern England Early Neolithic Causewayed sites, Windmill Hill and Hambleton Hill, the Mid Neolithic settlement of Runnymede and the Late Neolithic ceremonial site of Durrington Walls. The Orkney sites had higher mediums than the southern English sites but all sites had overlapping mid-ranges.

Although there were only 15 humerus “BT” measurements from LON, and 10 from Knap of Howar, these measurements were also plotted against the two southern English Early Neolithic sites of Windmill Hill and Durrington Walls and the Late Neolithic ceremonial centre of Durrington Walls. As with astragalus “GLl”, the Orkney sites had higher mediums, but overlapping ranges with the all three Neolithic sites from southern England. The co-efficient of variance (V, Sd/mean %) for humerus “BT” for all five sites was:

| | |
|---|---|
| • LON | 5.2 |
| • Knap of Howar | 7.2 |
| • Windmill Hill` | 6.7 |
| • Hambleton Hill | 7.3 |
| • Durrington Walls | 9.0 |

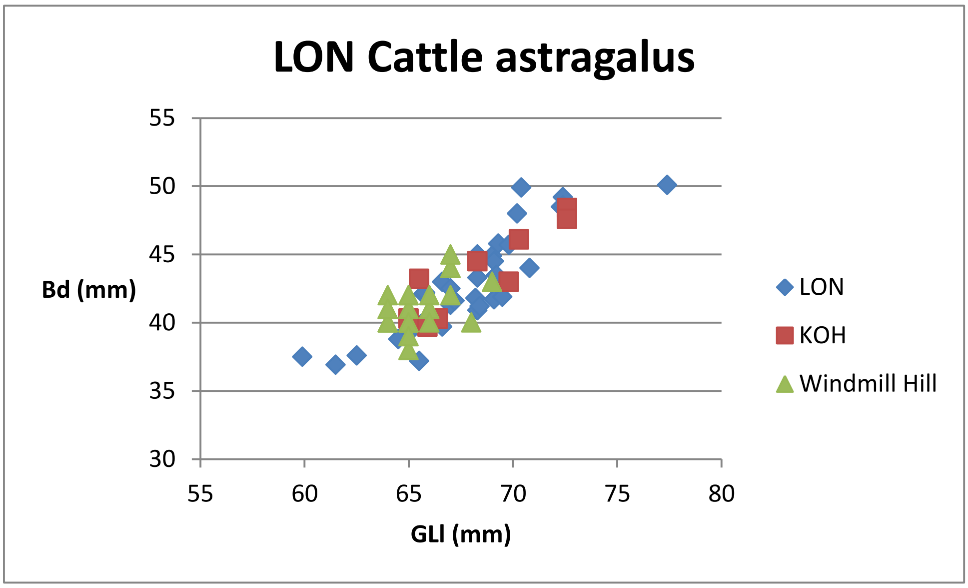
This indicates that, at least in the case for the Late Neolithic site of Durrington Walls, cattle bones from herds of different stature had been excavated since a value of 8.0 or more might indicate two populations were present (Rowley-Conwy et al., 2012).

If a Students t-test calculation is undertaken for the Early Neolithic site at Windmill Hill (Grigson, 1965, table VII, p157) with those from LON, the t-test for "GLl" astragalus (36 and 23 measurements respectively) indicates that the difference between mean values of 67.6mm and 65.5mm is only significant at 80 and 95% confidence levels. For "Bd" astragalus LON and Windmill Hill (39 and 22 measurements respectively) the difference between mean values of 42.8mm and 41.2mm was not significant. *See Table 25.*

**Table 25: Cattle astragalus measurements from two Neolithic sites: LON (Links of Noltland, Orkney, Late Neolithic) and Windmill Hill, Wiltshire (Early Neolithic)**

| Site | Dimension | No of measurements | Mean value (mm) |
|---|---|---|---|
| LON | Astragalus GLl | 36 | 67.8 |
| Windmill Hill | Astragalus GLl | 23 | 65.5 |
| LON | Astragalus Bd | 40 | 42.8 |
| Windmill Hill | Astragalus Bd | 23 | 41.2 |

However if astragalus "GLl" and "Bd" measurements are plotted on a scatter graph it appears that the two Neolithic Orkney sites may have a few values that were higher than those measured from Windmill Hill. See *Graph 69.* Hambleton Hill, which only produced six astragali measurements, had two "GLl/Bd" values that fell within the higher range of this graph (71.5mm*48.2mm and 73.0mm*47.1mm).



**Graph 69: Cattle astragalus plot of length (GLl) against breadth (Bd) (mm) for LON (Links of Noltland, Late-Neolithic); KOH (Knap of Howar, Mid-Neolithic) and Windmill Hill (Early Neolithic)**

### 9.2.3 Co-efficient of variation for LON measurable bones

Cattle bones from LON with more than eight measurements were inspected for V (co-efficient of variation). See *Table 26.*

**Table 26: LON (Links of Noltland) cattle bones inspected for V (co-efficient of variation)**

| Cattle Bone | Dimension | No | Mean | SD | V |
|---|---|---|---|---|---|
| Pelvis | LAR | 9 | 60.1 | 4.8 | 8.0 |
| Humerus | BT | 15 | 77.4 | 4.1 | 5.3 |
| Scapula | GPL | 12 | 67.6 | 4.1 | 6.1 |
| Astragalus | GLl | 36 | 67.8 | 3.5 | 5.2 |
| Astragalus | Bd | 40 | 42.8 | 3.7 | 8.5 |

LON pelvis “LAR” had a V of 8.0, a mean of 60.1mm and one outlier at 69.9mm. Astragalus “Bd” had a V of 8.5, a mean of 42.8mm and one outlier of 50.1mm. The combined astragalus values for this large outlier (GLl*Bd) are within the lowest range of Danish aurochs published by Degerbøl and Fredskild (1970. pp118-119, table 19). Two LON astragalus dimensions exceeded the ranges of domesticated cattle published within the same table (Degerbøl and Fredskild, 1970, pp118-119, table 19).

For smaller samples of LON cattle measurements, simple leaf and stem diagrams were examined for possible higher values. The following observations were made when these LON higher values were compared with tables of Danish aurochs and Neolithic domesticated cattle (Degerbøl and Fredskild, 1970). See *Table 27.*

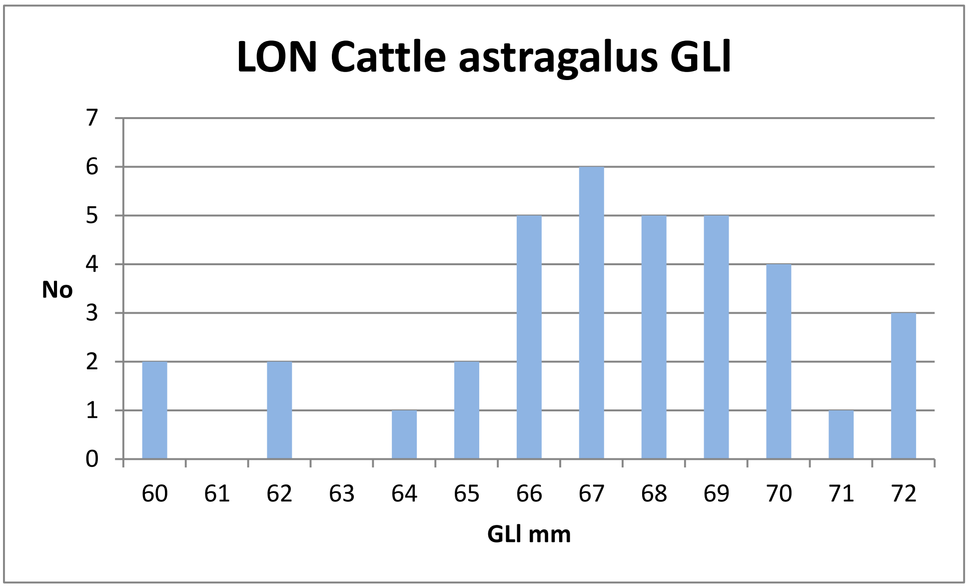
**Table 27: examination of higher cattle bone measurements from LON (Links of Noltland) cattle bones**

| **Cattle bone** | **Dimension** | **High measurement (mm)** | **Comparison with Degerbøl and Fredskild, 1970** |
|---|---|---|---|
| Humerus | BT | 86.6 | *> 2 female aurochs*<br>*≈ domesticated male cattle* |
| Tibia | Bp | 110.3 | *≈ 1 female aurochs*<br>*< 1 domesticated cattle* |
| Os Centrotarsale | GB | 63.0 | *> 1 female aurochs*<br>*> domesticated male cattle* |
| Phalanx 1 | GLpe | 69.6 | *> 1 male aurochs, and 3 female aurochs*<br>*> domesticated male cattle* |
| Phalanx 1 | Bd (*2) | 36.3; 37.1 | *> 5 female aurochs*<br>*> male domesticated cattle* |
| Phalanx 2 | GLpe (*3) | 45.1; 45.1; 47.9 | *> 2 female aurochs*<br>*> male domesticated cattle* |
| Metacarpal | Bd | 74.4 | *> female aurochs*<br>*> male domesticated cattle* |
| Metacarpal | Bd (*3) | 70.3; 70.5; 70.9 | *> 10 female aurochs*<br>*> male domesticated cattle* |

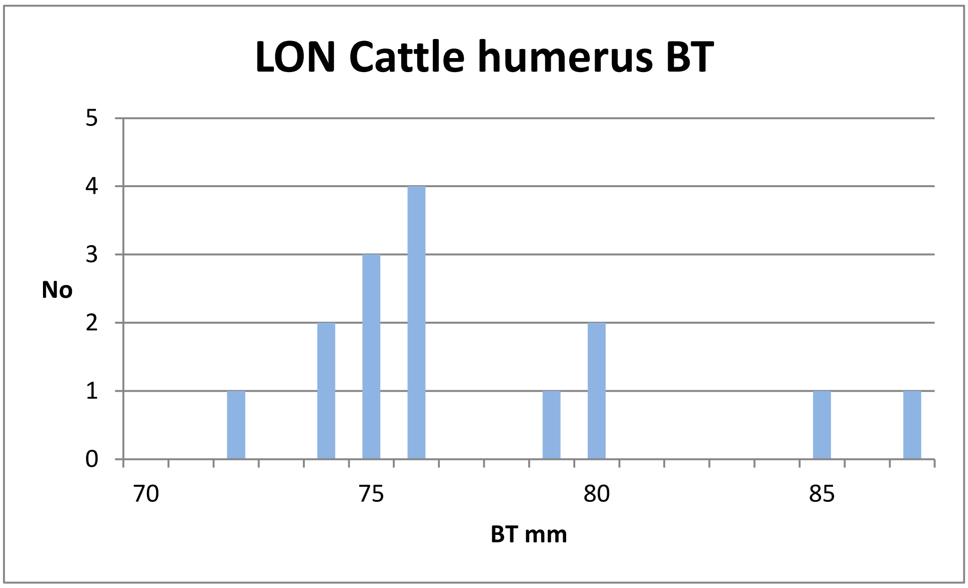
### 9.2.4 Cattle sex ratios

Some LON cattle bone measurements were plotted to examine whether any patterns emerged that might give some guidance on sex distribution of bones sampled. It is noted that different bones may display different levels of sexual dimorphism, with teeth, in particular, unlikely to show clear differences between males and females so were not illustrated in this section.

Distribution bar charts for LON astragalus “GLl” and humerus “BT”, both measurements available from cattle whose “age of death” was in the juvenile/sub-adult/adult categories were produced to determine if there was a clear distinction between two sets of measurements (male and female). If castrates are also present this distinction might have been less pronounced. See *Graphs 70 and 71*.



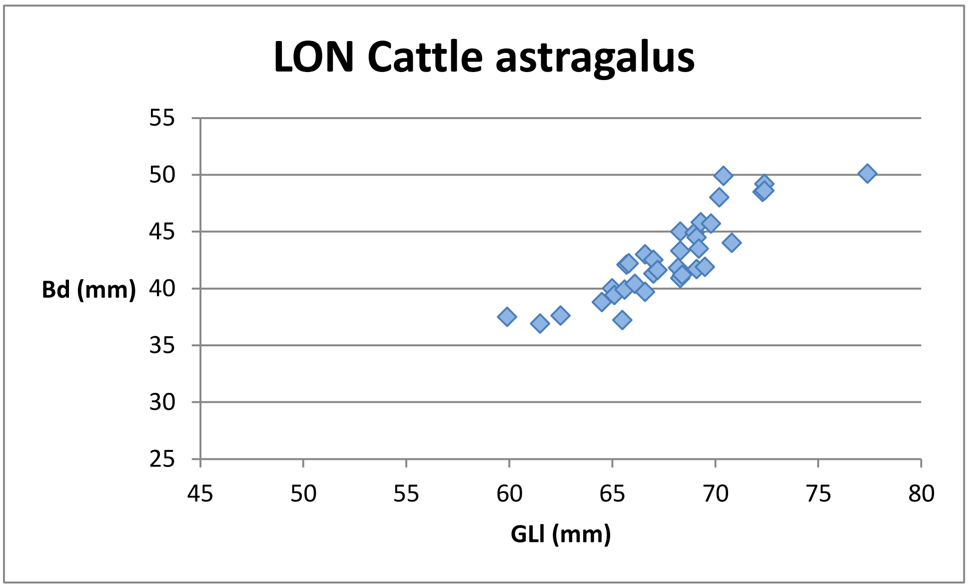
**Graph 70: Distribution of GLl cattle astragalus measurements (mm) at LON (Links of Noltland)**



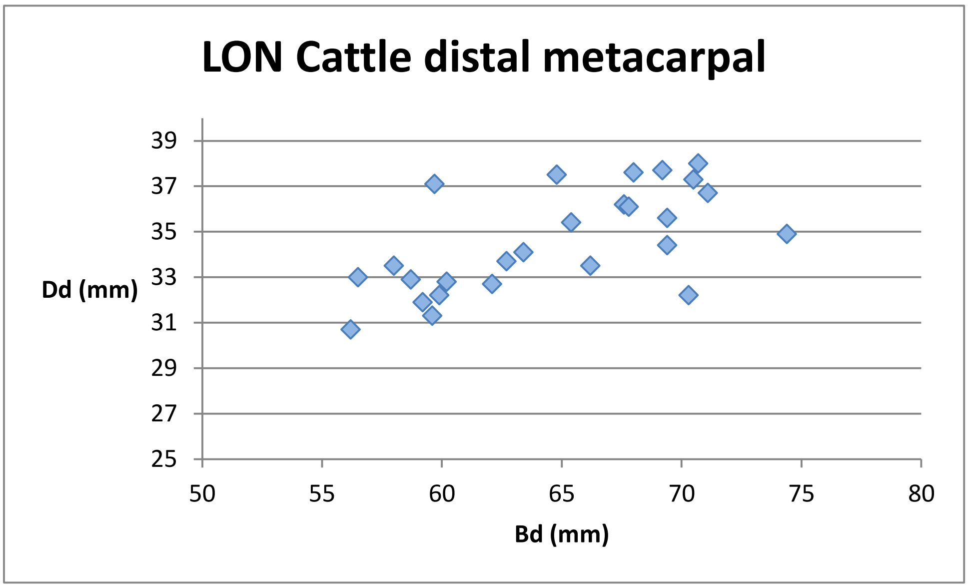
**Graph 71: Distribution of BT cattle humerus measurements (mm) at LON (Links of Noltland)**

The results were inconclusive, but it is possible that the smaller peak of higher measurements could be males/castrates, or from aurochs. It is interesting to note that there are also some lower values since any LON astragali that appeared to be from immature animals were eliminated from this data set. The shape of the humerus "BT" LON graph, based only on 15 measurements, reflects the pattern to the graphs from the Neolithic sites of Windmill Hill, Hambleton Hill and Durrington Walls where the smaller peak of higher measurements was attributed to males (Serjeantson, 2011, p21, table 2.9).

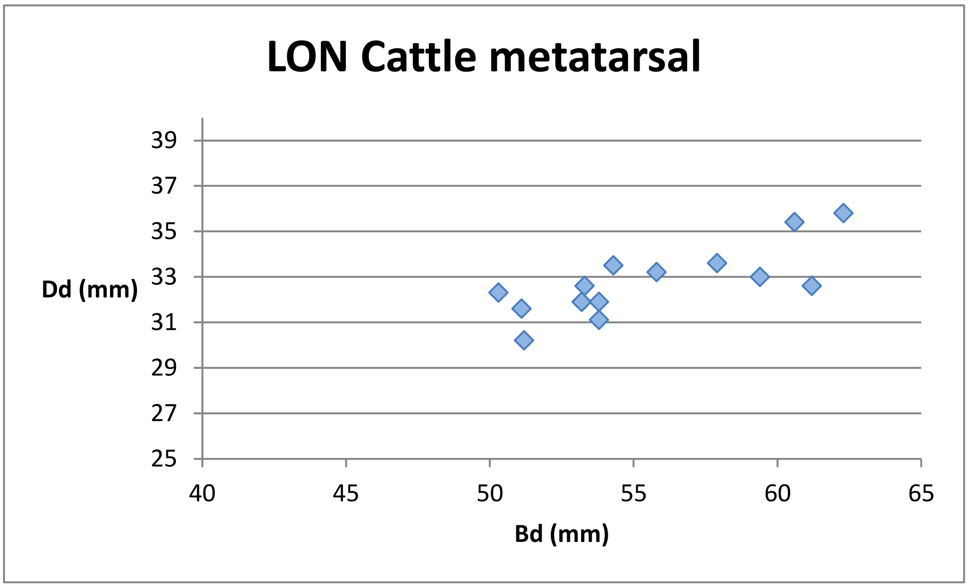
Width and breadth measurements for LON foot bones (astragalus, distal metacarpal and distal metatarsal bones) were plotted on scatter diagrams. The astragalus and distal metatarsal graphs suggest a possible separation with a small number of high values. However, the LON distal metacarpal graph did not show any distinct separation. The astragalus graph reflects cattle that died after the calf stage, but the metapodial graphs only cattle which died in the sub-adult/adult range. A. Legge, a proponent of early dairying in Britain, used seventeen metatarsal bones from the Bronze Age site of Grimes Graves to produce a scatter graph and suggested that the three larger results were from males, indicating that females exceeded male numbers by between 1:4 and I:6 (Legge, 1981, pp172-173, fig 2). At the previous excavation at LON a plot of ten metacarpals was considered to indicate a separation of depth/width analysis into eight cows and two bulls, and for metatarsals a possible separation into five cows and two bulls (Armour-Chelu, 1992, p147). See *Graphs 72 to 74.*



**Graph 72: LON (Links of Noltland, Late Neolithic) cattle astragalus GLl*Bd (mm)**

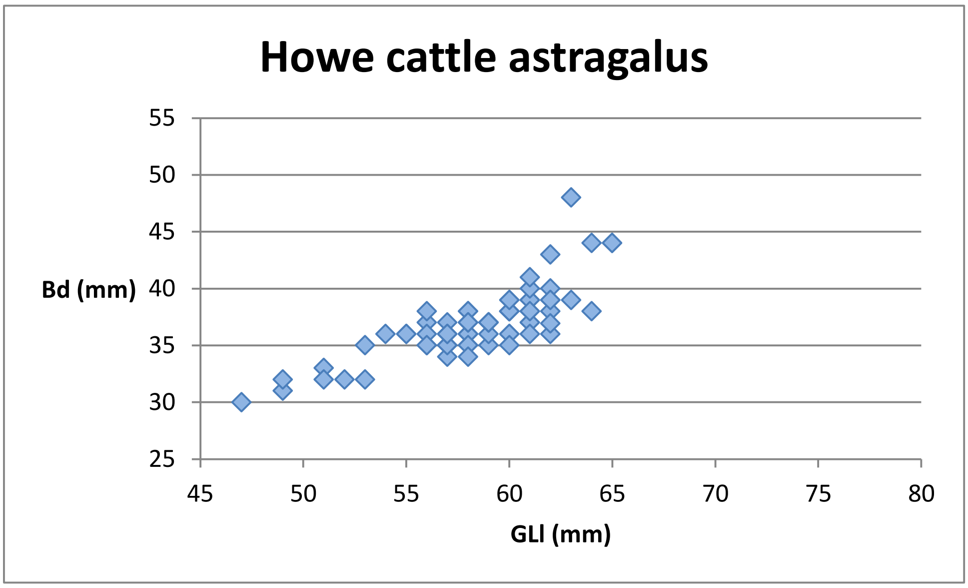


Graph 73: LON (Links of Noltland, Late Neolithic) cattle distal metacarpal Bd*Dd (mm)



Graph 74: LON (Links of Noltland, Late Neolithic) cattle distal metatarsal Bd*Dd (mm)

In addition, the length and breadth measurements for astragalus at the Orkney Iron Age site at Howe were plotted to determine if the distribution was similar or different to those of the Orkney Late Neolithic site of LON. See *Graph 75*.



**Graph 75: Howe (Iron Age) cattle astragalus measurements GLl*Bd (mm)**

In this graph it is possible that the higher dimensions at Howe were associated with males/castrates. The pattern of this graph is similar to that of LON, so, if it reflects the sex composition of animals that died after the calf stage, both periods may have adopted strategies which included the early removal of surplus males.

### 9.2.5 Summary

Cattle in Late Neolithic Orkney were taller and stockier than a early 20th century Shetland cow. There was a clear reduction in the size of cattle, both by width and length dimensions, between the Orkney Late Neolithic and Iron Age periods. The Late Neolithic Orkney cattle were also slightly larger than those from southern English sites, but smaller than most published aurochs dimensions, although some measurements overlap between domesticated males and female aurochs.

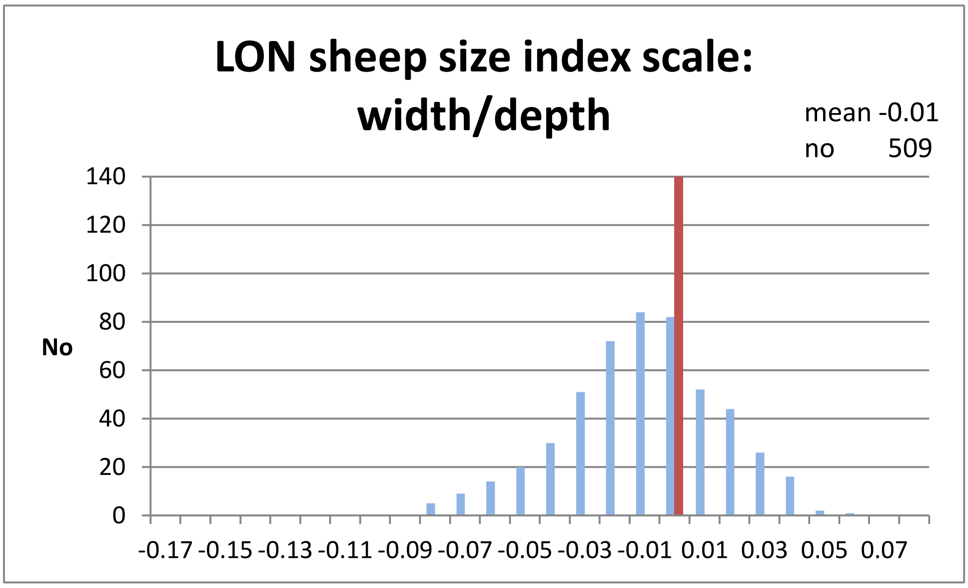
## 9.3 Sheep

### 9.3.1 Size index scale

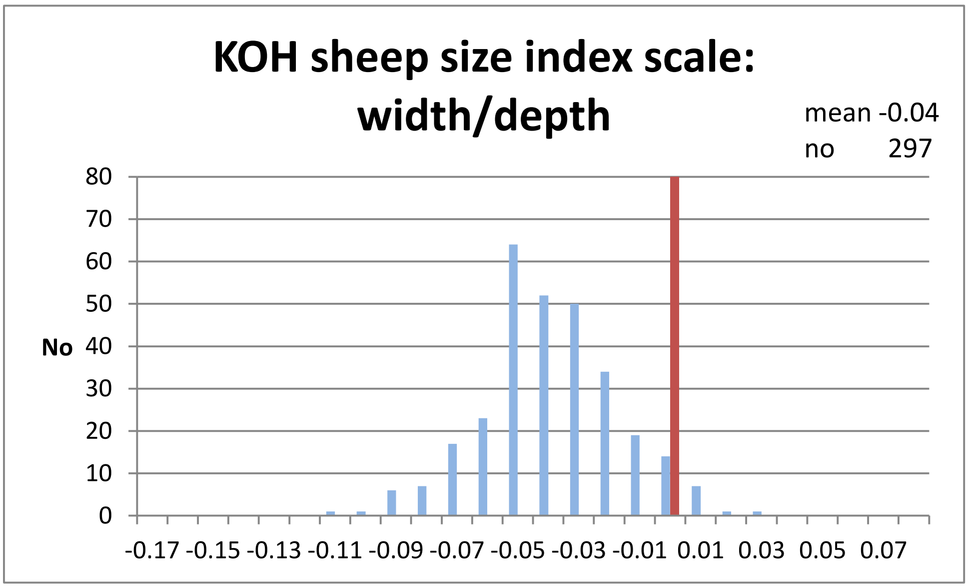
Sheep at LON produced the greatest number of measureable bones. For this study the log ratio used was $\log_{10}$ and the standard was:

- Mean values from 67 unimproved modern Shetland ewes, rams and castrates (Davis, 1996, p596, table 2, Popkin et al., 2012)

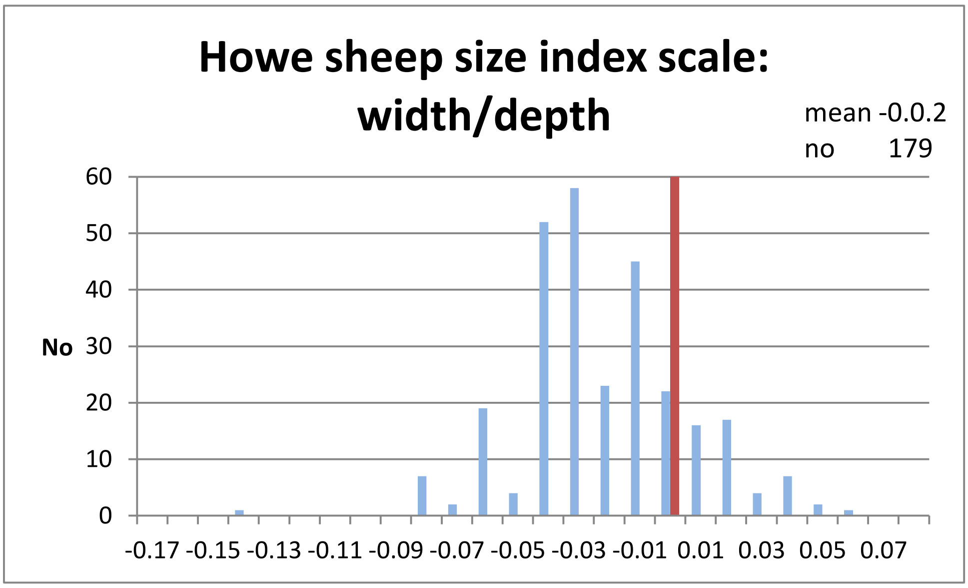
Shetland sheep are considered, along with other breeds such as Soay sheep and North Ronaldsay sheep, to be primitive breeds, relicts of the first migrations and currently confirmed to the periphery of north-west Europe (Chessa et al., 2009, Dýrmundsson and Niżnikowsski, 2009, Ryder, 1983, p47). Shetland sheep have, however been selectively bred for fleeces (Ryder, 1981, p187). Castrates were included in the standard population because it has been suggested that a Late Neolithic sheep skeleton from Raklev Hoje, Zealand, Denmark was a castrate, based on comparison of tooth eruption with epiphyseal fusion of long bones and examination of the horn core (Hatting, 1981, pp134-135). The proportions of rams, castrates and ewes in the standard population may not reflect the sex distribution of the prehistoric flocks in Orkney, and on present evidence Iron Age sheep may have been managed for wool but not Neolithic sheep (Ryder, 1981, p186). Although the horizontal axis labels are consistent for the size index scales, the ranges of the vertical axis reflect the number of measurements obtained. See *Graphs 76 to 83.*



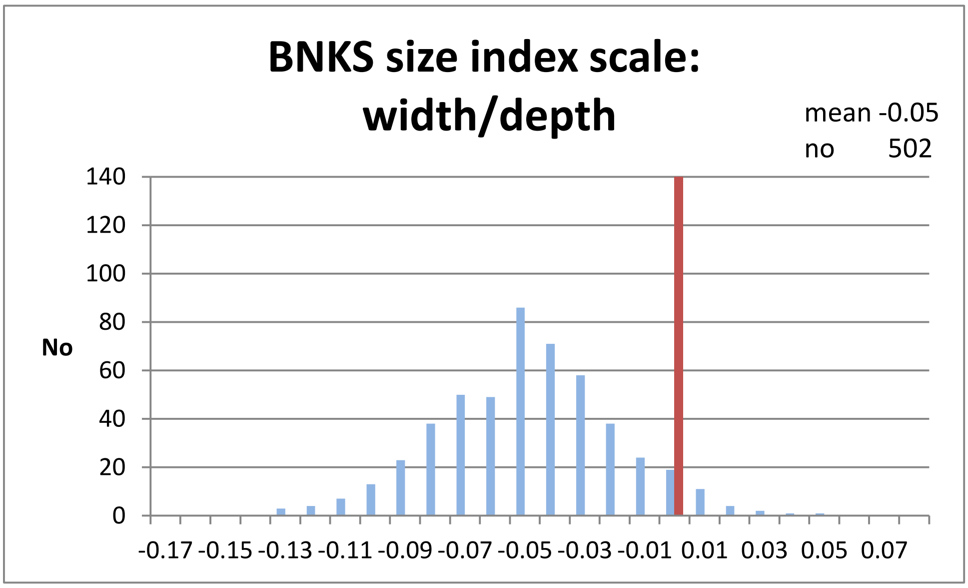
**Graph 76: Sheep size index scale: Shetland sheep population standard: width/depth: LON (Links of Noltland, Late Neolithic)**



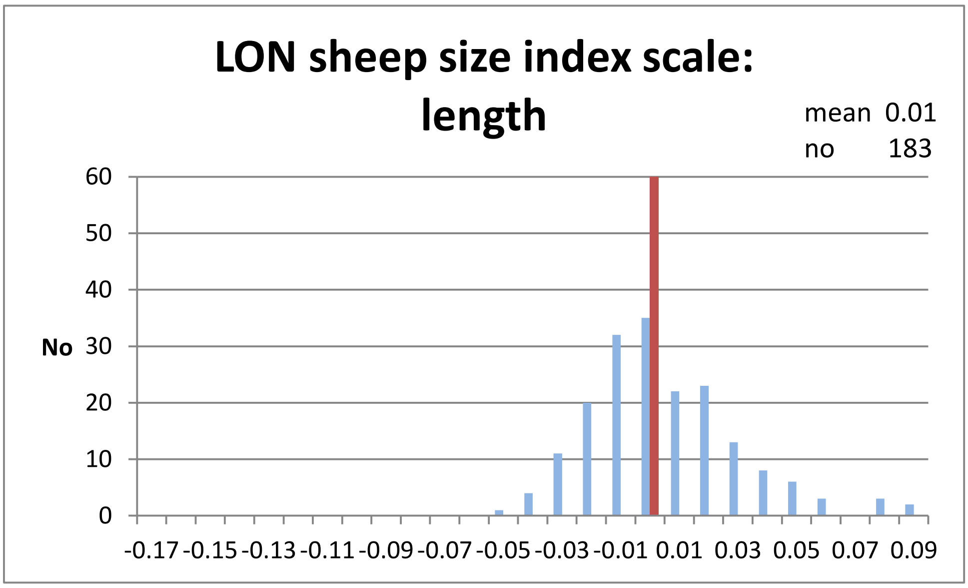
**Graph 77: Sheep size index scale: Shetland sheep population standard: width/depth: KOH (Knap of Howar, Mid Neolithic)**



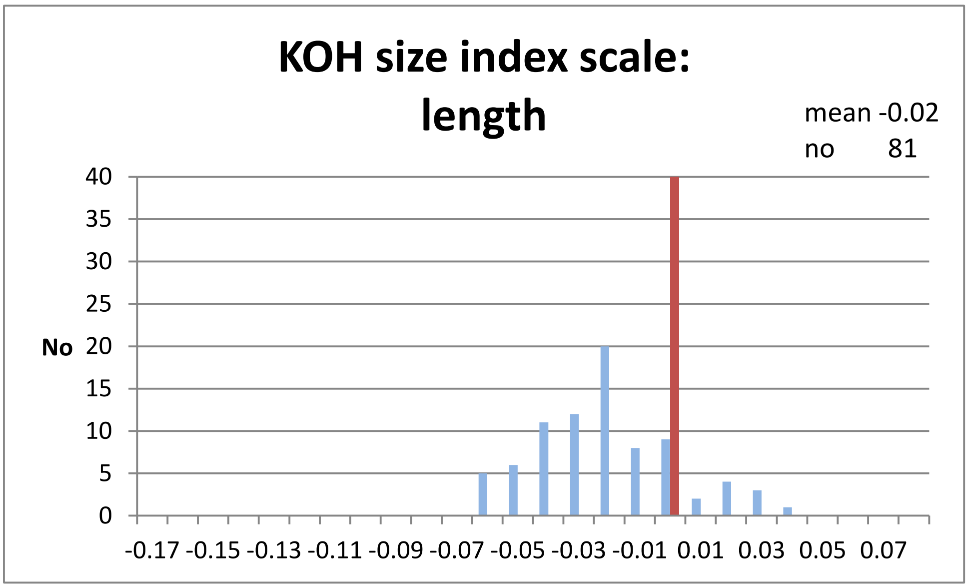
**Graph 78: Sheep size index scale: Shetland sheep population standard: width/depth: Howe (Iron Age)**



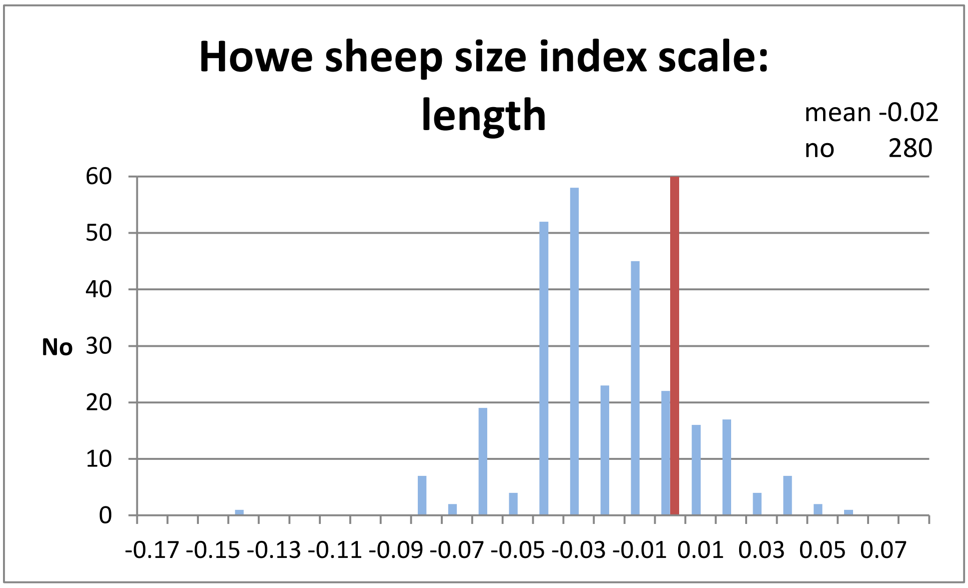
**Graph 79: Sheep size index scale: Shetland sheep population standard: width/depth: BNKS (Brest Ness, Iron Age)**



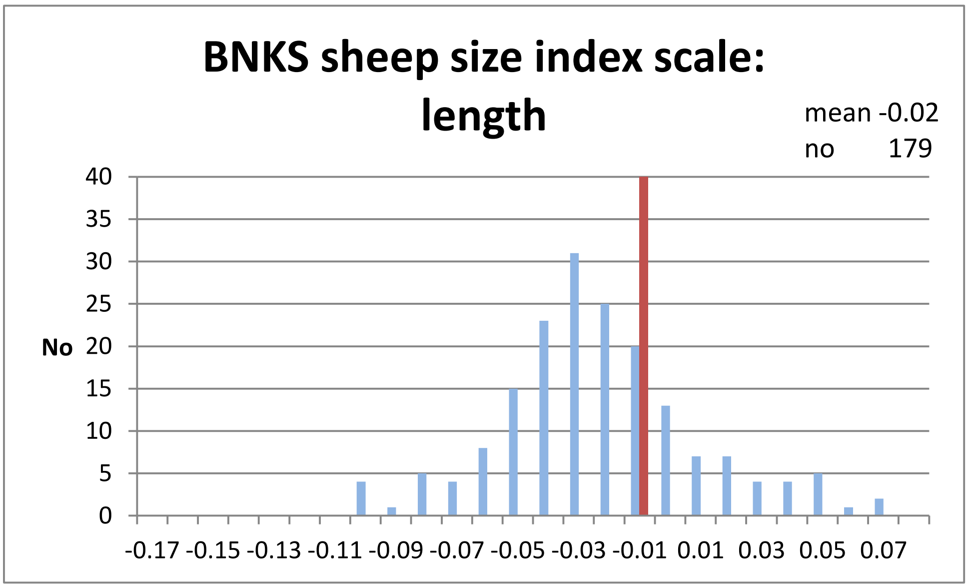
**Graph 80: Sheep size index scale: Shetland sheep population standard: length: LON (Links of Noltland, Late Neolithic)**



**Graph 81: Sheep size index scale: Shetland sheep population standard: length: KOH (Knap of Howar, Mid Neolithic)**



**Graph 82: Sheep size index scale: Shetland sheep population standard: length: Howe (Iron Age)**



**Graph 83: Sheep size index scale: Shetland sheep population standard: length: BNKS (Brest Ness, Iron Age**

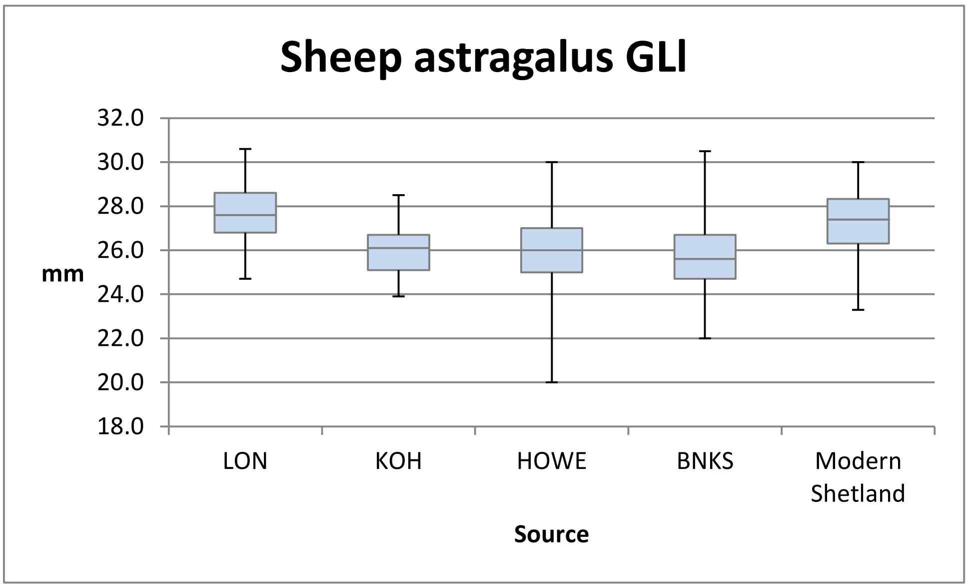
The results indicate that LON sheep bones were of similar dimensions to a modern flock of Shetland sheep, representing males, females and castrates. LON sheep had slightly lower width/depth measurements than the standard and greater length measurements (-0.01 and 0.01 respectively) perhaps indicting a slightly taller but more slender shape. This result aligns with an appraisal of sheep bone dimensions from the earlier LON excavation which states that Soay sheep legs were “relatively and absolutely shorter” than LON radius and metapodial bones (Clutton-Brock et al., 1990, p40).

The LON sheep bone measurements were greater than the two Orkney Iron Age sites, Brest Ness, Westray and Howe, Mainland, and, more surprisingly, also greater than those from the Mid Neolithic site of Knap of Howar.

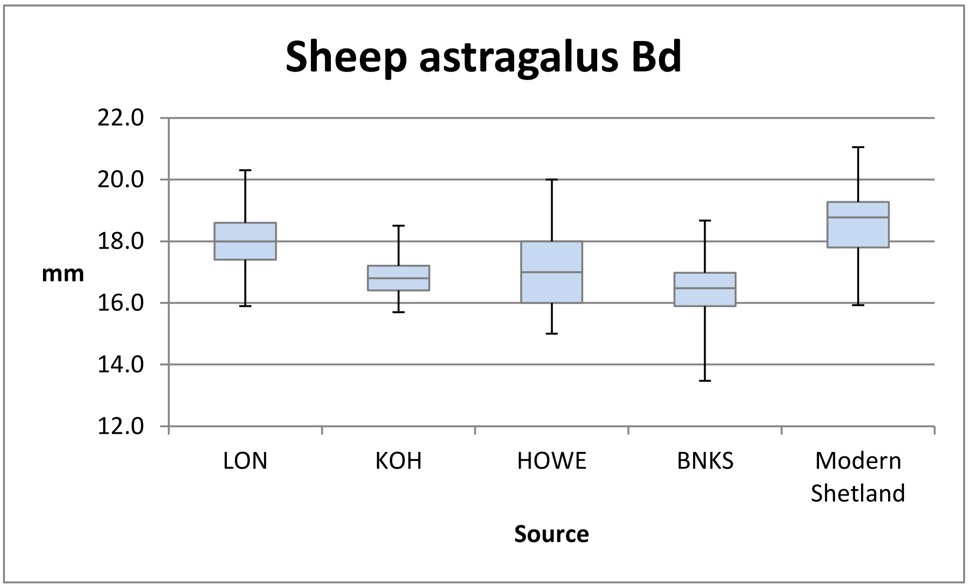
### 9.3.2 Batches of measureable bones

Sheep bones suitable for individual comparisons included astragalus, proximal radius, distal humerus and distal tibia. This sample includes dimensions from both length and width/depth. In the survey of unimproved Shetland sheep it was determined that astragalus was relatively independent of sex, nutritional plane or age (Popkin et al., 2012) making this bone’s dimensions suitable for comparison between sites when this information is unknown.

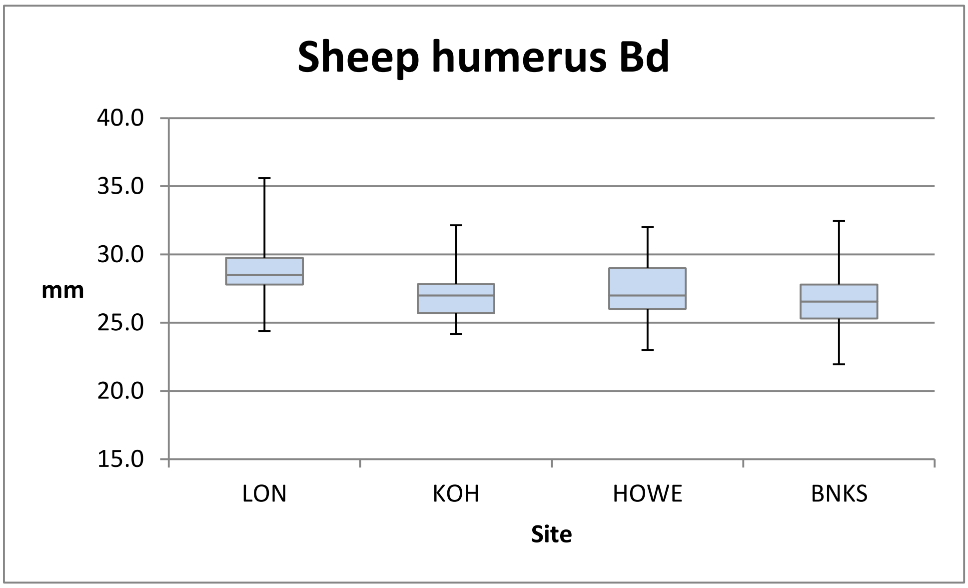
Measurements for sheep astragalus “GLl” and “Bd”, humerus “BT”, radius “Bp” and tibia “Bd” were plotted using box and whisper plots. The sites used for comparison were the Mid Neolithic site of Knap of Howar (KOH) and the Iron Age sites of Brest Ness (BNKS) and Howe. See Graphs *84 to 89 and Appendix 26.*



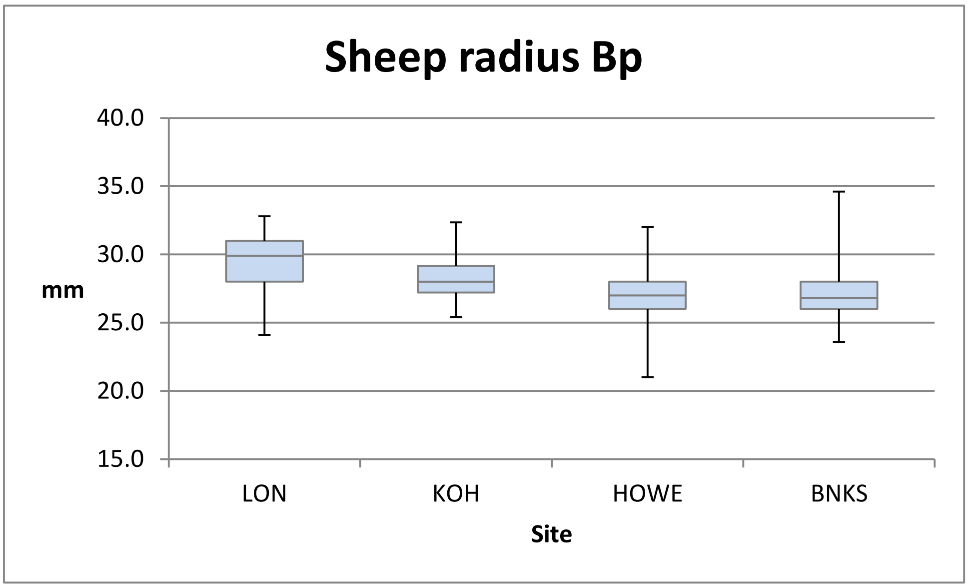
**Graph 84: Sheep astragalus GLl midspread (mm) from four Orkney sites: LON, (Links of Noltland, Late Neolithic, No 148); KOH (Knap of Howar, Mid Neolithic, No 61); Howe (Iron Age, No 163); BNKS (Brest Ness, Iron Age No 67). The modern sheep population values used in the size index scale graphs is also plotted. Graph represents median, 25% and 75% quartile values and maximum range**



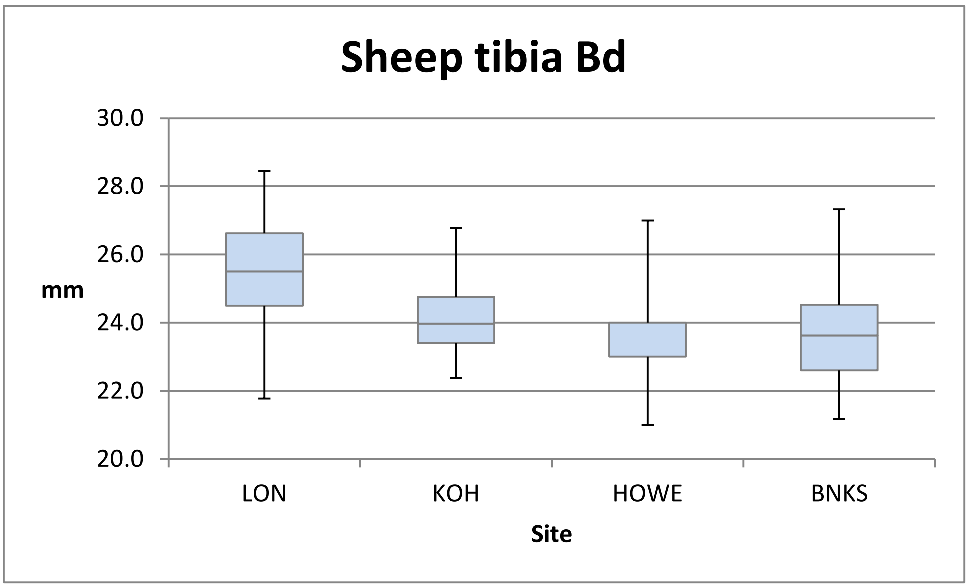
**Graph 85: Sheep astragalus Bd midspread (mm) from four Orkney sites: LON, (Links of Noltland, Late Neolithic, No 152); KOH (Knap of Howar, Mid Neolithic, No 61); Howe (Iron Age No 150); BNKS (Brest Ness, Iron Age No 98). The modern sheep population values used in the size index scale graphs is also plotted. Graph represents median, 25% and 75% quartile values and maximum range**



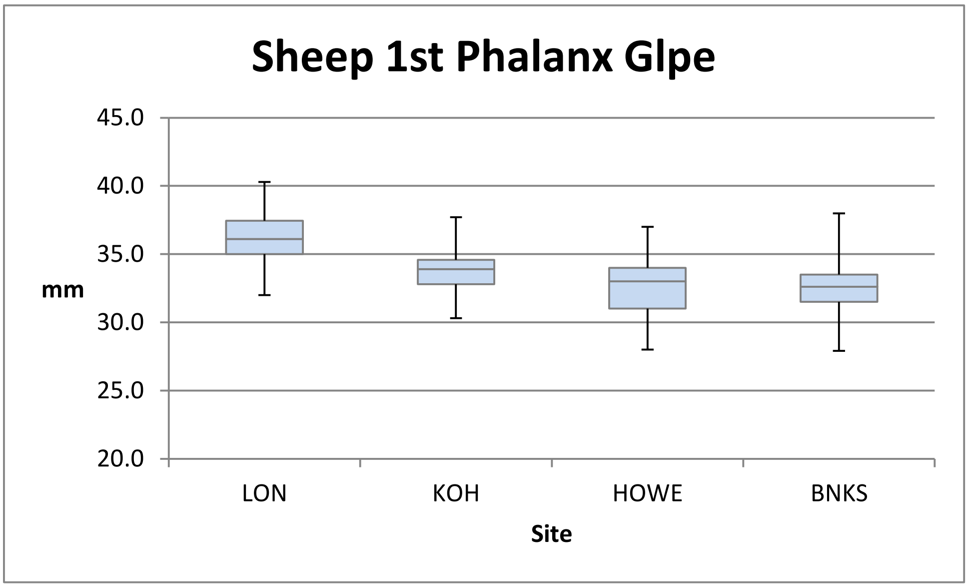
**Graph 86: Sheep humerus Bd midspread (mm) from four Orkney sites (Bd not BT measurement used so that Howe results can be included): LON, (Links of Noltland, Late Neolithic, No 59); KOH (Knap of Howar, Mid Neolithic, No 46); Howe (Iron Age No 106); BNKS (Brest Ness, Iron Age No 87). Graph represents median, 25% and 75% quartile values and maximum range**



**Graph 87: Sheep radius Bp midspread (mm) from four Orkney sites: LON, (Links of Noltland, Late Neolithic, No 152); KOH (Knap of Howar, Mid Neolithic, No 61); Howe (Iron Age No 150); BNKS (Brest Ness, Iron Age No 98). Graph represents median, 25% and 75% quartile values and maximum range**



**Graph 88: Sheep tibia Bd midspread (mm) from four Orkney sites: LON, (Links of Noltland, Late Neolithic, No 26); KOH (Knap of Howar, Mid Neolithic, No 26); Howe (Iron Age No 67); BNKS (Brest Ness, Iron Age, No 42). Graph represents median, 25% and 75% quartile values and maximum range**



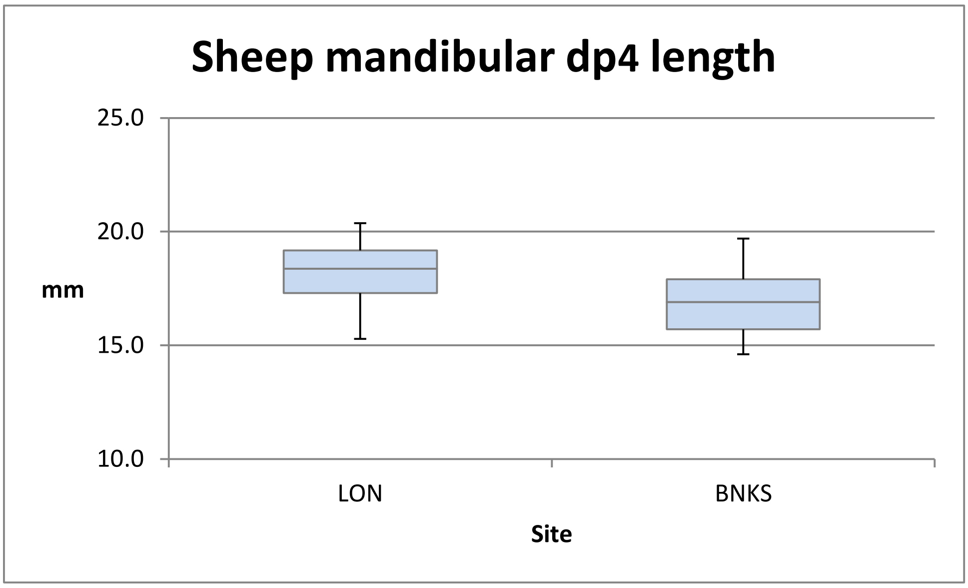
**Graph 89: Sheep 1st Phalanx GLpe midspread (mm) from four Orkney sites: LON, (Links of Noltland, Late Neolithic, No 99); KOH (Knap of Howar, Mid Neolithic, No 48); Howe (Iron Age No 230); BNKS (Brest Ness, Iron Age, No 199). Graph represents median, 25% and 75% quartile values and maximum range**

These graphs show the same pattern as the size index scale graphs i.e. that sheep bones from the two Orkney Iron Age sites are smaller than those from LON, and the Mid Neolithic site of Knap of Howar also has smaller sheep bone dimensions than the Late Neolithic site of LON. It is also of interest that the sheep astragalus “GLl” and radius “Bp” from the two

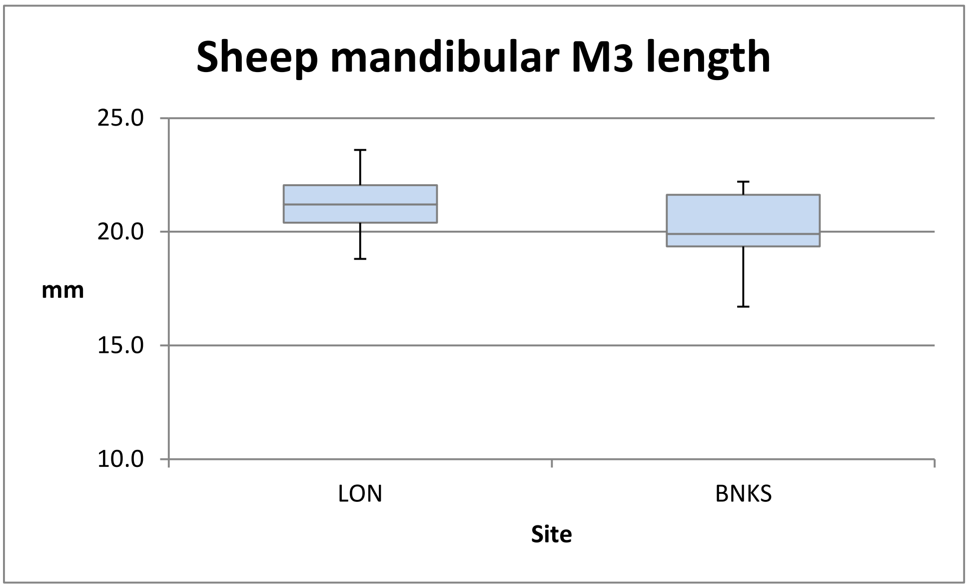
Orkney Iron Age sites, BNKS (Brest Ness) and Howe, although having lower median values than LON, have a greater range between maximum and minimum values, with maximum values being as great as those of LON. This perhaps indicates some variability of sheep stature over the Orkney Iron Age period, and this could be examined further since bones from both sites can be identified to different contexts/dates.

Using Students t-test the difference of the mean values for the dimensions illustrated by the graphs show differences greater than 99% confidence levels. The differences for astragalus "GLl" and "Bd" and humerus "BT" at LON and Knap of Howar noted in the medium/quartile graphs are therefore confirmed by this straightforward statistical test.

Tooth measurements were only available from LON and the Iron Age site of BNKS (Brest Ness) but the length measurements for both the deciduous mandibular tooth $dp_4$ and the mandibular permanent tooth $M_3$ reflect the same pattern of reduction as noted in the limb bones. See *Graphs 90 and 91* and *Appendix 26.*



**Graph 90: Sheep deciduous mandibular tooth $dp_4$ length midspread (mm) from two Orkney sites: LON, (Links of Noltland, Late Neolithic, No 98); BNKS (Brest Ness, Iron Age, No 45). Graph represents median, 25% and 75% quartile values and maximum range**



**Graph 91: Sheep permanent mandibular tooth M3 length midspread (mm) from two Orkney sites: LON, (Links of Noltland, Late Neolithic, No 83); BNKS (Brest Ness, Iron Age, No 14). Graph represents median, 25% and 75% quartile values and maximum range**

### 9.3.3 Published mean and range measurements from other Orkney sites

Comparison with mean and ranges of selected bone dimensions from the previous LON excavation 1979/81 (Armour-Chelu, 1992, Appendix) demonstrate that both excavations appear to have produced sheep bones with a similar range of dimensions. See *Table 28.*

**Table 28: Selected sheep measurements from current LON (Links of Noltland) excavation and D. Clarke's 1979-81 excavation, Armour-Chelu, 1992**

| **LON:LON (previous excavation)** | **Dimension** | **No of samples** | **Range (mm)** | **Mean (mm)** |
|---|---|---|---|---|
| LON | radius Bp | 49 | 24.1-32.8 | 29.6 |
| LON (1979-81) | radius Bp | 60 | 25.4-33.0 | 29.5 |
| LON | astragalus GLl | 148 | 24.7-30.6 | 27.7 |
| LON (1979-81) | astragalus GLl | 91 | 25.0-31.4 | 27.7 |
| LON | astragalus Bd | 150 | 15.9-20.3 | 18.0 |
| LON (1979-81) | astragalus Bd | 91 | 16.2-20.5 | 17.9 |
| LON | tibia Bd | 26 | 21.8-28.4 | 25.5 |
| LON (1979-81) | tibia Bd | 26 | 22.4-28.5 | 24.9 |

The mean and ranges from selected sheep bones from the Neolithic site at Tofts Ness are smaller than those of LON. So, for example the mean astragalus "GLl" from this site is 26.4mm (range 23.3-28.3mm, no 35). This dimension is closer to the result from the Mid

Neolithic site of Knap of Howar which had a mean “GLl” of 26.1mm (range 23.9-28.5mm, no 62).

The mean and range for radius “Bp”, tibia “Bd”, humerus “BT” for Tofts Ness were also smaller than those from LON, and in these cases closer to the dimensions for the Orkney Iron Age sites of BNKS and Howe (Nicholson and Davies , 2007, table 6.3.1.17).

### 9.3.4 Summary

Measurements of sheep bones confirm that LON sheep were of similar stature to modern northern sheep breeds. Stature appears to diminish between the Late Neolithic and Iron Age period in Orkney. Mandibular teeth lengths reflect the same trend of diminution of size. It is of interest that sheep from the Mid Neolithic site of Knap of Howar, Papa Westray, are also smaller than those from LON.

## 9.4 Red deer

### 9.4.1 Size index scale

For this study the log ratio used was $\log_{10}$ and the standard animal for red deer was:

- A modern Islay, Western Isles, red deer (male) Z.2009.30.1, NMS Collection Centre, chosen because it is a Scottish island specimen from a population considered to have been subject to few recent introductions to “improve” the herd.

In addition, post-glacial red deer skeleton (male) dimensions were used in some calculations because they represented the shape of red deer living in forest habitat during the early Holocene:

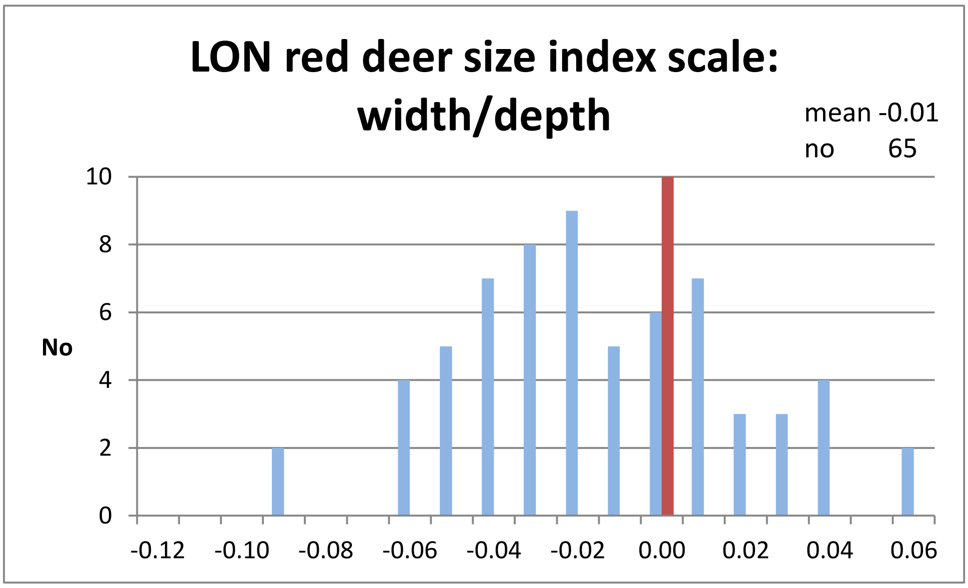
- Red deer (male) Auchterarder, Perthshire, excavated from peat bog by Curator, Dr A. Clarke in 1931, unregistered, NMS Collection Centre (excavation notes stored with skeleton). “The testimony of the marl-mosses and peat bogs is unanimous as to the great size of the Red Deer in past days” (*in Scotland*) (Ritchie, 1920, p335).

The graphs of red deer width/depth and length size index scaling measurements from LON were compared with:

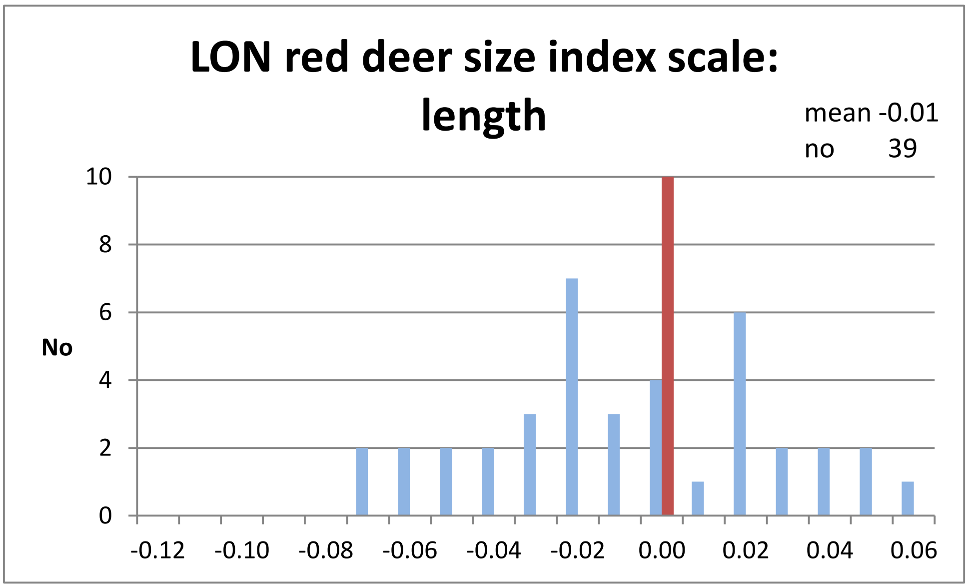
- Mid/Late Neolithic cairn site of Knowe of Yarso associated with large deposits of red deer bones (measured from material held at the NMS Collection Centre)
- Iron Age Howe, Mainland (from C. Smith’s records).

No red deer bones were recovered from the Mid Neolithic settlement of Knap of Howar, but a few published measurements were available from the Late Neolithic site of Skara Brae, Mainland (Noddle, 1982, tables of deer bone dimensions, pp323-333).

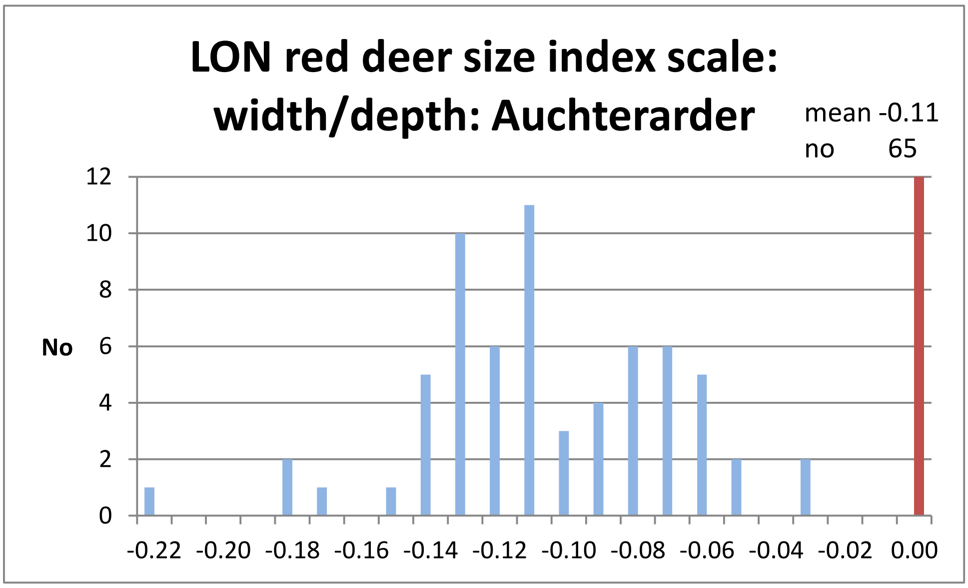
In both the width/depth and length size index scales, LON red deer bones appear to be close to, but slightly smaller than, the Islay red deer male standard. If red deer males and females were present in the LON sample, and the bimodal distribution of results suggests this may be the case, then the modern Islay red deer population may be a reasonable guide to the stature of the LON Neolithic Orkney population. In contrast, when LON red deer bone width/depth and length size index scales are plotted against the Auchterarder post-glacial male red deer standard, all LON values are negative. The $\log_{10}$ negative deviation from the Auchterarder standard for both width/depth and length measurements is consistent, suggesting that the LON red deer retained the same proportions as large post-glacial mainland Scottish red deer, although more diminutive. See *Graphs 92 to 97*.



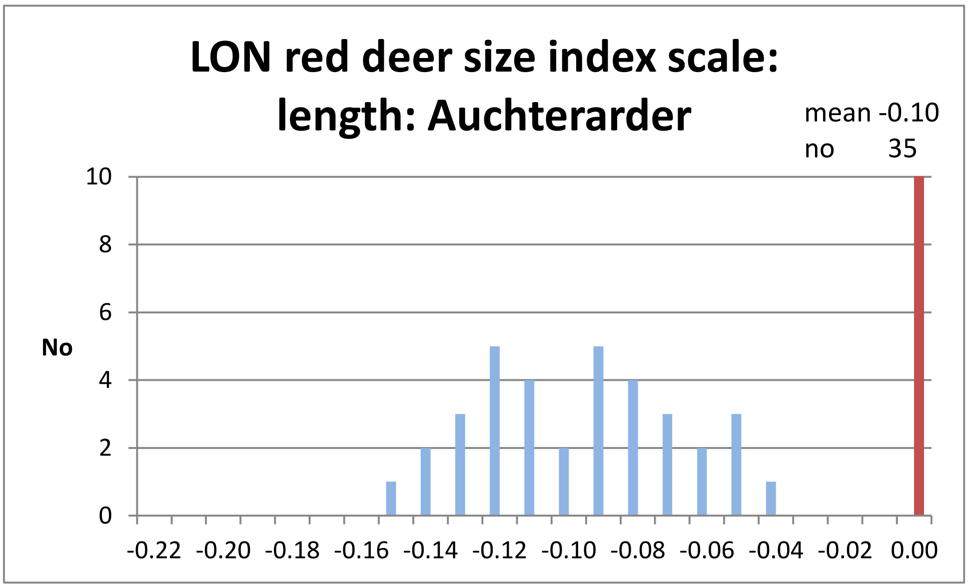
**Graph 92: Red deer size index scale: Islay male red deer standard: width/depth: LON (Links of Noltland, Late Neolithic)**



Graph 93: Red deer size index scale: Islay male red deer: length: LON (Links of Noltland, Late Neolithic)

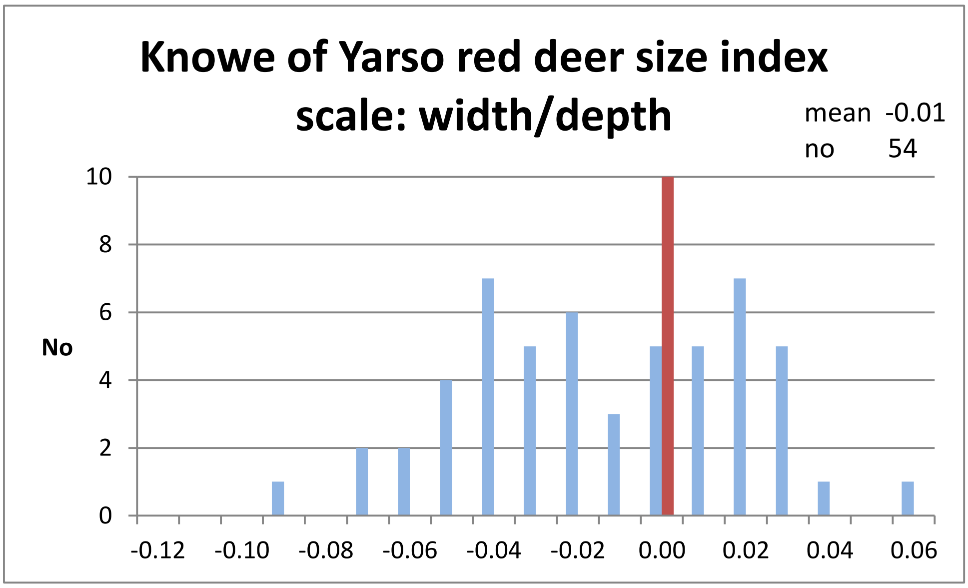


Graph 94: Red deer size index scale: Post-glacial Scottish mainland male red deer, Auchterarder: width/depth: LON (Links of Noltland, Late Neolithic)

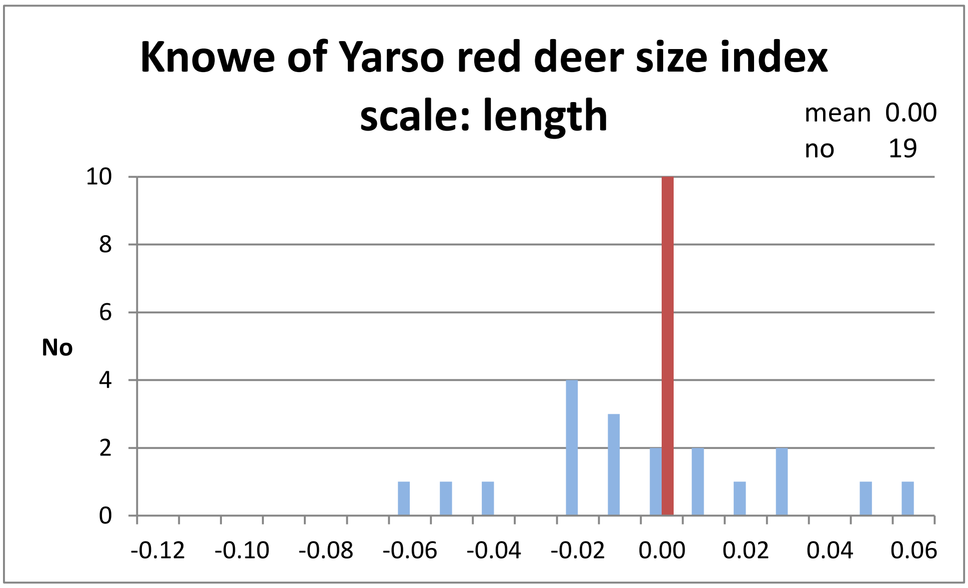


**Graph 95: Red deer size index scale: Post-glacial Scottish mainland male red deer, Auchterarder: length: LON (Links of Noltland, Late Neolithic)**

Measurements for red deer from the Neolithic cairn of Knowe of Yarso, Rousay plotted on size index scale graphs with the same Islay male red deer as standard produced a similar pattern to that of LON.

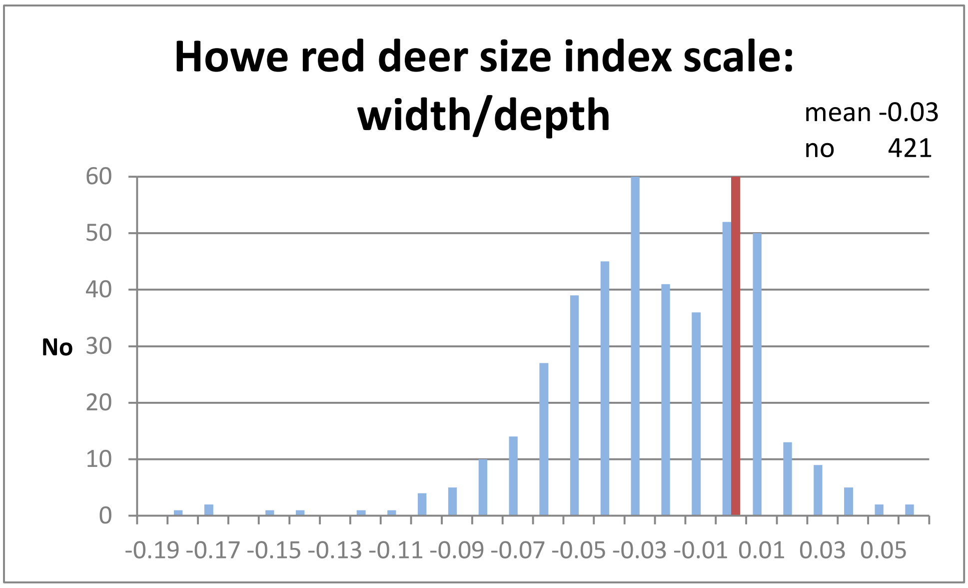


**Graph 96: Red deer size index scale: Islay male red deer standard: width/depth: Knowe of Yarso (Neolithic cairn)**

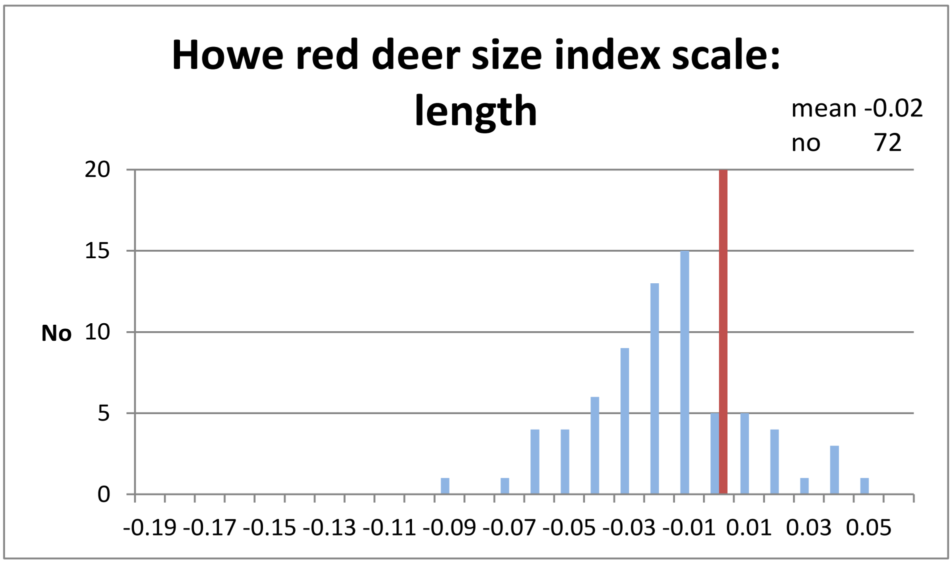


**Graph 97: Red deer size index scale: Islay male red deer standard: length: Knowe of Yarso (Neolithic cairn)**

When red deer bones recovered from the Iron Age site at Howe, Mainland, are plotted against the standard Islay male red deer there is a slight reduction in size compared with results from LON Late Neolithic settlement and Knowe of Yarso Neolithic cairn. See *Graphs 98 to 99.*



**Graph 98: Red deer size index scale: Islay male red deer standard: length: Howe (Iron Age)**

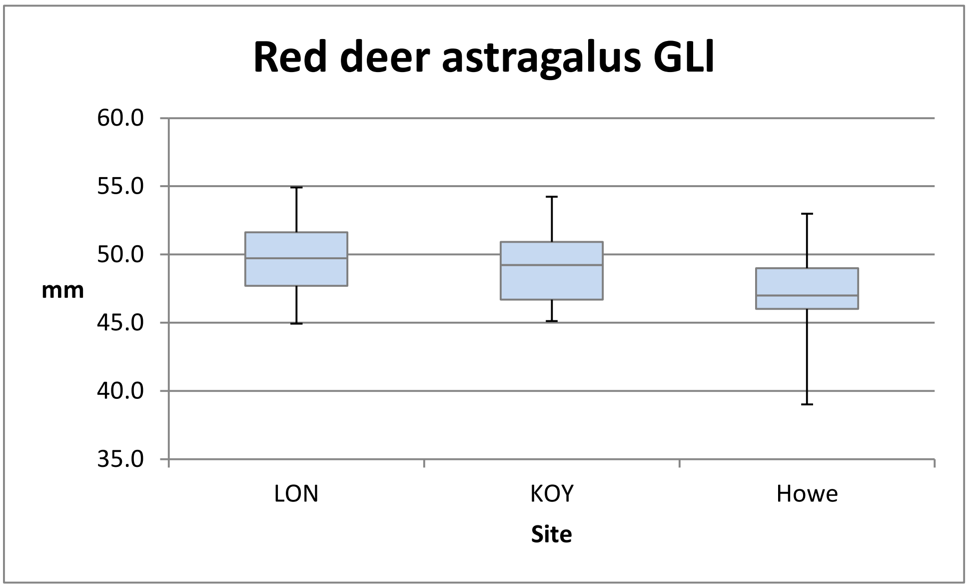


**Graph 99: Red deer size index scale: Islay male red deer standard: length: Howe (Iron Age)**

The results indicate that the majority of red deer on the Orcadian islands of Rousay and Westray were of small stature by the Late Neolithic period. Red deer size is an expression of phenotype, not genotype, with stunting the result of environmental constraints (Clutton-Brock and Albon, 1989, p11, Callander and Mackenzie, 1991). So, for example, offspring of eight Scottish red deer of reduced stature exported to New Zealand in 1870 and grazing on prime grassland were able to attain double the weight of the founding population (Banwell, 1968). There may have been a further reduction in red deer stature between the Neolithic and Iron Age periods.

### 9.4.2 Batches of measureable bones

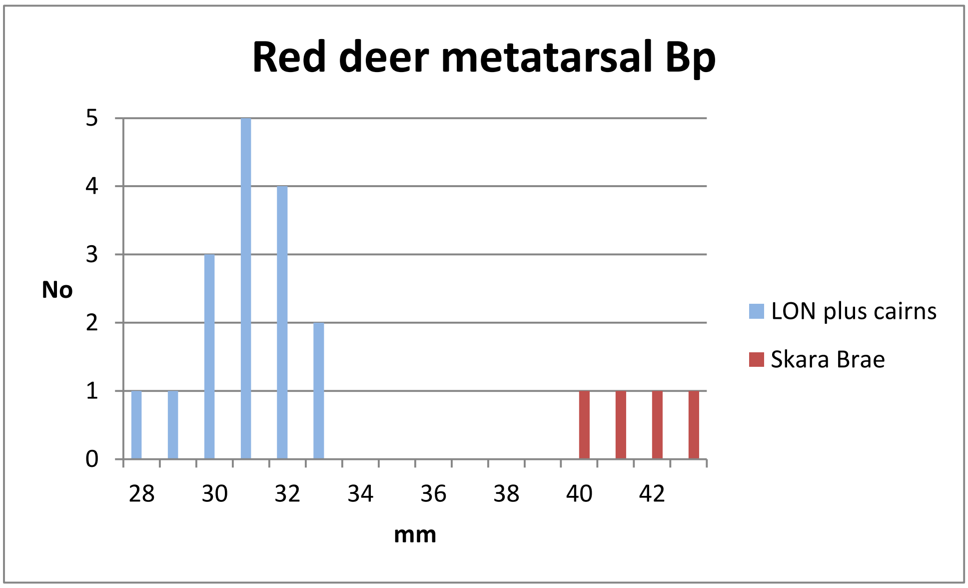
The only red deer bone with a substantial number of measurements from Neolithic and Iron Age Orkney were astragali. If the lengths of astragalus bones “GLl” are plotted, the results also indicate that the red deer from the Iron Age site of Howe, Mainland, are smaller, although there is some overlap in the 25-75% quartile zone. Using the Students t-test, the difference between the values from LON and Howe, Mainland were not significant. See *Graph 100 and Appendix 27.*



**Graph 100: Red deer astragalus GLl (mm): LON (Links of Noltland, Late Neolithic No 20); KOY (Knowe of Yarso, Neolithic, No 10); Howe (Iron Age, No 45). Graph represents median, 25% and 75% quartile values and maximum range**

### 9.4.3 Published mean and range measurements from other Neolithic Orkney sites and the Mesolithic site of Oromsay

The fifteen published measurements for the Late Neolithic site of Skara Brae, Mainland are within a similar range to those of LON except for four larger values from proximal width metatarsal measurements (40, 41, 42 and 43mm) similar in dimensions to that of the post-glacial Scottish mainland male red deer (Auchterarder standard male red deer Bp 42.2mm) (Noodle, 1982). The proximal metatarsal measurements from Skara Brae were compared with the same measurement from LON; D. Clarke's previous excavation at LON; other Orkney cairn sites (measured at the NMS Collection Centre) and all were smaller than the four measurements from Skara Brae. See *Graph 101*.



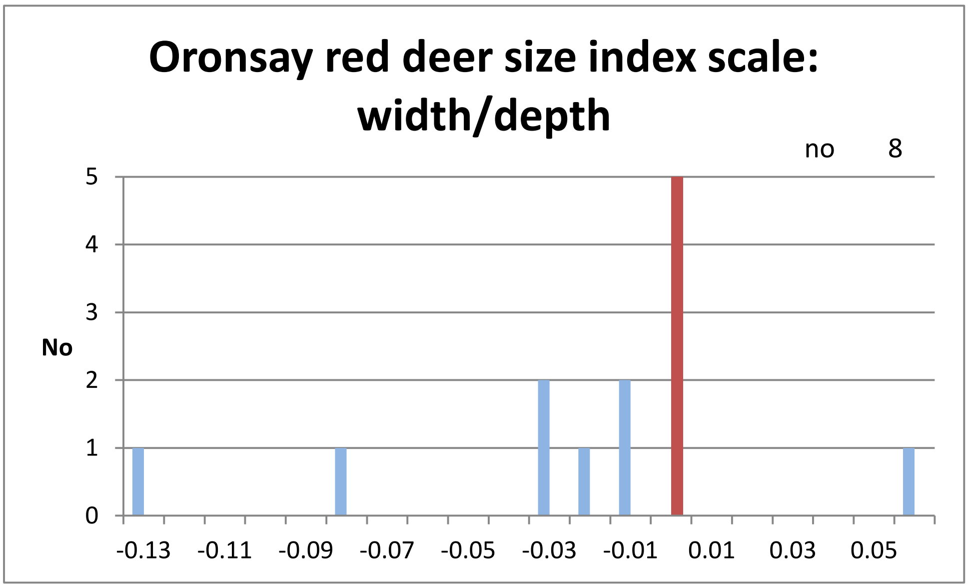
**Graph 101: Red deer metatarsal Bp (mm) results from LON, D. Clarke's LON excavation and cairns vs Skara Brae (Noodle, 1982)**

The results from Skara Brae may indicate that red deer on Mainland, Orkney in the Late Neolithic period were larger than those on Westray and Rousay, but since this observation centres on only one bone dimension, further measurements, which will become available when D. Clarke's Skara Brae report is fully published, should be consulted.

At Knowe of Ramsay Mid/Late Neolithic cairn, based on the rather slender evidence of a proximal rib fragment, it was stated that one red deer bone was "of enormous size, comparable with the large prehistoric deer of the mainland Scotland" (Platt, 1936, p27). An examination of measurements of bones from the Knowe of Ramsay material stored at NMS Collection Centre revealed one large outlier, a distal metacarpal measurement "Bd" of 47.0 (0.09 on size index scale using Islay red deer as standard; Auchterarder red deer "Bd" 46.3mm), so this bone was also an equivalent size to a mainland Scotland deer, and supports the evidence of the proximal rib fragment.

In addition, at the Mid Neolithic cairn of Quanterness, Mainland, although three published red deer width/depth measurements were within the range for LON and Knowe of Yarso, a distal radius Bd of 55.5 mm (0.07 on size index scale using Islay red deer as standard) described as "a much larger deer" was at the top of this range. There are therefore at least three red deer bones from Orkney cairns that may be from full-size red deer, either because they were transported into Orkney as joints, or because some less diminutive red deer were living in Orkney during the Mid Neolithic period.

At the earlier Mesolithic site at Oronsay, Western Isles published results were tabulated using the male Islay red deer measurements as standard and the same selection for width/depth measurements as applied to the LON red deer results. See *Graph 102.*



**Graph 102: Oronsay red deer size index scale: standard Islay male red deer: width/depth (Mesolithic). This graph excludes phalange width/depth measurements in order to remain consistent with the results from LON (Links of Noltland, Late Neolithic)**

The shape of the graph supports the original analysis that there may have been more than one possible source for these red deer, with one smaller than any red deer measured from Neolithic Orkney (Grigson and Mellars, 1987).

### 9.4.4 Summary

Red deer were of similar stature to modern Islay red deer during the Orkney Neolithic and may have declined slightly in stature between the Neolithic and Iron Age period in Orkney but, if so, this diminution is not as marked as those of cattle. Results from a Mesolithic site in Oronsay indicate that red deer "dwarfing" may have occurred at a relatively stage of the Holocene for Scottish island populations.

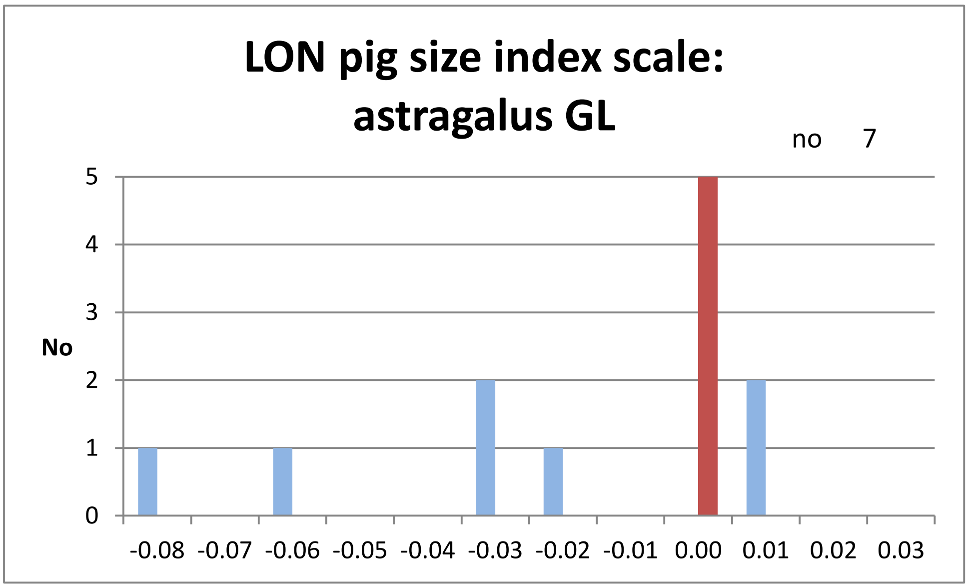
## 9.5 Pig

### 9.5.1 Size index scale

Very few pig bones were recovered from LON. For this study the log ratio used was $\log_{10}$ and the standard pig was:-

- Biometrical database of Late Neolithic pigs, Durrington Wells, Wiltshire (Albarella and Payne, 2005, table 598, table 7).

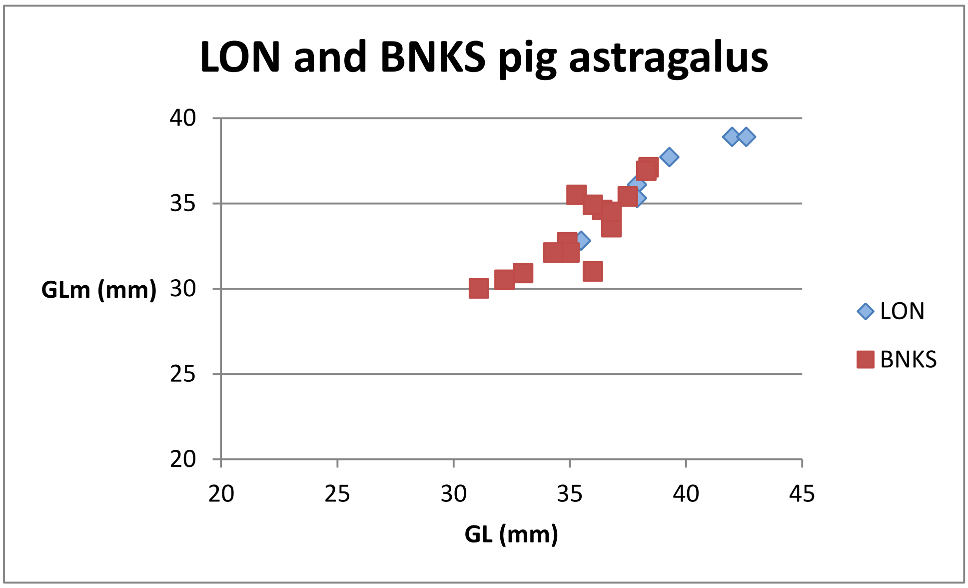
This standard is not from an individual animal but a compilation of a series of measurements from a Late Neolithic southern England site, contemptuous with LON. The only abundant measurable LON bone was the "GL" of astragalus (8 bones). The size index scale ranged around both sides of zero, with one measurement low at -0.08, but it is possible that this astragalus was from a juvenile inadvertently included. See *Graph 103*.



**Graph 103: Pig size index scale: Durrington Walls standard: astragalus GL: LON (Links of Noltland, Late-Neolithic)**

### 9.5.2 Batches of measureable bones

Eighteen pig astragali measured from the Iron Age site at BNKS (Fraser unpublished) so although the samples from BNKS and LON were too small for statistical comparison a scatter plot graph indicates some LON pig astragali were larger than those from the Iron Age site. See *Graph 104.*



**Graph 104: Pig astragalus GLl/GLm (mm) from LON (Links of Noltland, Late Neolithic, no 6) and BNKS (Brest Ness, Iron Age, no 15)**

The LON pig astragali, with a "GL" range at 34- 42.6mm; mean 38.9mm (SD 3.18, V 8.17), do not appear to be out-with ranges of other Orcadian Neolithic or Iron Age sites. So, for example, at the Neolithic site of Pool, Sanday three astragali had a "GL" range of 38.7-40.1mm (mean 39.3mm), all three values lower than the Durrington Walls standard of

40.8mm (Nicholson and Davies, 2007, p194, table 6.3.1.18). Twenty-three pig astragali from the Iron Age site of Bay of Skaill, Mainland had a "GL" range of 28- 43mm (mean 35.3mm) (Noodle, 1997, p243, table 17.6) and the Iron Age site of Howe, Mainland fifty-two pig astragali had a "GL" range of 29- 41mm. *See Table 29.*

**Table 29: : pig astragalus "GL" from Orkney Neolithic and Bronze Age settlement sites; LON (Links of Noltland); Pool, Sanday; Bay of Skaill, Mainland; Howe, Mainland**

| Site | Period | No. pig astragalus | GL range (mm) | Mean (mm) |
|---|---|---|---|---|
| LON | Neolithic | 8 | 34.0-42.6 | 38.9 |
| Pool | Neolithic | 3 | 38.7-40.1 | 39.3 |
| Bay of Skaill | Bronze Age | 23 | 28-43 | 35.3 |
| Howe | Iron Age | 52 | 29-41 | |

LON pig astragalus V (co-efficient of variation) is sufficiently large to suggest two populations may be present. However, in small samples this value may be unduly influenced by individual outliers (Rowley-Conwy et al., 2012, p16). All LON pig astragali measurements fall within the range illustrated for the Mid Neolithic site of Hambleton Hill and the Late Neolithic site of Runneymede in southern England (Viner-Daniels, 2014, p67, fig 3.52).

Mandibular molar $M_3$ length and width measurement are considered variable (Arabella and Payne, 2005). Two of four LON teeth (length 33.6- 38.4 mm, anterior cusp 16.5- 17 mm) were larger than six recovered from the Iron Age site of BNKS (Brest Ness). The one tibia "BdP" recommended as a useful measure (Albarella and Payne, 2005) was 27.5mm at LON, smaller than the "standard" Durrington Walls pigs.

### 9.5.3 Summary

Measurable LON pig bone dimensions do not indicate that pigs were wild boar unless the herd had undergone some level of diminution due to the island habitat. There may have been a slight reduction in stature in Orkney pigs between the Neolithic and the Iron Age but a greater number of measurements would be required to test this statistically.

## 9.6 Overview

Neolithic cattle in Orkney were larger than Iron Age cattle. Some measurements for Neolithic cattle exceed published measurement ranges for domestic cattle or overlap between domestic bulls/aurochs females. LON sheep resemble stature of other primitive north-eastern Europe breeds, but were larger than those from Orkney Iron Age sites, and, perhaps more unexpectantly, larger than those from the Mid Neolithic site of Knap of

Howar. Neolithic red deer have a reduced stature when compared with post-glacial mainland red deer from Scotland, with only three bones from cairns that appear to be from larger animals. Pig bones did not approach the size of wild boar.

# *10 Supporting Analysis*

## 10.1 Cattle mtDNA

### 10.1.1 Introduction

Cattle mtDNA analysis was carried out by A. Schlumbaun, J, Elsner and J. Granado, Integrative Prehistory and Archaeological Sciences, Basel University, funded by Historic Scotland.

Modern cattle mtDNA diversity has been intensively studied (e.g. Troy et al., 2001, Achilli et al., 2008). To date, seven major haplogroups (hg) have been identified, with “T” dominating in taurine and “I” in indicine cattle (zebu). Hg “P”, “Q”, and “R” are very rare in modern cattle; and hg “E” and “C” apparently did not survive in the domestic gene pool. Cattle were first domesticated in the Near East and it seems reasonable that during the subsequent spread throughout Europe, local aurochs would have been sporadically incorporated into the domestic stock, or domesticated stock escaped and formed feral populations, but if so, these events were very rare and thus have left no distinctive traces (Bollongino et al., 2006; Bollongino et al., 2012).

### 10.1.2 Sample

Tooth samples were selected for mtDNA analysis from five skulls from LON foundation course, Structure 9 (ORK 1, *F4257*, ORK 3 *F6693*, ORK 4 *F4462*, ORK 5 *4460*, ORK 6 *4459*), and one associated mandible (ORK 2 *F4917*) plus a distal humerus associated with the skull deposit (ORK 13).

Two cattle distal metatarsal samples from the midden underlying Structure 9 (ORK 15 *F17528* and ORK 16 *F17206*), one proximal cattle radius sample from the midden overlying Structure 9 (ORK 10) and a cattle mandibular tooth from the midden deposit immediately north of Structure 9 (ORK 7 *F8442*) were also analysed for mtDNA. In addition, a maxillary tooth and proximal radius sample from midden in the northern section of the Area 5 (ORK 8 and ORK 9), a distal metatarsal sample from midden in the south-western area (ORK 12), a 1st phalanx from midden in the eastern area (ORK 11) and a 1st phalanx from infill to Structure 8 (ORK 14) were sampled. See *Appendix 28*.

### 10.1.3 Results

Thirteen of sixteen samples yielded reproducible results (81%). Two samples (ORK11, ORK16) had no mtDNA preserved and results from a third (ORK13) could not be confirmed on second extraction. All samples exhibited considerable post mortem damage, particularly deaminations.

Three variations of the most common European domestic cattle hg “T3” were identified from twelve samples:

- ORK4, ORK5, ORK7, ORK9 and ORK15 (haplotype 1)
- ORK1, ORK2, ORK3, ORK12 and ORK14 (haplotype 2)
- ORK8 (haplotype 3)

ORK6 belonged to the most common European aurochs hg “P”

### 10.1.4 Morphology of mtDNA cattle skull samples

Aurochs and domestic cattle both display sexual dimorphism. Female skulls are shorter and narrower and may have less conical horn cores (Degerbøl and Fredskild, 1970, Grigson, 1969, 1975, 1978, 1982, 1999). The horn core of skull ORK 6 *F4459* (hg “P”) may be female. Horn cores from the other four skulls subject to mtDNA analysis were too damaged to determine sex (ORK 1, ORK 3. ORK 4 and ORK5: hg “T3”).

The only available measurements from the five mtDNA skulls were maxillary tooth rows (field measurements) and individual teeth. Cattle maxillary tooth rows are designated “difficult to take” (von den Driesch, 1976, p27). Maxillary tooth row dimensions are not strongly gender related but vary during life, greatest at termination of teeth eruption and comparatively smaller in older animals (Degerbøl and Fredskild 1970, p83, Grigson, 1974, p374, p366, table 4).

Maxillary toothrow lengths from the mtDNA cattle skulls fell below quoted tooth row lengths for aurochs. However *F4459* (ORK 6) the skull with a hg “P” profile had the greatest toothrow length, at 142mm, just below M. Degerbøl’s aurochs range. See *Tables 30 and 31.*

**Table 30: Maxillary tooth row lengths (mm) for LON (Links of Noltland) mtDNA cattle skulls**

| **Find no** | **Toothrow length (mm)** | **Age** | **mtDNA haplogroup** |
|---|---|---|---|
| 4459 | 142 | A | P |
| 4460 | 123 | SA | T3 |
| 6693 | 130 | A | T3 |
| 4462 | 137 | A | T3 |
| 4257/8 | 132 | A | T3 |

**Table 31: Comparative published aurochs maxillary tooth row measurements (mm). M. Degerbøl and B. Fredskild's measurements from Danish aurochs, C. Grigson's measurements from British, Danish and Swedish aurochs and British museum collections of domestic cattle breeds**

| Source | Aurochs (mm) | Domestic cattle (mm) |
|---|---|---|
| Degerbøl and Fredskild 1970 | 143-182 (*no 36*) | 125-149 (*no 18*, Neolithic) |
| Grigson 1974, 1978 | 146-183 (*no 29*) | 109-149 (*no 48*, Museum Collections) |
| Smith 1872 (Scottish) | 152-178 (*no 5*) | |

Few published measurements for individual aurochs or domestic cattle maxillary teeth are available for comparison. However, at the Late Bronze Age site at Irthingborough, Northhamptonshire (barrow 1) remains of 185 cattle skulls and one/two aurochs skulls were recovered. The collection was dominated by loose maxillary teeth and circumferences of their crown bases measured using cotton thread, a measurement considered age-independent. This method was replicated with teeth from LON skulls (Davis 2011, p669 fig SS4.17, Davis and Payne, 1993).

For maxillary 3rd molar teeth ($M^3$) all LON mtDNA tested skulls were within the basal circumference range listed at Irthingborough for domestic cattle and well below the 116mm measurement for an aurochs. As with the toothrow measurement, however, *F4459* (ORK 6) hg "P" had the largest value of the four skulls' $M^3$ that could be measured. For $M^2$, *F4459* (ORK 6) basal circumference measurement was greater than those listed for domestic cattle, but considerably smaller than an aurochs. Other LON $M^2$ teeth from mtDNA-tested skulls lay within domestic cattle measurements. For $M^1$ the *F4459* (ORK 6) basal circumference was slightly greater than those listed for domestic cattle, but 6mm less than aurochs. *See Tables 32 to 35.*

**Table 32: Measurements of maxillary molar teeth basal circumference from Irthingborough (mm) (Davis, 2011)**

| Irthingborough | Domestic cattle (mm) | Aurochs (only one specimen, mm) |
|---|---|---|
| $M^1$ | 73-86 | 99 |
| $M^2$ | 77-94 | 109 |
| $M^3$ | 84-103 | 116 |

**Table 33: Dimensions of left maxillary 1st molar ($M^1$) (mm) from LON cattle skulls ORK 6 (F4459) hg "P" highlighted**

| Find no | Occlusal length (mm) | Occlusal breadth (mm) | Cervical length buccal (mm) | Circ. of base (mm) |
|---|---|---|---|---|
| **4459** | 24.8 | 22.2 | 21.5 | 93 |
| 4460 | 29.0 | 19.8 | 18.4 | |
| 4462 | 26.3 | 18.5 | 18.6 | |
| 6693 | 26.7 | 18.0 | 18.6 | |
| 4257/8 | 24.4 | 21.0 | 18.6 | 83(r) |

**Table 34: Dimensions of left maxillary 2nd molar ($M^2$) (mm) from LON cattle skulls ORK 6 (F4459) hg "P" highlighted**

| Find no | Occlusal length (mm) | Occlusal breadth (mm) | Cervical length buccal (mm) | Circ. of base (mm) |
|---|---|---|---|---|
| **4459** | 30.5 | 24.0 | 24.8 | 96 |
| 4460 | 31.5 | 19.9 | 22.4 | 91 |
| 4462 | 29.9 | 20.4 | 22.7 | |
| 6693 | 31.0 | 19.1 | 22.2 | 93(r) |
| 4257/8 | 28.2 | 21.0 | 23.6 | 89(r) |

**Table 35: Dimensions of left maxillary 3rd molar ($M^3$) (mm) from LON cattle skulls ORK 6 (F4459) hg "P" highlighted**

| Find no | Occlusal length (mm) | Occlusal breadth (mm) | Cervical length buccal (mm) | Circ. of base (mm) |
|---|---|---|---|---|
| **4459** | 31.3 | 23.3 | 29.9 | 101 |
| 4460 | 29.3 | 18.6 | 26.3 | 94 |
| 4462 | 27.1 | 18.3 | 24.3 | |
| 6693 | 28.6 | 18.2 | 24.8 | 93(r) |
| 4257/8 | 28.0 | 18.4 | 27.5 | 93(r) |

ORK6 (*F4459),* mtDNA hg “P”, has greater molar toothrow length and $M^1$, $M^2$, $M^3$ (and $P^4$ and $P^3$) teeth from ORK 6 (*F4459)* and were significantly wider than the maxillary teeth from other skulls. *F4459* and *F4257/8* are the oldest animals from the collection, with lower crown heights, and this may influence these results. However, the widths of the teeth for *F4257/8* (ORK 1), *F4460, F4462,* and *F6693* are similar, regardless of the state of wear, so the additional width in *F4459* may meet Degerbøl’s criteria that aurochs teeth tend to be wider (Degerbøl and Fredskild 1970).

Cattle skull, *F4458*, which was not mtDNA tested, had maxillary molar $M^2$ and $M^3$ basal circumferences that exceeded the range for domestic cattle at Irthingborough. Additionally *F 6718*, a skull with maxillary tooth alveoli, but no teeth, had a molar tooth row of approximately 170mm (field measurement) and an estimated condylobasal length greater of 550mm.

### 10.1.5 Radiocarbon dates for MtDNA cattle

Radiocarbon dates confirm that all cattle bones sampled were from the Late Neolithic period. See *Appendix 2.* These will be subject to future Bayesian analysis of dates. Four cattle skull deposits, F6693, 4462, 4460, 4459, a group that includes the skull carrying a hg "P" have a range of 2916-2678 cal BC. One skull, however, has a range of 2578-2349 cal BC and this will be re-measured to verify this date, since this skull was clearly lying within the foundation course. An ashy floor deposit from Structure 9 has a date range of 2577-2348 cal BC, perhaps towards the end of the structure's use which leaves the intriguing question whether this skull was deposited at the closure of the structure.

### 10.1.6 Overview

mtDNA analysis of five cattle skulls from foundation course, Structure 9 and eight other cattle post-cranial bones or teeth demonstrates that the main European haplogroup for European domesticated cattle hg "T" is present in twelve samples, but that three distinct haplotypes are present, perhaps indicating more than one introduction of domestic cattle into Orkney during the Neolithic period. One cattle skull carried the aurochs hg"P" profile.

## 10.2 Isotopes

### 10.2.1 Introduction

LON $\delta^{13}C$ and $\delta^{15}N$ isotope results were obtained from sixteen bone collagen and eight tooth collagen samples, generated from radiocarbon dating. Although not specifically targeted for palaeodietary analysis these isotope determinations were made from bone collagen and suitable for discussion, although duplicate results are not available. All LON samples, except one, were within the C/N ratio range of 2.9-3.6, indicating bone collagen sufficiently well preserved for isotope analysis (DeNiro, 1985). The LON ratio was also within the more stringent range of 3.1-3.4 set for isotopic determinations from Neolithic causewayed enclosure deposits (Hamilton and Hedges, 2011, p672) or the 3.0-3.4 ratio set for the study of aurochs and cattle from Neolithic and Bronze Age sites in England (Lynch et al., 2008, p1026).

Examination of $\delta^{13}C$ and $\delta^{15}N$ isotopes in bone collagen may give insight into vegetation consumed by LON herbivores, and indirectly, their selection of food plants and habitats. Isotope results reflect averaged diet since turn-over is approximately ten years in bone collagen and absent in tooth collagen (Hedges et al., 2007, Hamilton and Hedges, 2011, p671, Von den Merwe and Vogel, 1978, p815) and may be influenced by inter-individual variation caused by growth, lactation, disease and genes, so examining large data sets is preferable to examination of individual results (Hamilton and Hedges, 2011, p671).

A particular issue with isotope analysis is that younger individuals still consuming their mother's milk will have values one trophic level above the mother, since the level of $^{13}$C is enhanced with each upwards step in a food chain (Balasse and Tresset, 2009, p77). However none of the bones examined from LON were from neonatal or juvenile animals.

The $\delta^{13}$C is a measure of relative abundance of stable isotopes $^{12}$C and the rarer, heavier $^{13}$C. In plants, $\delta^{13}$C values can vary significantly depending on whether there is a $C_3$ or $C_4$ photosynthetic pathway, not a consideration for the current analysis since $C_4$ plants were absent in Neolithic Britain (Hamilton and Hedges, 2011, p670, Montgomery et al., 2013 p1064). $C_3$ plants have an average $\delta^{13}$C value of -27.1‰, a lower ratio than the atmosphere, because transpiration and photosynthesis processes discriminate in favour of the lighter $^{12}$C fraction in $CO_2$ (Sealy, 2001, p270, Tieszen, 1991, p227, p229). M. Balasse calculates a slighter higher $\delta^{13}$C level for vegetation in Orkney by assuming a value of -27.1‰ for modern $C_3$ plants and adding the impact of burning fossil fuels, arriving at an estimated ratio of pre-industrial $C_3$ plants of -25.6‰ (Balasse et al., 2006, p3). Enrichment of 5‰ is assumed for herbivores grazing on $C_3$ plants, the first trophic level in the food-web (Noe-Nygaard, 1995 p863, Pollard and Wilson, 2001, p196, Sealy, 2001 p271).

Calculation of $\delta^{13}$C enhancement can be influenced by environmental factors. For example, $C_3$ plants in more shaded environments may have lower $\delta^{13}$C values than plants growing in open areas, even from the same species (Drucker et al., 2003, Francey and Farquhar, 1982, Hamilton and Hedges 2011, p270, Noe-Nygaard, 1995 p863, Tieszen, 1991 p230). Also plants growing in water-rich conditions such as freshwater marshes and river margins have a faster uptake of $CO_{2,}$ apparently through greater stomatal conductance, allowing greater discrimination against $^{13}$C and consequently lower $\delta^{13}$C values (Lynch et al., 2008, p1032). Conversely, plants grown in water stress or arid conditions may have enhanced $\delta^{13}$C values because large vapour deficits decrease $CO_2$ in leaf intercellular spaces relative to atmospheric $CO_2$ and increase $\delta^{13}$C values in the plant (Francey and Farquhar, 1982, Heaton, 1999, p638, Lynch et al., 2008, p1032, Tieszen, 1991, p230). $\delta^{13}$C values may also increase in more saline soil due to stomatal closure in non-halophytic (salt intolerant) plants (Heaton, 1999, p638).

Marine plants have enriched $^{13}C$ values when compared with terrestrial plants and hence higher $\delta^{13}C$ values (Montgomery et al., 2013, p1063). Terrestrial plants use atmospheric $CO_2$ for photosynthesis; macro algae procure inorganic carbon in the form of HCO3- and/or $CO_2$ (Balasse et al., 2006, p1). In North Ronaldsay, Orkney sheep restricted to seashore feeding areas consume a variety of brown, red and green macro-algae (micro-algae $\delta^{13}C$ values between -18.5‰ to -13.1 ‰, significantly higher than the value for $C_3$ terrestrial plants) (Balasse, 2005 et al., p284, table 1). Values from five macro-algae species collected from Pool Bay, Sanday had a similar range of values, -17.23 to -11.84 ‰ (Ambers in Dockrill et al., 1994, p125).

The ratio between the stable isotopes of nitrogen $^{15}N$ and $^{14}N$ ($\delta^{15}N$) depends on nitrogen cycling in the soil and less predictable than $\delta^{13}C$. The initial source of nitrogen is atmospheric $N_2$ converted by microbial activity to a form of nitrogen that can be assimilated by plants. At the other end of the cycle denitrifying bacteria convert decaying organic nitrogen back to inert $N_2$ gas (Pollard and Wilson, 2001, p197). In general herbs and grasses have a $\delta^{15}N$ value of approximately 3‰ whereas leguminous plants that fix nitrogen themselves, a value closer to 0‰ (Drucher et al., 2003, p382, Noe-Nygaard et al., 2005 p863).

An enrichment of approximately 3-5‰ in $\delta^{15}N$ is assumed for herbivores in temperate climates, although greater enrichment ranges from 1.7-6.9‰ have been recorded (Ambrose, 1991, p297, Bocherens and Drucker, 2003, p49, Hedges and Reynard, 1997, Noe-Nygaard et al., 2005, p863, Sponheimer et al.,2003 p81). Higher terrestrial values may be associated with saline soils and arid environments (Ambrose, 1991, p312, Heaton et al., p823, Sponheimer et al., 2003 p81). Herbivores under drought stress also have increased $\delta^{15}N$ related which may be related to a possible increase in urea output (depleted in $^{15}N$) (Sealy, 2001, p272).

Pastures or crops that have been treated with animal manure have higher $^{15}N$ values because of preferential loss of the lighter $^{14}N$ as volatile gaseous ammonia (Bogaard et al., 2007, p336). In Orkney, during the historic period, seaweed was used to fertilise land (Fenton, 1978) and this, along with manuring with animal waste, may be another route by which enriched values of $^{15}N$ can enter herbivore food-chains (Milner et al., 2004. p16).

### 10.2.2 Isotope cattle results from LON

Isotope results for LON are listed in *Tables 36 and 37.*

**Table 36 Isotopes (non-dietary) from LON (Links of Noltland) cattle (tooth and bone collagen)**

| **LON** | **$\delta^{13}C$ ‰** | **$\delta^{15}N$‰** |
|---|---|---|
| No | 15 | 15 |
| Mean | -21.3 | 6.0 |
| SD | 0.3 | 0.9 |
| Min | -21.7 | 4.7 |
| Max | -20.4 | 7.4 |
| Median (Md) | -21.3 | 6.0 |
| 75% | -21.1 | 6.7 |
| 25% | -21.6 | 5.3 |
| Midspread | 0.5 | 1.4 |

**Table 37: Isotopes from LON cattle (bone and tooth collagen results separated)**

| | **$\delta^{13}C$** ‰ tooth | **$\delta^{13}C$** ‰ bone | **$\delta^{15}N$‰** tooth | **$\delta^{15}N$‰** bone |
|---|---|---|---|---|
| No | 8 | 7 | 8 | 7 |
| Mean | -21.2 | -21.4 | 6.6 | 5.5 |
| SD | 0.4 | 0.2 | 0.8 | 0.8 |
| Min | -21.7 | -21.6 | 5.4 | 4.7 |
| Max | -20.4 | -20.9 | 7.4 | 6.8 |
| Median (Md) | -21.3 | -21.4 | 6.7 | 5.3 |

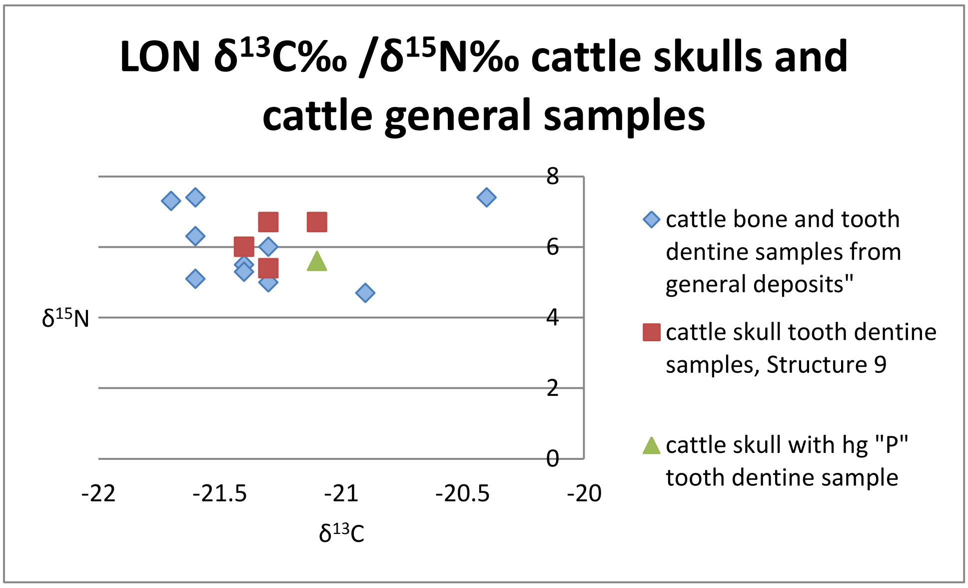
The results indicate that LON cattle tooth samples have slightly elevated $\delta^{15}N$ and $\delta^{13}C$ values when compared with bone samples, in terms of mean and median. However, all LON $\delta^{13}C$ values are within the range of a 5‰ enhancement from an adjusted value of -25.6‰ (but not the unadjusted figure of -27.1‰). The LON $\delta^{15}N$ values are also within the range of an assumed 3-5‰ enhancement from plants with values of approximately 3‰. One $\delta^{13}C$ value, 20.4‰, was greater than two SD from the mean; this was from a mandibular $M_3$ associated with the cattle skull deposit with “T3 haplotype 2”. See *Table 38.*

**Table 38: Isotopes from LON (Links of Noltland) Structure 9 cattle skulls (teeth)**

| **Skull No** | **mtDNA** | **Basel Lab No** | **$\delta^{13}C$‰ tooth** | **$\delta^{15}N$‰ tooth** | **C/N ratio** |
|---|---|---|---|---|---|
| 4257/58 | T3/2 | ORK 1 | -21.3 | 5.4 | 3.3 |
| **4459** | P | ORK 6 | -21.1 | 5.6 | 3.2 |
| 4462 | T3/1 | ORK 4 | -21.4 | 6 | 3.2 |
| 6693 | T3/2 | ORK 3 | -21.3 | 6.7 | 3.2 |
| 4460 | T3/1 | ORK 5 | -21.1 | 6.7 | 3.2 |
| | | *Mean* | *-21.2* | *6.1* | |

Domestic cattle skull and the hg "P" cattle skull tooth collagen had similar δ$^{13}$C results to those from other cattle bone and dentine samples from general LON deposits, but appeared to have a greater range of δ$^{15}$N values.

The isotope values from five dentine samples from cattle skulls deposited in foundation course, Structure 9, are also similar to all isotope values obtained for the site. There is no evidence, based on these results that the hg "P" animal was grazing in a different environment, for example a wetter or a more wooded area, than the other four cattle analysed from the skull deposit, Structure 9. *See Graph 105.*



**Graph 105: Comparison of isotopes from LON (Links of Noltland) cattle skull tooth dentine samples, Structure 9,cattle skull with hg "P", Structure 9 and cattle bone and dentine samples from general deposit**

In a palaeodiet survey of Neolithic cattle bones from a selection of Orkney and the Western Isles sites, including LON, the results for δ$^{13}$C‰ and δ$^{15}$N‰ are represented in *Table 39.*

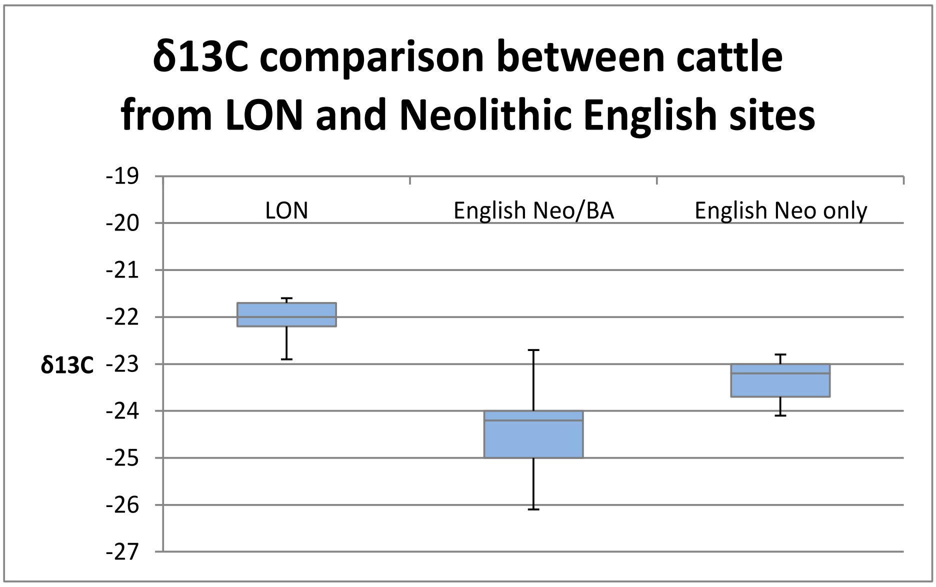
**Table 39: Comparison of isotopes between LON and mixed Orkney and Western Isles Neolithic (4500 to 2500 BC) palaeodiet cattle samples: *Source Jones et al., 2012***

| | Orkney | Western Isles | LON |
|---|---|---|---|
| δ$^{13}$C‰ | -21.6 | -21.3 | -21.3 |
| δ$^{15}$N‰ | 6.0 | 5.1 | 6.0 |
| No | 18 | 7 | 15 |

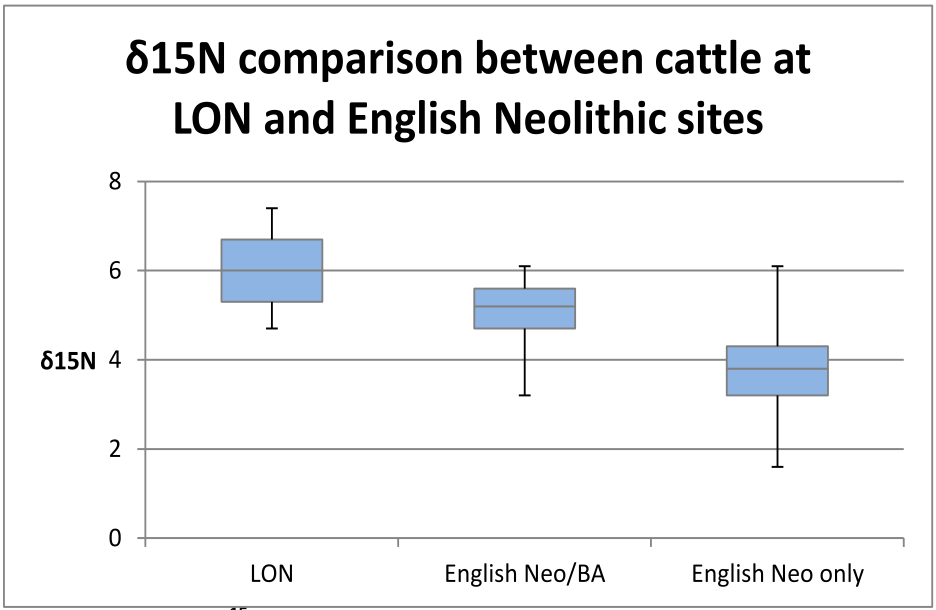
The survey for Neolithic Orkney (4500 to 2500 BC) produced a δ$^{13}$C value of -21.6‰, slightly lower than results from LON. The LON mean values matched those of the Western Isles. However, the differences between the Orkney and Western Isles results were not considered statistically significant using the U-Mann-Whitney test (Jones et al., 2012). The LON and Orkney mean $\delta^{15}N$ values were identical, those from Western Isles less elevated.

### 10.2.3 Cattle isotope results from other British sites

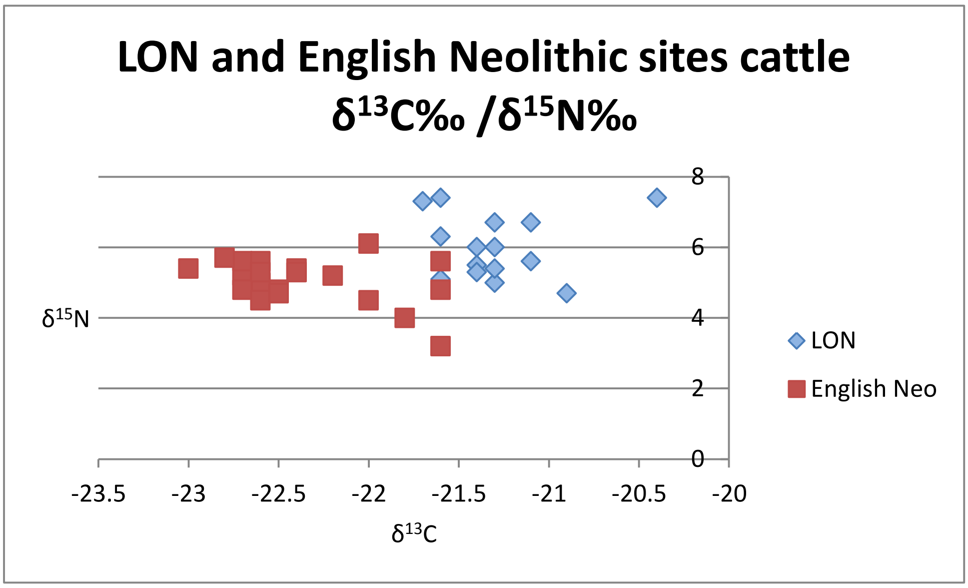
As part of a palaeodiet survey of English domestic cattle and aurochs bone collagen isotopes were determined from twenty-one domestic cattle from six Neolithic sites (Lynch et al., 2008, p1026). The criteria for bone sample selection are not provided. See *Graphs 106 to 108 and Appendix 29.*



**Graph 106: Comparison of $\delta^{13}C$‰ values between LON cattle and English Neolithic and English Bronze Age domestic cattle *Source: Lynch et al., 2008***



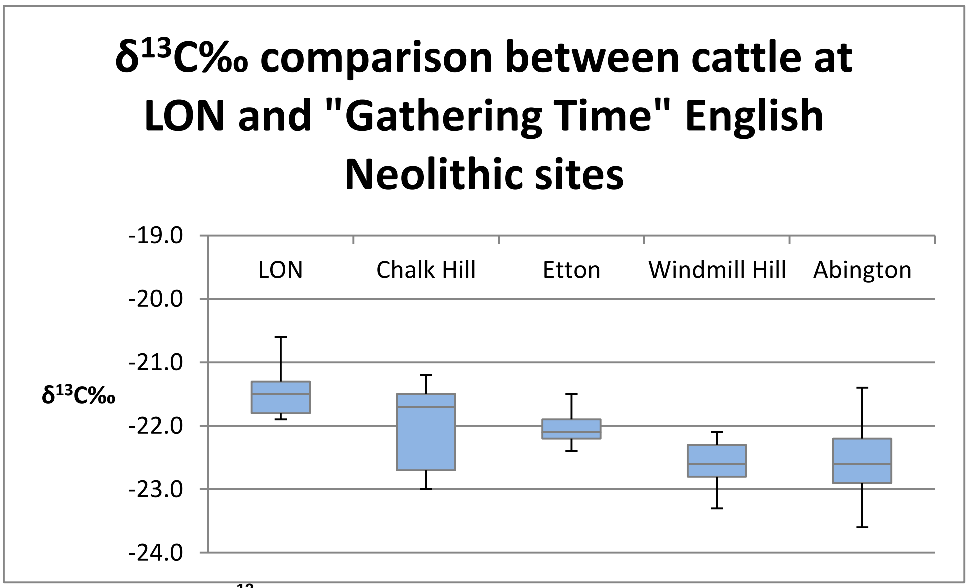
**Graph 107: Comparison of $\delta^{15}N$‰ values between LON cattle and English Neolithic and English Bronze Age domestic cattle. *Source: Lynch et al., 2008***



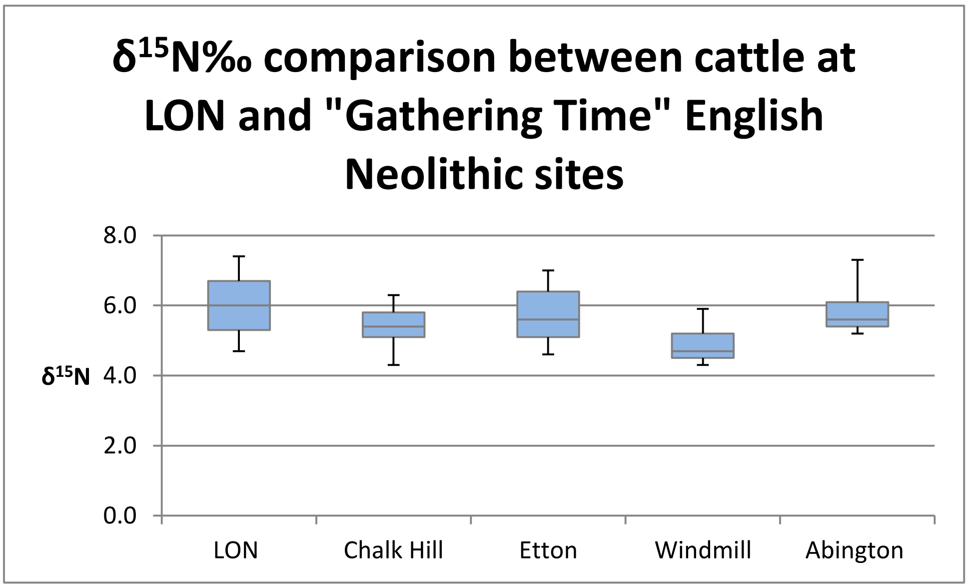
**Graph 108: Comparison of isotopes identified in cattle bone from LON (Links of Noltland, Late Neolithic) and English domestic cattle (Neolithic) *Source Lynch et al., 2008***

LON $\delta^{13}$C‰ results are elevated from those of the English Neolithic domestic cattle, both in terms of mean, median and mid-range. Using the Students t-test is it *extremely unlikely* that the LON and English Neolithic domestic cattle were from the same population. This direction of enhancement is contrary to the expected north-west to south-east European enhancement trend (van Klinken et al., 1994) and perhaps indicates that these English Neolithic domestic cattle were grazing in more humid areas, possibly with woodland shading. Alternatively, it may show that Orkney cattle had an element of marine vegetation in their diet. The results indicate that the LON cattle bones also had elevated levels of δ15N when compared to these Neolithic sites in England.

The "Gathering Time" project examined cattle palaeodiet isotope values from Early Neolithic causwayed sites, with results similar to those of the general survey of English Neolithic sites. See *Graph 109 and 110 and Appendix 30.*



**Graph 109: Comparison of δ$^{13}$C‰ isotopes identified in cattle bone from LON (Links of Noltland, Late Neolithic) and English domestic cattle surveyed for the "Gathering Time" project. Source *Hamilton and Hedges, 2011***



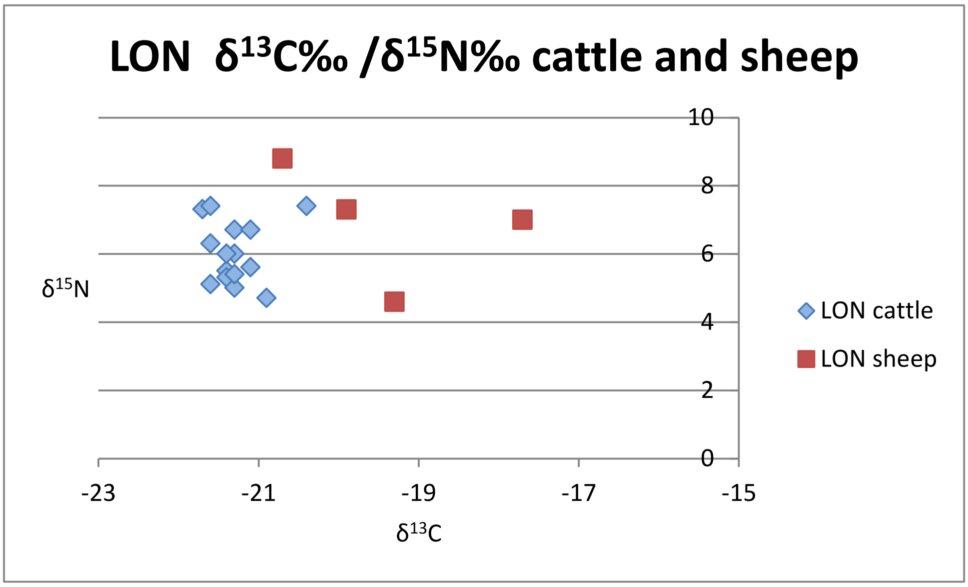
**Graph 110: Comparison of δ$^{15}$N‰ isotopes identified in cattle bone from LON (Links of Noltland, Late Neolithic) and English domestic cattle surveyed for the "Gathering Time" project. Source *Hamilton and Hedges, 2011***

Differences between LON and Windmill Hill causewayed site, using the Students t-test, are significant and it is *extremely unlikely* that the two sets of δ$^{13}$C and δ$^{15}$N values could be from a population grazing under the same conditions. In the case of Abington causewayed site results being compared with LON, although it is *extremely unlikely* that the δ$^{13}$C values were from the same population, it is *fairly likely* that δ$^{15}$N values could be from the same population.

The δ$^{13}$C results for LON cattle are within the expected range for 5‰ enhancement from predicted plant values of 25.6‰. With a mean of δ$^{15}$N 6‰, cattle are also within the range predicted for a 3-5‰ enhancement on plants with a value of approximately 3‰. When separated into tooth and bone cattle collagen, tooth collagen has slightly elevated isotope values when compared with bone collagen, perhaps reflecting a subtle difference in deposition of isotopes between the two types of skeletal elements.

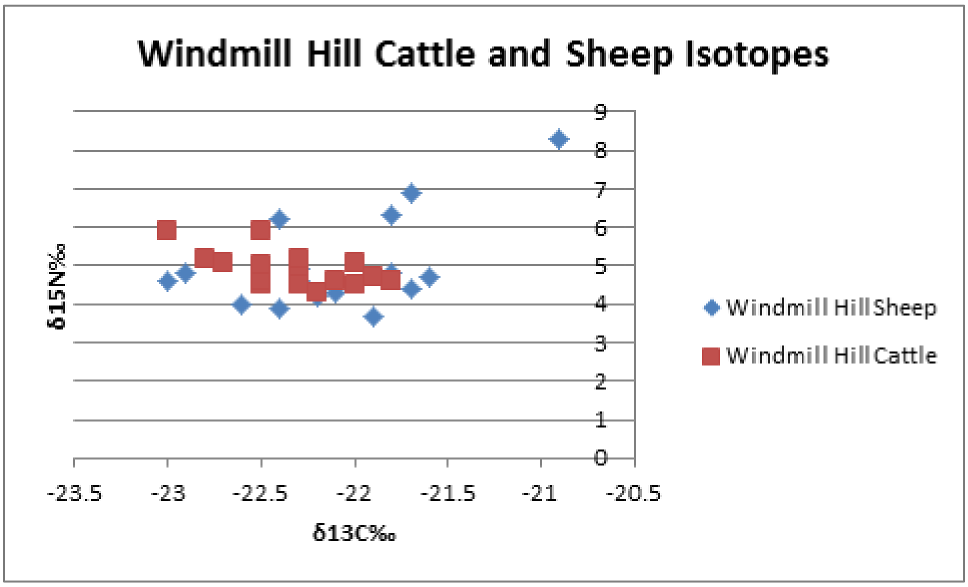
### 10.2.4 Sheep isotope results from LON

Non-palaeodiet isotope results from four LON sheep bones indicate a distinction between cattle and sheep, although one cattle bone has a higher $\delta^{13}C$ value than one sheep bone. The mean value for LON sheep $\delta^{13}C$ is -19.4‰, for LON cattle -21.3‰. See *Graph 111*.



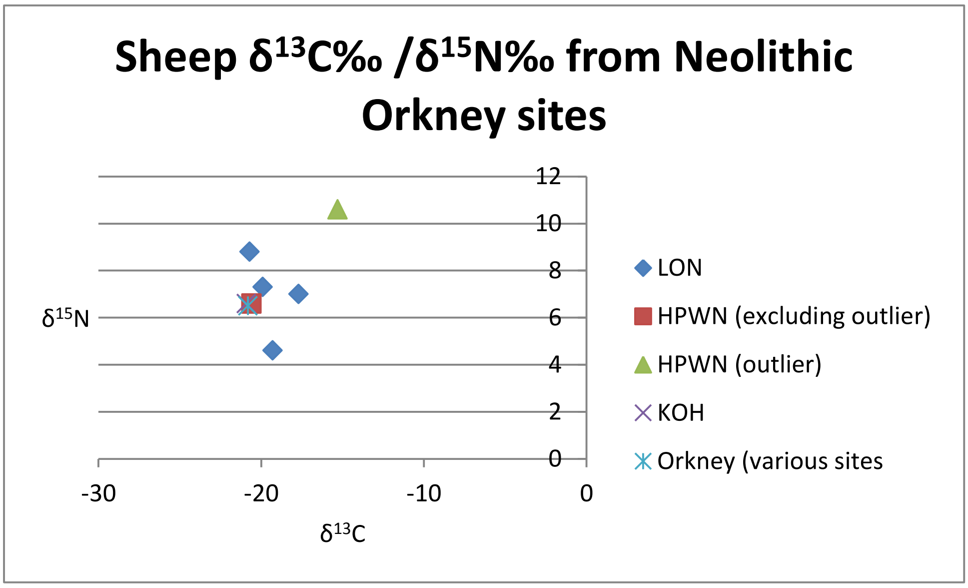
**Graph 111: Isotope results for LON (Links of Noltland) sheep and cattle *bones***

This difference does not appear to be due to partitioning of grazing since the same pattern was not noted quite so clearly in the early southern England Neolithic site of Windmill Hill (Hamilton and Hedges, 2011). See *Graph 112.*



**Graph 112: Isotope results for cattle and sheep from Windmill Hill, southern England Early Neolithic site**

Mid Neolithic site of KOH (Knap of Howar), the cairn site HPWN (Holm of Papa Westray North, minus foetal sheep outlying result) and the mean from a general study of sheep from Neolithic Orkney were plotted. See *Graph 113.*



**Graph 113: Comparison of isotopes from sheep bones: LON (Links of Noltland, Late Neolithic, no 4); KOH (Knap of Howar, Mid Neolithic, average from no 6); HPWN (Holm of Papa Westray North, Neolithic, average from no 2); other Orkney sites (Neolithic, average from no 19)** ***Sources Jones et al., 2012, Schulting and Richards 2009***

The results indicate that LON sheep, in three of four determinations, have slightly elevated levels of δ$^{13}$C. The most elevated level is only -2.4‰ less than the Holm of Papa Westray North cairn outlier, a foetal lamb, assumed to be influenced by the mother's seasonal intake of seaweed (Schulting and Richards 2009, p71).

## 10.3 Overview

The difference between LON $\delta^{13}C$ results and twenty-one Neolithic cattle from England was 1‰ for mean, 1.2‰ for median, with the English sites producing less enhanced values. The $\delta^{15}N$ values are also lower for Neolithic cattle in England by 1‰ than those from LON. Recent results from the Early Neolithic causewayed sites show similar patterns. The LON results contradict the predicted pattern of $\delta^{13}C$ enhancement at lower latitudes. It is therefore possible that Orkney cattle were grazing on less water-rich areas, perhaps influenced by saline deposits carried onto land by prevailing westerly or south-westerly winds (Cramp et al., 2014). The cattle may also have been consuming small quantities of marine vegetation, although an analysis of five cattle molar bioapitite samples from Knap of Howar did not produce evidence of this (Balasse et al., 2006, p6, Balasse and Tresset, 2009, p81).

There were fewer isotope results for LON sheep than cattle. However, the $\delta^{13}C$ mean for sheep is considerably higher than those for cattle (-19.4 and -21.3‰ respectively). The difference between the two species does not appear to be due to partitioned feeding behaviours because the Early Neolithic sheep and cattle at Windmill Hill displayed no difference in values. Since sheep lived in the same location as cattle in Westray, it seems possible that the higher value was due to a greater consumption of marine macro-algae. Analysis of modern macro-algae consumption of North Ronaldsay sheep verifies that different isotope values from marine vegetation in Orkney are reflected in collagen analysis (Balasse et al., 2005, Balasse et al., 2006).

Based on historic and modern evidence the question might not be why sheep diet was supplemented with marine macro-algae in Neolithic Orkney, but why cattle consumed either small quantities or none of these plants. Possibly this species had not yet undergone physiological adaptation to allow digestion of this food source, as suggested for the sheep at the Early/Mid Neolithic site at Knap of Howar, or were not given macro-algae for winter fodder. Alternatively, as observed in the feral herd on Swona, Orkney, it may have been because the cattle found movement on slippery, loose rocks uncomfortable (Hall and Moore, 1986, p93) or that they were more closely herded than sheep with little access to the shore line.

# *11 Discussion*

## 11.1 Introduction

This chapter discusses the depositions of cattle and sheep skulls and articulated red deer skeletons from the Late Neolithic site of LON in Westray, Orkney. Details of the cattle skull representations or collections from other prehistoric sites are then outlined and rituals that may have been associated with these unusual depositions explored. Finally, consideration is given to the arrival and characteristics of the cattle, sheep, red deer and pig herds and flocks in Orkney, an archipelago considered to have no surviving mammals after the Last Glacial Maximum in northern Europe.

## 11.2 LON cattle and sheep skull depositions

### 11.2.1 General

The LON cattle and sheep skull deposits in Structure 9 and Structure 18 offered a unique opportunity to consider the role of cattle in Neolithic belief systems. “We snatch glimpses of meaning in symbols only rarely and through the darkest of glasses” (Brookbank, 2000, p2). In Structure 9, 28 cattle and two sheep skulls were recovered, carefully placed between the inner and outer walls of the foundation course. In Structure 18 between 15 and 23 cattle skulls and eight sheep skulls were deposited in a less obviously structured deposition, associated with blocking a passageway between Room 1 and 3. Both cattle skull depositions were predominately from adult/older adults. In Structure 9 both females and males/castrates were identified, in Structure 8 female cattle dominated skulls that could be sexed.

### 11.2.2 Post-cranial bones associated with LON skull depositions

Several cattle pelves and red deer antlers were deposited with cattle and sheep skulls in Structure 9, and a cattle scapula with skulls within Structure 18. The cattle pelves had been carefully butchered and kept intact, perhaps with the intention of depositing them adjacent to the cattle skulls. No specific bone caches were noted, unlike the one hundred and twenty cattle astragali and eight red deer astragali recovered from hut 2, Skara Brae, Mainland (Stewart and Boyd, 1914, p346, Childe, 1931, p33) or the cattle tibia concentration at Ness of Brodgar, Mainland (Mainland et al., 2014).

Cattle post-cranial bones dominated the wall core material adjacent to, and overlying, the skull deposit in Structure 9 (contexts 9116/9123). Since bone density calculations demonstrate better survival for lower density limb bones in Structure 9 wall core when compared with midden contexts 7302 and 9031, lack of sheep/medium mammal bones in this wall core material does not appear to be due to poor preservation. The cattle post-cranial bones were from a range of ages, including neonates and calves, and did not reflect “age of death” profiles of the deposited cattle skulls.

There were no articulated cattle post-cranial bones within the wall-core material and no intact long bones. The only complete bones were non-meat bearing bones such as carpals, tarsals and phalanges. The post cranial cattle bones, and those from red deer and sheep, displayed cut and chop marks associated with disarticulation/filleting and mid-diaphysis long bone spiral breaks consistent with extraction of marrow, indicating these bones had been exploited for food. This contrasts with the Neolithic site at Pool where dumps of articulated cattle bone were found "*in situ"* (Dockrill, 2007, p73, Bond, 2007, p227, illus 7.2.12), including a collection of two cattle left forelimbs, one left hindlimb and a right femur, associated with a scatter of undecorated pot and limpet shells. At Tofts Ness a partially complete post-cranial cattle skeleton was recovered from the Neolithic midden (Bond, 2007b, pp196-202).

The evidence therefore indicates that there was no selection of specific bones for deposition in wall core material, Structure 9, apart from cattle skulls and pelves (plus three red deer antlers). The dominance of cattle post-cranial bones may be because sheep were less significant in the LON settlers' diet when these contexts were formed, or that the wall core material was deliberately sourced and re-deposited from an area associated with secondary butchering or storage of cattle bones.

### 11.2.3 Mammal bone depositions below and within Structure 9

Cattle bones dominated the midden below Structure 9 (contexts 9681/9690). Although these contexts had a poorer survival rate for less dense bone portions, approximately 50% of sheep carpals/tarsals and 75% of sheep phalanges were recovered intact, so the relative absence of sheep/medium size mammal bones is not attributable sorely to taphonomic loss. The proportion of red deer bones (minus antler) some with evidence of cut marks, was greater than other LON areas studied. A significant proportion of the recovered bones were burnt, but since only a small area of the total midden lying below Structure 9 was investigated, and this was adjacent to, and north of, the excavated hearth, it is possible that indirect burning may have been impacted on underlying midden material. This area of the LON site may have had a designated purpose prior to the construction of Structure 9, or underlying midden material relocated from an area associated with large mammal butchery. The alternative is that sheep comprised a smaller proportion of diet, red deer a higher proportion, in the period prior to the construction of Structure 9.

The location of Structure 9, separated, and to the north of, the enclosed structure complex in Area 5 might indicate a dedicated function. Overall, floor deposits in Structure 9 have a lower percentage of burnt bones than those associated with hearths and ashy deposits. However, both types of deposit contain a similar group of mammal species. In addition, a number of unburnt bones from the hearth contexts, and in particular the articulated red deer lower foot bones in context 9125, indicated some bone fragments were deposited after Structure 9 hearths went out of use, possibly associated with infill material. Cattle and large mammal dominated all contexts, sheep the next most abundant species with pig and red deer bone less well represented. No other species were present, apart from an unidentified sea mammal fragment.

A higher proportion of cattle and large mammal bones were burnt when compared with sheep and medium mammals and the few pig and red deer bones recovered were unburnt. However, there was no evidence of full calcination of bone fragments from either hearth or floor deposits, and bones appear to have been subjected to variable burning, perhaps due to causal disposal of bones on a fire. There is also no pattern of charring on bone fragments to suggest prime meat joints were being roasted in the hearth. There are not enough bones to produce age profiles, but newborn and juvenile sheep, pigs and cattle were all recovered, as were adult sheep, cattle and red deer.

There is therefore no evidence of special selection or treatment of mature cattle within the building. Neither is there any evidence of unusual mammal bone depositions, so, if Structure 9 had a special function for the community at LON, this is not reflected in mammal bone deposition recovered during excavation.

## 11.3 Scottish prehistoric cattle deposits

In many cultures, from Neolithic examples through to 19th/20th century hunting trophies, animal heads or bucrania have been put on display above ground but it is less common for the heads to be buried and concealed (Wilson, 1999, p303). LON cattle skull foundation and passageway depositions are unique within published Neolithic site records in Britain but it is possible that other skull deposits exist but are hidden by overlying infrastructure, or have been misallocated, for example, as barrow content rather than building deposits at sites in southern England (e.g. Ascott under Wychwood or Beckhampton Road) (Ashbee et al., 1979, p247, Bishop, 2013, p78, Thomas, 1991, p28, 2013, p407).

In Neolithic Orkney no cattle skull depositions have been recovered from other Neolithic settlements, but various cattle skulls found in closing deposits or in rubble from Orkney Neolithic sites may attest to the intentional retention of cattle skulls. At Tofts Ness, the fact that a Neolithic cattle skeleton was fairly complete, but with the skull missing, may indicate that the skull was of greater importance than the rest of the skeleton of a potentially fallen animal and had been removed. The only single sheep skull deposition recorded is from the cairn site of Quoyness, Rousay (Childe, 1952).

Hidden mammal bones deposits at Bronze Age/Iron Age sites in Scotland such as Howe, Orkney (Smith 1994), Jarlshof, Shetland (Platt, 1956), Sollas, Western Isles (Finlay, 1991) and Cladh Hallan, Western Isles (Mulville et al., 2012) attest to the continuing practice of "animating" structures beyond the Neolithic period. However, although partially articulated mature cattle skeletons feature in some deposits such as High Pasture Cave, Skye (Drew, 2005) and Brest Ness, Westray (Fraser unpublished) remains of mature cattle do not dominate these deposits and there is no focus on skull deposition.

Human skulls were afforded a particular status during the Mid Neolithic period of Orkney. Sorting and handling of skulls and other post-cranial bones would therefore have been a familiar concept to earlier Orkney communities. Bones may even have been circulated in the early domestic site of Knap of Howar (Noble, 2006, pp134-135). An evocative description of this practice is given by A. Whittle "appeals to dry bones, fingerings of empty skulls and motionless limbs" (Whittle, 1996, p1). Human skulls from several cairns were detached from post-cranial skeletons and deposited together indicating an emphasis on collective rather than individual burials, so the concept of a cache of human skulls representing ancestors was already familiar to Neolithic people in Orkney and may have informed the use of cattle skulls as symbolic objects.

No partial or complete cattle skulls were deposited at Neolithic cairn sites, however, denying the possibility that skulls of humans and cattle were interchangeable in the belief system of early Orkney settlers, a suggestion made for barrow sites in south of England. However, at the cairn site at Holm of Papa Westray North, human and sheep skulls (possibly fallen animals) were used to block the entrance to a cell, perhaps presaging the later passageway infill at LON, Structure 18.

As highlighted in *Chapter 3*, examples of cattle skull deposition/display, complete cattle skeletons honoured by special burials and artistic representations of bucrania have been identified from sites throughout the Near East, continental Europe and Britain from the Pre-Pottery Neolithic onwards, even before aurochs domesticated. This provides further evidence that many Neolithic people regarded cattle not purely by the economic/subsistence framework advocated by the Cambridge Palaeoeconomy School (e.g. Higgs, 1972, Higgs and Jarman, 1969, following from Clark, 1952) but as integral to social/belief systems for thousands of years prior to the excavation of cattle skull deposits in Late Neolithic Orkney (Holt, 1996, Russell 2012). The LON cattle and sheep depositions may therefore have been the result of entrenched and familiar traditions carried to Orkney by incoming settlers, but it is clear by the variety of depictions and depositions of cattle during this period that the transmission was associated with the idea of the symbolic significance of mammals, particularly cattle, not a single prescribed ritual.

## 11.4 Possible beliefs associated with LON skull deposits

Cattle, sheep (and one red deer) skulls deposited in Structure 9 and Structure 18 were selected by the LON community to confer some form of energy, spirit, defence or memory to these buildings, although the skulls would not have been visible after installation. The ratio of cattle skulls to sheep skulls reflects the proportion of post-cranial cattle and sheep bones from the midden below Structure 9, the foundation deposit Structure 9, but not from the overlying middens, where sheep bone fragments are more numerous.

Several published hypotheses for Neolithic animal bone deposits in buildings include:

- Create lineage continuity and communal integration via the construction of collective memories and identities (Twiss 2008, p437)
- Ensure resistance of building to all forms of destruction (Cauvin, 2000, p125)
- Embody tangible evidence of ancestry and descent (Thomas, 2103, p409)
- Provide a protective “skin” to contain and protect the inhabitants (Richards, 2013, p80)
- Reflect holistic relations between humans, plants, animals and dwellings (Verhoeven, 2004, p263)
- Represent on-going relationships between the building and lives of the community (Herva, 2005)
- Retain some special power that needs to be harnessed or contained (Russell 2012 p389)
- Transform and/or comment upon the significance of a particular place and remove particular artefacts from circulation (Thomas, 1999, p224)
- Symbolise the settlement’s rights to graze animals (Lewis-Williams and Pearce, 2005, p193)

Although these hypotheses vary, they cohere around the general theme that all structures were “*animated*” by the deposit (Bradley, 2005, p52). Selection of skulls may have been founded in a belief that the “essence” or “power” of an animal is lodged in its head even after the animal was no longer biologically alive. Also with cattle skulls, horn cores, associated with defence, were always present on each skull (Russell, 2012, p58, p83). Cattle skulls were preferred for deposition at LON, but the presence of sheep skulls and one red deer skull perhaps indicates the actual process of skull deposition may have been of overriding importance.

The word “*synecdoche*”, adopted by J. Chapman to describe selective removal of parts that become representative of the whole and its associated symbolic meaning, may be an appropriate term for describing LON skulls. The butchering and distribution of joints of meat represents the part/whole relationship with animals and can also act as metaphors for social relationships so the concept of a part skeleton, in this case a posterior skull, representing a whole animal could have been an embedded view within the community (Chapman, 2000, p136, p144, p222).

Skulls used for structural deposition may also have represented little loss of resource. It appears that mandibles had been removed to allow access to the tongue, scrape and cut marks indicate skinning and fileting on some skulls, particularly in Structure 18, and frontal bone breaks could have allowed access brain material (Grant 1984, p125).

Both sexes of cattle were represented in LON skull depositions, although older females probably dominated cattle from Structure 18. The deposition was not therefore associated with a “bull cult”. The bull (aurochs) and goddess symbolism at the advent of the Neolithic proposed by J. Cauvin, based on his work in the Near East and excavations at Çatalhöyük (Cauvin, 2000, Cauvin et al., 2001) is now challenged. Although imagery of women and bulls did appear at Çatalhöyük, the symbolism for cattle may be linked with feasting (Hodder and Meskell, 2011, p236, Russell, 2012, pp241-243). There was, however, a preference for males at feasts and ceremonies at this site (Twiss and Russell, 2009), which was not noted at LON. In Britain, at Early Neolithic causewayed sites such as Etton, Cambridgeshire, Hambleton Hill, Dorset, Maiden Castle, Dorset and Windmill Hill, Wiltshire, where mammal bone depositions were made into ditches, adult cattle predominated and, where sex could be established, mostly cows (Grigson, 1999, p236).

There was no elaborate modification on LON cattle skulls such as trimming bones, plastering, painting or adding items such as shells. There was also no evidence that skulls were displayed on walls/posts or incorporated into the walls of buildings such as the plastered bucrania from the Early Neolithic site of Çatalhöyük (Russell, 2012, p337). In addition, there was no artistic representation of cattle, or other domestic animals recorded in Neolithic Orkney, although other prehistoric examples from continental Europe exist and were discussed in *Chapter 3.* The LON cattle and sheep skull deposits are therefore the only evidence that these mammals played an important role in the belief system in this region.

Lack of artistic representation means that, unlike settlements such as Çatalhöyük, it is not possible to gain from this source on how LON cattle and sheep were killed and processed, so it is difficult to determine whether the animals were culled, sacrificed or killed in a spectacular way, such as in Viking Iceland (Lucas and McGovern, 2007, pp19-26) or modern-day bull-fight. It is also unknown whether skulls or other parts of the body were used for divination.

An interesting component of the skull deposition at LON is that although they may "animate" the building, the skulls can no longer be viewed, so their presence becomes perpetuated by those who were present when they were deposited, or by oral tradition. The deposition must have marked the end of a long chain of events or life histories (Hodder, 2012, LaMotta and Schiffer, 2001), all of which are observable prior to deposition. The removal of the skulls from view may have parallels with some examples of hidden art work at the Orkney Neolithic ceremonial site of Ness of Brodgar (Thomas and Card, 2012) and deposition of the figurines at LON (G. Wilson per comm.).

## 11.5 Source of LON skulls

### 11.5.1 General

There are five possible options for generation of cattle and sheep skulls:

- Catastrophic death of herd through disease or raiding
- Exceptionally large ceremony/feast held at LON
- Several smaller ceremonies/feasts/rituals at LON with skulls curated
- Ceremony included import of curated skulls
- Ceremonies held elsewhere, skulls retained and later deposited at LON

### 11.5.2 Catastrophic deaths

Cattle diseases were noted in early historic Scottish, English and Irish texts but occurrence during the Neolithic period has not been investigated in detail, although modern biochemical studies may soon remedy this shortfall (Professor Krause, University of Tübingen, Germany, Edinburgh Infectious Diseases Lecture, 6/11/14). It is established that infectious diseases passed between livestock and humans from the Neolithic onwards, presumably associated with more crowded living conditions (Brüssow, 2009, Crosby, 2004, p31, Diamond, 2005, p205-207, Krause, ibid). In Adomnán's Life of St Columba [11 4], written in the 7th century AD but relating to the previous century, cattle disease was portrayed graphically as "a rain that will raise awful sores full of pus on the bodies of people and on the udders of cattle" (Sharpe, 1995). The Chronicum Scotorum in AD 1081 records "mortality of men and cattle" thought to be a reference to a cattle plague (Lucas, 1989, p39). In England a cattle plague in AD 694 was “a great morren of cowes throughout all England” and in Ireland in AD 1133 “great cow mortality occurred throughout all Erin, for which no likeness was found since… 432 years” (Lucas, 1989, p38, p40).

These early historic references suggest that cattle disease was episodic, but potentially devastating, to cattle herds, and on some occasions, settlers. Cattle plague, or *Rinderpest*, the most highly infectious and lethal of bovine diseases may not have been present in Neolithic Orkney, having been brought west from central Asia by the Scythians in the 9th or 8th century BC (Spinage, 2003, p3). However, other cattle diseases may have impacted on LON herds, so the question is whether it would be rational to remove skulls from carcasses/skeletons of diseased animals and deposit them. Although Neolithic communities would not possess a scientific understanding of epidemiology, it seems probable that they would have recognised the dangers of handling diseased animals, perhaps through ritual avoidance (Douglas, 2002, p37), and so cattle and sheep skull deposition from this source seems unlikely. Alternatively, a proportion of the cattle herd may have succumbed to starvation, although there is no evidence of previous ill-health manifested on the bones, and it is unlikely that such animals would be butchered.

Another possible explanation is that raiders killed a large proportion of the LON herds. There is a growing body of evidence of inter-personal warfare in the European and British Neolithic (Hutton, 2013, p79, Jones, 2007, p166, Schulting and Fibiger, 2012). Although it would be more rational to steal rather than kill your enemies’ cattle and sheep, there are many historic examples of violent destruction of grain and livestock. The argument against this scenario is that if herds and livelihoods had been destroyed it seems unlikely that the surviving community would carefully butcher, extract and consume meat/offal from all the dead cattle. Also, unlike early medieval Ireland, where extensive cattle raiding are recorded, there is no evidence of defensive structures such as ringforts to protect LON cattle from raiders (McCormick, 2008, p214). Outer walls surrounding Skara Brae settlement, Mainland and Area 5, LON could not have accommodated many animals in times of emergency. It is not possible, however, to fully dismiss the possibility that skulls from animals killed by raiders were later retrieved and re-deposited.

### 11.5.3 Feasting/Ritual

#### 11.5.3.1 General

In a non-capitalist society any feast or ritual, large or small, removes mammals from the economic system (deFrance, 2009, p136). LON cattle and sheep skulls were not selected from a cohort of uniform age and it is unlikely that they were raised purely for sacrificial ritual or feasting but their management may have involved more than economic considerations and environmental constraints (deFrance 2009, p145, Edmonds, 1999, pp27-28, Jones and Richards, 2003, Pollard, 1996, p137, Whittle, 2003). Cattle's symbolic significance at LON may have been as important, or more important, than their economic contribution (Grant, 1991). These animals may have been be kept "on-the hoof" as vehicles of food storage (Halstead, 1996. p35, Thomas, 2013, p124) until a predetermined date, unless ill or injured.

When cattle were culled in Neolithic Orkney, there would be a sudden availability of large quantities of meat, fat and offal, even from one animal (Hayden, 2001, p44, Grigson, 1999, McCormick 2012, Serjeantson, 2006, p114, Thomas 2013, pp410-411). Although some meat, blood and offal could have been preserved for a short time (e.g. salted or smoked) it is unlikely that long-term preservation by salt was available during the Neolithic period (Parker Pearson, 2002, p12, Serjeantson, 2006). A feast would therefore ensure no resource wastage (Russell, 2012, p377) since the perishable nature of meat and offal limits its value for trade or exchange (Dietler, 1996, Jones 2007, p149, McCormick, 2008, p219, Thomas, 2013, p124). Sharing food may have been a sensible risk-reduction strategy designed to encourage support from adjacent communities in times of hardship (Kuijt, 2009).

Eating meat may have been a relatively rare occurrence and inhabitants may have had what is described by N. Fiddes as "meat hunger" (Fiddes, 1991, p13) and anticipated, enjoyed and clearly remembered feasts that included preparation of beef. It is noted, however, that in B. Hayden's fifteen archaeological signatures of feasts only one, special food disposal is noted from LON, although it is possible that special serving vessels were also present at the site (Hayden, 1996, p40, table 2.1).

Feasting is widespread and persistent over time in all societies and has the potential to transform a living animal into an interaction that can be associated with a wide range of objectives:

- Build alliances (with actual or adopted kin)
- Increase or reduce competition
- Create indebtedness
- Mobilise labour
- Create social distance or inclusion,
- Intercede with ancestors

- Attract desirable mates
- Produce surplus for elite use
- Solicit favours or compensate for transgressions

(deFrance 2009, p141, Dieter, 1996, Dieter and Hayden 2001, Hayden, 1996, 2001, M Jones, 1997, Marciniak, 2005, p70, Parker Pearson, 2003, p10, Thomas 2013, p123, Twiss, 2008, 2012). This list assumes that feast providers were rational and obtained practical benefits from inviting non-householders to participate (Dietler and Hayden, 2001, p12). One reason why LON skulls may have been preserved was that debts, in a broad sense, were not forgotten or neglected (Hayden, 2001, p45, Russell, 2012, p386).

In his analysis of the Neolithic, C. Renfrew considered that relatively egalitarian small groups existed in Mid Neolithic Orkney, but by Late Neolithic a chiefdom society was emerging. He labelled this as “centralising tendencies” and based his main argument on the observation that simple cairn building of the post settlement period used to validate local land tenure had been superseded by the sophisticated planning, visualisation and labour required to produce the two standing stone ceremonial constructions, Stones of Stenness and Ring of Brodgar, Mainland, Orkney and the high level of design and masonry work of tombs such as Maes Howe (all located within the Heart of the Neolithic Orkney World Heritage site). Initial cairn building may have been the product of small groups of locally based people, but larger monuments may have marked the emergence of an elite to which all Orkney residents owed an allegiance This pattern was also observed in other areas of southern Britain during the same period, for example the Early Bronze Age construction of the Stonehenge circles, Wiltshire (Kinnes, 1985, pp42-43, Renfrew 1979, pp199-218).

C. Renfrew’s prophetic argument was formulated prior to excavation of the extensive settlement at Barnhouse and Ness of Brodgar building complex, Mainland (Card in Discovery and Excavation in Scotland (DES), 2007-2014, Richards, 2005). It is noted, however, that the emergence of Orcadian elites with contacts to Ireland, mainland Scotland and southern England have now been allocated to the earlier date of the last quarter of the 4th millennium BC by more recent research (ScARF Neolithic Panel Report, Schulting et al., 2010). Feasting in Orkney may have evolved over the Neolithic period to reflect changes in society.

#### 11.5.3.2 One-off event/feast

Estimates for meat, fat and offal from cattle at the Early Neolithic causewayed site of Hambleton Hill, Dorset were approximately 250-300kg/animal (Legge, 2008, p543, p559, Healey et al., 2011, p149). At the Late Neolithic/Chalcolithic settlement of Newgrange, Co Meath, Ireland estimates for useable meat fat and offal from single cattle lay between 147 to 234kg (Wijngaarden-Bakker, 1986, p45, table 6). Differences in sex were reflected in another estimate for useable meat from Neolithic cattle (estimated at 50% of live weight) at 350kg for bulls, 300kg for castrates and 200kg for cows (Gregg, 1988, p106, extracted from table 16).

Notwithstanding the variation, each estimate demonstrates that one animal could feed hundreds of people if none, or little, of the meat was preserved. If all twenty-eight cattle from Structure 9 were killed at once, and this is probably an underestimate of the skulls deposited, the food generated could provide meat for approximately two to six thousand people (this total would exclude babies and infants who would not consume meat).

An isolated herd of feral cattle on the island of Swona, 4km south of South Ronaldsay in the Pentland Firth, abandoned for over forty years and receiving no winter food or shelter from trees and shrubs (although shelter from ruined buildings is available) has a density of one animal per 3.4 hectares. Based on this observation, and assuming half the land was suitable grazing, Neolithic Westray could have supported over six hundred cattle if there had been few sheep or red deer as competitors and little cultivated land (Hall and Moore, 1986, www.countryfile com/countryside/breed-apart-swona, accessed 16/10/12). It is therefore theoretically possible to cull twenty-eight predominately adult cattle for one event without jeopardising the survival of the herd.

However, it is unlikely that several thousand people could gather together at LON, Westray for a single feast. There may have been ten to fifteen families living in Late Neolithic communities such as Skara Brae or LON (Clarke and Sharples, 1985, p81). The actual number of people living Orkney during the Neolithic period is unknown, but based on a rather convoluted series of assumptions, C. Renfrew suggests that the total population of Orkney may have been approximately 6,000 (Renfrew, 1979, p217). The majority of participants would have to access LON by boat, a daunting logistical operation, although it is acknowledged that the land area of Orkney may have been greater than today (Lowe and Walker, 1997, Strut et al., 2013, Van de Noort, 2001, Wickam-Jones, 2011) and sea passages the preferred medium for establishment and maintenance of social relations (Richards, 2005, p21, Sturt, 2005). Boats would have carried a limited number of people per voyage and each passage would be dependent on boat availability and light/tide conditions, so it could have taken many days to bring the numbers required for a one-off feast to LON. Also, domestic flocks and herds were integral to Neolithic subsistence, so not all farmers from the Orkney archipelago or mainland Scotland could have attended a feast held any distance from their settlement because of stock maintenance duties or to use a description by I. Hodder they would have been "entangled" by their farming commitments (Hodder, 2012).

A one-off feast based on the argument outlined above, plus evidence of variation of bones associated with each skull, appears the least likely explanation for the LON cattle and sheep skull depositions. However, this view is contradicted by C. Richards, who suggests that the cattle skull deposit from Structure 9 was *"results of an expenditure of wealth, through mass slaughter and consumption"* (Richards 2013, p80). It is noted that 120 cattle astragali recovered at Skara Brae, Mainland must have come from a minimum of sixty animals, but it is suggested they had been preserved over time, not remnants of one feast (Stewart and Boyd, 1914, p346, Childe, 1931, p33). The rejection of a one-off feast does not imply that there were no representatives from out with the community who attended feasts in Westray, simply that they were not numerous enough to justify the slaughter of a minimum of twenty-eight cattle.

Another factor to support rejection of a one-off feast is the level of exploitation of the skulls; the absence of unbroken or articulated limb bones and the careful removal of all mandibles, indicating no food was wasted. It is probable that less waste occurred in archaeological sites from small or intermediate feasts than large ones (Albarella and Serjeantson, 2002, Hayden 1996, p49, Serjeantson, 2006, p123, Twiss, 2008, p422, table 1, Thomas, 1999, p218). As a contrast to LON, articulated portions of cattle limb bones were recovered from the Early Neolithic causewayed site of Windmill Hill, Dorset (Grigson, 1999) and the Late Neolithic settlement of Durrington Walls, Wiltshire (Parker Pearson et al., 2011, p86), both considered to be sites of large communal feasting events.

#### 11.5.3.3 Multiple feasts/rituals and curation of skulls

The most likely explanation for the source of cattle and sheep skulls deposited in LON Structures 9 and 18 was that they were from more than one feast or ritual, held either at LON, Westray or elsewhere, and that some skulls were preserved as memories from earlier events, and deposited in Structure 9 and 18 at a later stage, perhaps accompanied by some skulls consumed immediately prior to deposition. The isotopic evidence gives no indication that any cattle skulls used for Structure 9 deposition were grazing in areas where environmental conditions varied from those of Westray. The skulls had been carefully butchered to ensure the frontal/occipital area containing the horncores remained intact. The pelves in Structure 9 may also have been carefully curated or associated with a feast prior to deposition, the latter explanation offered for the pelves and scapula bones recovered with cattle skulls at the early Bronze Age barrow at Irthingborough, Northamptonshire (Davis and Payne, 1993, Russell, 2012, p107).

It is possible that skulls were initially left in locations that promoted loss of flesh and skin, transforming them into more attractive material symbols, or they were part of hide costumes that eventually disintegrated. Evidence that some skulls were curated is (i) their presence in niches within Structure 18 (ii) some interior skull bones retaining better surface condition (iii) differing amount of skull bones per skull and the low incidence of protruding bones such as complete zygomatic arches (iv) missing teeth from maxilla alveoli in Structure 9, even when deposited with maxilla facing upwards (Hambleton, 2013, pp483-486). At Irthingborough, Northhamptonshire it was suggested that most of the skulls/loose maxillary teeth recovered originated from curated skulls (Davis and Payne, 1993, Russell, 2012, p107).

In Structure 18 a few cattle skulls had chop marks on their occipital condyles, others not, perhaps suggesting that the separation of the post-cranial body from the skull was not identical on every occasion. In addition, one sheep skull displayed scorching on the occipital condyles. These slight variations may also provide supporting evidence that the skulls were not from one event, but a series of different feasts or events.

Other examples of curation prior to deposition of cattle bones include the Early Neolithic site at Windmill Hill, Wiltshire, where it is proposed that processed cattle bones may have been located in middens or surface spreads prior to their incorporation into the causewayed ditches (Whittle and Pollard, 1999, p386). At the Late Neolithic site at Stonehenge, Wiltshire, two right cattle mandibles, a crushed cattle skull and a red deer tibia pre-dated the construction of the enclosure ditch, indicating that these bones had been kept for many years before being placed in their final contexts. The mandibles were in good condition but had lost their teeth, and it is thought that they either been retrieved from middens or deliberately stored (Ray and Thomas, 2003. p40, Serjeantson, 1995, p449).

### 11.5.4 Selection of LON cattle skulls

Since the farming communities were established in Orkney at least half a millennium earlier than the construction of LON Structures 9 and 18, a deep understanding of the genealogy and biographies of ownership of herds and flocks at LON must have existed (Case, 1969a, Jones, 2008, p178, Marciniak, 2011, p36, Pollard, 1996, p139, Thomas, 2013, p409). Cattle are long lived and produce relatively few calves over a cow’s lifetime, making their population structure comparable with those of humans (Orton, 2010). Given the preponderance of adult animals in the skull deposit, and the intimate and close relationships Orkney Neolithic farmers would have with their livestock, it is possible to speculate that many would have had been individually recognised with known genealogical histories and links with memories (Jones, 2008, p178, Thomas 2013, p409). For example, it seems probable that the older bull skull (F4458) with asymmetric horns was a familiar animal in the LON community and his skull instantly recognisable. The lack of calves skulls and small numbers of younger animal skulls, which dominated the midden areas examined at LON, may reflect that relationships between farmers and animals that died or were culled early were less well developed.

The deposit at Structure 9 included at least one cattle carrying an mtDNA haplogroup associated with aurochs genes being present through the female line. Based on field measurements another skull may also have belonged to an aurochs. In addition, a 3rd maxillary molar of a cattle skull from Structure 18 had slightly larger dimensions than expected from domestic cattle. Horn shapes of all deposited skulls with sufficient horn cores remaining, were simple curves, the beginning of the "*primigenius*" spiral, although the mtDNA results demonstrates that at least some of these animals were from domestic haplogroups. Other Neolithic site reports have noted that the cattle appear to resemble small aurochs, from the Mid- Neolithic farmstead at Knap of Howar dimensions "overlap with lighter aurochs" (Noddle, 1983, p97) and at D. Clarke's earlier excavation at LON it was stated that, based on measurements, that recently domesticated aurochs or aurochs/domestic hybrids were present (Armour-Chelu, 1992, p168). However at Skara Brae an earlier animal bone report concluded that "oxen possess no special resemblances of significant character to *Bos primigenius*" (Watson, 1931, p202), although B. Noddle in a later publication contradicts this by stating that some horn cores from Skara Brae as "typical of the aurox form" (Noddle, 1979, p294).

The large size of cattle, and their distinctive horn core shapes persisted for many hundreds of years after first arrival in Orkney, a period over which there would have been adequate time to select for cattle of smaller stature or horns that did not grow forwards and upwards, both characteristics which might have rendered them easier to handle and reduced the requirement for winter fodder (Barker, 1985, p30), although some researchers dispute that reduction in size makes cattle more tractable (e.g. Jarman and Wilkinson, 1972, p84).

It is therefore possible that as well as their capacity to provide food, LON cattle were selected and maintained to be "aurochs-like" because of the desirability of these characteristics for ceremonies and feasts. Earliest written descriptions of aurochs convey the impression of fearless and impressive animals. For example in Julius Caesar's Gallic Wars 6.28 "[t]heir strength and speed are extraordinary; they spare neither man nor wild beast which they have espied (Twiss. 2008, p421), so perhaps fierce and strong animals were preferred. Even modern bred-back aurochs (Heck cattle) are extremely fierce and unmanageable (Zeuner, 1963, p205, Times 6th January, 2015). In the earlier Levels VI and V at the Neolithic site at Çatalhöyük, Turkey where although most of the deposited midden bone was from domesticated cattle, the artistic representation on walls and deposition and display of cattle bucrania were aurochs (Hodder, 2012, p109, Russell et al., 2005, Twiss, 2008, p437) and these high value and symbolically powerful animals may have been important for specific cultural events (Arbuckle and Makarewicz, 2008, p683).

Hunted wild animals may have been regarded as independent, perhaps as part of the same community as humans, or as spirits (Ingold, 1980, p282, 1988, p15, Robb, 2013, p663, Russell, 2012, p156, Tapper, 1988, p52) whereas domesticated animals may have been regarded as controllable objects, as possessions and as vehicles of exchange (Davis, 1987, p126, O'Connor, 2000, p147, Russell, 2012, pp209-213). This dichotomy is probably too simplistic (e.g. Ingold 1988, p15, Tapper, 1998, p53) but the belief systems at LON settlement may have regarded it important for domestic cattle to retain wild cattle characteristics.

It is possible that aurochs skulls were deposited at LON with other skulls, as was the case in some of the early southern British Neolithic causewayed camps such as Windmill Hill and Etton (Grigson, 1999, Pryor, 2006). The deposition of a red deer fawn skull in the doorway adjacent to the passageway and antler deposits in the foundation course, Structure 9 also show that this potentially wild species was not excluded from deposition within buildings. It is noted that the distinction between wild and domestic cattle following the Linnaean species classification system in use today may not have been as clear-cut in Neolithic Orkney (e.g. Clark, 1952, p92 Hodder 1990, Thomas, 1991).

### 11.5.5 Possible sequence of LON cattle skull deposition

It was proposed that the sequence for cattle, and possibly, sheep skull deposition was as follows:

- Breed/acquire
- Nurture
- Cull (either normally or under ceremonial circumstances)
- Consume (possible feast if cattle)

- Convert to object
- Curate
- Deposit

Neolithic settlers must have regarded their cattle as a form of wealth and status (Russell, 2012, pp298-304) and considered them as part of their community (Thomas, 2013, p408). The shared genealogical histories of cattle and people living in Late Neolithic Orkney have led some researchers to suggest that farmers had a "fictive kinship with cattle" (Ray and Thomas, 2003, p38). However, although it appears that cattle were predominately selected for deposition, certain sheep, and a red deer fawn, also merited special treatment perhaps indicating relationships existed with species other than cattle.

It is also probable that cattle represented a living social capital (Hayden, 1996, 2001, Russell, 1998, p45, Thomas, 2013, p409). Once dead, perhaps it was important for the LON community to recognise the lost potential of the animal, to give it a new role in death.

## 11.6 LON red deer deposition

### 11.6.1 General

Red deer bones have been recovered from three different locations in Neolithic Orkney (i) midden material at settlements (ii) cairns (iii) articulated or semi-articulated deposits within rubble infill or above settlement middens. Since all elements red deer skeletons and all age groups were represented it is probable that red deer lived on Orkney and remains were not the result of selective import of meat joints and antler.

Red deer could have produced antler for tools, an important renewable resource prior to the advent of metal for the LON community. They could also have supplied meat, fat, hides and sinews, potentially acting as back-up supplies in cases of failure of domestic stock production even although red deer are not such efficient converters of vegetation into protein as cattle and sheep (Jarman, 1972, p137). Additionally red deer may have fulfilled a role in hunting, perhaps still regarded as relevant in Neolithic society, red deer having been the main large mammal prey for Scottish Mesolithic communities during the preceding five thousand years (Jarman, 1972, p131, Wickham-Jones, 2006, p29) or met needs of rituals requiring non-domesticated mammals.

### 11.6.2 Procurement

Red deer were present on Orkney, from, as a minimum, the Late Neolithic to the Norse period (approximately four thousand years) so it is probable that their populations were in equilibrium with their food supply and the human community and perhaps did not suffer a population explosion after arrival followed by collapse and extinction (Clutton-Brock and Albon, 1989, Klein, 1970, Williamson, 1981), although multiple restocking cannot be ruled out. As well as culling by humans, the populations would be influenced by factors such as:

- Availability of grazing
- Winter temperatures
- Wind speeds
- First conception in hinds
- Other physiological factors

(Clutton-Brock et al., 1982, McVean and Lockie, 1969, Boyd and Boyd, 1989).

A modern example of herbivore population fluctuations is from the island of Hirta, St Kilda, Western Isles. Soay sheep have roamed free on this island since 1932 when the island group's human population was evacuated. This sheep flock is not managed, has no wild or feral competitors and is subject to little predation. Between 1985 and 2000 this population has fluctuated, with the peak population being over three times greater than the lowest (663 versus 2022) (Clutton-Brock et al., 2004, p53, p54, fig 3.1). When resources are limited over half the sheep flock can starve in late winter, a mechanism for population regulation. Juveniles, being smaller than adults, die first, because their lower body reserves are depleted faster through higher thermoregulation requirements. Parasitism may also be a contributory factor in the deaths of these weak animals (Clutton-Brock et al., 2004, p44).

It is assumed that Neolithic people in Orkney chose not to eliminate red deer (Sharples, 2000, p112). Added to this is the possibility that without modern weapons or horses it might have been difficult to remove the red deer population completely even if this was desired. It is difficult to kill red deer in one to one encounters in open ground (Legge and Rowley-Conwy, 1988), particularly without guns. For example, one hind from the herd introduced to Mainland, Orkney in the mid-19th century was not encountered during the cull in 1870/72 and left on the hill until she succumbed to old age (Buckley and Harvie-Brown, 1891, p82). Current red deer stocking levels in Scotland vary from 25/km$^2$ in Grampian; 5-10/km$^2$ in Lewis and 2/km$^2$ in Skye (Scottish Natural Heritage, 1996). If a stocking rate of 5/km$^2$ is assumed then, for the present day land area of Westray, a theoretical maximum herd size of 235 animals could have been reached.

Three main hunting tools/techniques may have been available for capture of red deer in Westray (i) communal hunting (ii) trapping (iii) elite hunting.

Red deer could have been acquired by communal hunting when a herd was driven into a trap or over a cliff and then attacked indiscriminately (Davis, 1987, pp111-114, Kenyon, 1997, O'Connor, 2000, pp133-136, Reitz and Wing, 1999, p267). Barriers to guide red deer into traps could have been constructed from stones, turf or even seaweed (McGovern, 2000, Sharples, 2000, Wickham-Jones, 2001). Nets are another option and Boece's 1531 Scotorum Historia suggests that "Picts" stretched nets across meadows droving the deer into them (Gilbert, 1979). Both types of communal hunting would be possible in Westray since there are cliffs close to LON at Noup Head and evidence of Bronze Age walls (G. Wilson, per comm.). Netting has been preserved in several continental European Neolithic deposits (Clark, 1952, p227). The remains of an adult stag from a Bronze Age site on Moaness, Hoy, Orkney (listed as Moaness, Raasay, Orkney) reveals that the animal had been driven into a bog, another form of natural trap, and then partially butchered (I. Mainland, unpublished, in Mulville, 2010, p48).

Secondly red deer traps or pits could have been installed to protect cultivation areas in Neolithic Orkney since there is evidence of cereal production in this period (Bishop et al., 2009, table 1, Balter, 2014, p23). There are many contemporary Scottish records of red deer raiding crops (Hull, 2007, p260) and red deer introduced to Melsetter, Mainland, Orkney in the mid-19th century were eliminated for this reason (Buckley and Harvie-Brown, 1891, p82). Spring grown crops would need protection from April to July (Case, 1969a, p177). In Scotland an alder trap has been radiocarbon dated to AD 4-6th century (Alcock, 2003, p417, Foster, 2004, p52). Initially this find was considered to be an otter or beaver trap, until a connection was made between the trap and an illustration on the Iron Age Clonmacnois slab in Ireland (Clark, 1952, p53, 1957, p187). A replica confirmed that a deer placing its foot in the trap would not escape or drag it away (Munro and Gillespie, 1919, Graham Smith, 1923). Historic examples of this type of trap are held at the Danish Hunting Museum, Horsholm and the National Museum of Ireland, Dublin. The only possible evidence of the use of a trap at LON is an unhealed perforation in one red deer astragalus and the possible faint "cut marks?" on two calcanei.

Thirdly there may have been skilled/prestigious hunting. In the Scottish early historic period, there is evidence of horses, spears, bows and hunting dogs used to pursue individual red deer in hunting scenes from post-Christian Pictish monuments, designated class II monuments (Henderson, 1993, Gilbert, 1976). Using dogs to hunt was also described in the AD 6th century Celtic lament "the Gododdin" (Aneirin, edited by Short, 1994). By the Scottish Iron Age it may only have been the elite that had the time, skill, weapons and rights to hunt but this may not have been the situation in Neolithic Orkney. There is no evidence of horses and dog remains are rare.

Bows have been recovered in Scotland during the Late Mesolithic/Early Neolithic in Scotland, for example, a yew (*Taxus baccata*) longbow, radiocarbon dated to 4040-3640 cal BC, recovered from the Tweedsmuir Hills near Moffat (www.canmore.rchams.gov.uk, accessed 23/10/14). Most flint arrowhead finds in Neolithic Scotland are currently associated with large accumulations at Culbin Sands, Moray, Glenluce Sands, Wigtownshire and Little Ferry, Sutherland (Clarke, 2004, pp47-48) but a few leaf-shaped arrowheads or crude leaf-shaped arrowheads have been recovered from Knowe of Yarso and Unstan cairns in Orkney (Davidson and Henshall, 1989) and from LON (G. Wilson pers comm.). In addition, the use of simple weapons such as stones, bolas or wooden lances which would leave little trace in the materials record cannot be ruled out. There were no obvious hunting injuries on the bones apart from an unhealed depression on the lateral face of a red deer pelvis at Blackhammer cairn and stored in the NMS Collection Centre, and the unhealed depression on one LON ulna.

Although it is very probable that LON settlers culled red deer and so, to a greater or lesser extent “managed the herds” to sustain a population below the island’s carrying capacity, there is not sufficient evidence to deduce which method (s) of culling were adopted, but all three methods discussed are viable options.

### 11.6.3 LON articulated red deer skeletons

The current LON excavation supports, and adds to, the evidence of deposition of complete or semi-complete articulated red deer skeletons recovered in D. Clarke’s previous excavation. In the same area of LON where these fifteen red deer were found (Armour-Chelu, 1992, pp266-267, Sharples, 2000, pp111-113) bones from up to eight red deer were recovered, all fawns/juveniles. At least two of the animals from the current excavation were in the age range of 5-10 months; one was 10-14 months old. These ages would agree with the suggestion of spring death for some of the fifteen red deer recovered during the previous excavation (Armour-Chelu, 1992, p267). As discussed previously, since the bone count used for the calculation of MNI in the earlier excavation is not provided, it would be inappropriate to add the two totals of red deer recovered together.

The red deer skeletons are semi-articulated and must have been covered rapidly after death to prevent the dispersal of bones through carnivore/pig/bird scavenging or other factors such as wind blow. The recovery of many of long bone epiphyses adjacent to their diaphyses supports this. There is no evidence these remains had been exploited for meat since filleting is unlikely to have left partial or almost complete skeletons lying in the correct anatomical configuration (Serjeantson, 2011, p72). The red deer articulated skeletons were in association with cattle and sheep bone fragments, which, in contrast to the red deer bones, demonstrated evidence of butchery.

There were also some articulated red deer skeletons recovered from infill to Structure 10, Area 5, adjacent to a kiln. A minimum of three red deer were noted (i) a mature adult with an almost complete articulated skeleton (ii) additional bone fragments for another adult and a fawn. The almost complete articulated skeleton had several pathological features, the most notable being an example of “spavin” on the right hindfoot. This adult red deer was radiocarbon dated to the end of the Late Neolithic period in Orkney. The other feature of this deposit were surplus red deer ulnae- seven left and four rights, three/four from adults and four from sub-adult/juvenile/fawns. None of these bones were complete and all had breaks in the distal diaphysis, some closer to the articulation complex than others. These did not appear to be part of other red deer skeletons, so, speculatively, they were discarded tools/points but no wear analysis is possible since distal diaphyses were not recovered.

These relatively intact red deer skeletons may have been culled or died relatively close to the settlement, or were transported from elsewhere. If culled at a distance from the site and transported by land, it would, however, be more efficient for the carcass to be segmented and elements such as the head discarded and/or consumed at the culling site (Legge, 2008, p551).

The only LON red deer bone directly radiocarbon dated (F11013) produced dates between 2580 and 2349 cal BC, the end of the Late Neolithic/Chalcolithic period. More radiocarbon dates are required to determine if the other articulated deposits are also from this period.

Three previous explanations offered for the first set of fifteen red deer skeletons recovered at LON were:

- Feeding on crops growing around settlement and slaughtered to prevent further incursions (Armour-Chelu, 1992, p267)

Evidence of cultivation in Neolithic Orkney includes ard marks at LON (Clarke and Sharples, 1985, pp73-75, H. Moore pers. comm.) and charred cereal remains at settlements such as Pool and Tofts Ness (Bishop et al., 2009, table 3), Skara Brae (MacLean and

Rowley-Conway,1984, p670, Barnhouse (Hinton, 2005, p340), Ha'Breck (Balter, 2014, p23) and LON (Clarke and Sharples, 1985) and cairns such as Isbister, Knap of Howar (Bishop et al., 2009, table 3).

- A carefully collected, arranged and protected red deer deposit with its potential not realised (conspicuous non-consumption) because red deer were regarded as distinctive (Morris, 2005, Sharples, 2000)

N. Sharples considered that the red deer deposit had been modified prior to, or during, deposition with the addition of a detached set of antlers, bones from a cod and two bird wings, one which appears to be a gannet, indicating that the deposit had been arranged by humans (Sharples, 2000, p112).

- Red deer slaughtered for a special event and not a simple butchery deposit. Placed at the periphery of the settlement, this special event might be remembered by the stench of rotting carcasses (Ritchie, 2004, p97)

Another three possible explanations are now offered:

- Red deer sheltering from wind to reduce heat loss and energy consumption behind the protection of walls in unoccupied areas of Links of Noltland succumbed in the late winter/spring

Shelter is the equivalent of ameliorating the climate by a few degrees (Leach, 2003) and reduces loss of body heat (Clutton-Brock and Albon, 1989). Bones from fallen animals, for example, present day North Ronaldsay sheep, do not remain in articulation, with epiphyses still attached, for more than a season, so, for this explanation to be viable, red deer bones must have been covered rapidly by wind-blown sand. The LON red deer age profiles and season of death could support this scenario. For example, in Rum, Inner Hebrides, the mortality after a hard winter of 1978/79 was 34.8% of male fawns and 34.5% male yearlings; 15.8% of female fawns and 25% of female yearlings, so losses from a Westray herd would be a possible source for the articulated skeletons. In addition, although hinds and their followers (males and females up to three years old) generally form different groups from stags out-with the autumn rut there may be up to 10-20% of older stags in association with hind groups during winter (Clutton-Brock, 1982, pp178-179, Legge and Rowley-Conwy, 1988), so the presence of an adult male in the earlier LON excavation deposit does not necessarily imply that the deer came from more than one group

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- Red deer captured in traps or herded into killing areas when weak in late winter/early spring, too lean for profitable meat exploitation, but skins possibly providing a valuable resource

Evidence on the red deer bones for skinning is sparse. However, the presence of broken ulna bones that could be used as pegs adjacent to one articulated skeleton is of note. The possibility that LON red deer was exploited for skins was rejected by N. Sharples because of absence of cut marks and presence of metapodials (Sharples, 2000, p115, note 6). It is unlikely that if red deer skins were exploited some distance from the settlement that carcasses would have been transported back to the settlement.

- Culling red deer herds (Clutton-Brock, 1979, p120, Jarman, 1972), perhaps to control numbers but ensure continuity of antler. The removal of males and young animals would be the least destructive for continuation of herd (Chaplin, 1983, p42, Jarman, 1972)

Late spring, a date when many of LON articulated red deer died, is a poor time of year for obtaining venison. A more favourable time for culling would be autumn when the red deer were in good condition after feeding on spring and summer growth and congregate together during the rut (Boyle, 2006, p20).

Based on current evidence it is not possible to determine which of these explanations is superior, but ritual deposition promoted in an earlier publication (Sharples, 2000) and referred to with more circumspection by later authors (e.g. Morris, 2005, p11, Jones and Richards, 2003, p50, Ritchie, 2004, p97, Thomas, 2013, p413) is only one of a number of viable options. Red deer culled at this in late winter/early spring would not be in prime condition, reducing the non-realised potential of their carcasses (ritual loss) although trapping/skinning is possible.

Alternatively, perhaps societal changes were taking place in Westray in the Late Neolithic/Chalcolithic and management of the red deer herds had declined leading to increased numbers of starving red deer sheltering behind walls in unoccupied areas of the settlement during late winter and dying “in situ”. Red deer bones were recovered from the Iron Age site of Brest Ness (BNKS) on Westray however, so if there was a collapse in red deer populations during the Late Neolithic/Chalcolithic it did result in total elimination of the species from the island.

In contrast to the LON cattle skull depositions, there are no other records of similar red deer articulated skeleton in the Neolithic of Britain, apart from a red deer articulated leg recovered from the late Neolithic Stonehenge Avenue ditch (Serjeantson, 2011, p65) and cranium remains of a juvenile in the Late Neolithic level at Windmill Hill (Grigson, 1999, p233). In addition, some unarticulated red deer bones were part of a collection of pottery, wild and domesticated animals recovered from a pit, the Coneybury Anomaly, Wiltshire, in the Early Neolithic period, one of the earliest features in the Stonehenge environs (Thomas, 2013, p246, Whittle, 2003, p234). As the pit name implies, either deliberately or coincidently, this find has no parallels at other British Neolithic sites.

### 11.6.4 Other Neolithic/Chalcolithic Orkney articulated red deer accumulations

These finds were presented in *Chapter 5*. The red deer bone accumulation at Bay of Skaill, dated to the end of the Late Neolithic or the early Bronze Age in Orkney, was associated with a hearth, although bones were not burnt, and with partial butchery of red deer carcasses. This pattern of off-site butchering adjacent to a wall at the edge of the (possibly no longer occupied) Skara Brae settlement may have similarities to the treatment of red deer in V.G. Childe’s excavation of the uppermost layers of his Skara Brae excavation. There is not enough data on semi-articulated portions and red deer bone accumulations from Point of Buckquoy other than to state that they may date from Bronze Age and that red deer were being processed in Orkney during that period. The articulated red deer skeletons from Ness of Brodgar may be from a post-Neolithic date, possibly around the closure of the site as a ceremonial centre, or representing the demise of a red deer in the abandoned structure.

### 11.6.5 Red deer midden deposits in Neolithic Orkney settlements

Small numbers of red deer bones have been recovered from Neolithic settlement middens at Pool and Tofts Ness, Sanday, Skara Brae, Mainland and from D. Clarke’s earlier LON excavation. The current excavation at LON has produced the only assemblage in which some butchery marks and spiral diaphysis breaks are recorded, apart from the single chop mark on the neck of a scapula at Tofts Ness; Sanday (Nicholson and Davies, 2007, p183).

Even assuming that red deer bones at settlements included meat processing remains and not merely refuse from skinning and tool-making, the contribution of venison to the diet in Orcadian Late Neolithic settlements was modest. This may imply that the red deer population was not sufficiently large to merit intensive hunting or trapping. So, either the red deer herds were predominately left alone, apart from passive collection of antler, or most red deer meat returned to settlements off the bone. Although there is a trade-off between carrying butchery tools to hunting sites versus carrying complete carcasses back to the settlement (Metcalfe and Jones, 1988, Winterhalder, 2001) in Westray the ubiquitous Skaill knifes could have been manufactured "*in situ*" at kill-sites as required.

Red deer bones were not well represented in settlements in southern Britain, a time when wooded environments would have ensured that this species would have flourished. Red deer in southern Britain may therefore have been (i) rarely exploited (ii) consumed away from the settlements or (iii) consumed at settlements and their bones disposed off-site (Pollard, 2006, pp136-137, fig 10.1, Serjeantson, 2011, p40). These possible scenarios are also applicable to Orkney during the Neolithic period.

### 11.6.6 Cairn deposits in Neolithic Orkney

No cairn red deer bones recovered in Orkney have currently been accurately radiocarbon dated to the Mid Neolithic, only the Late Neolithic. There are, in contrast, calibrated radiocarbon dates from the Mid Neolithic for human bones, the period when it is assumed that Orkney cairn construction began, although these dates are only available for deposition of human bones, not for the earliest building activities (Barber, 1997, p7, p60, Ritchie, 2009, p27).

At two cairns on Rousay, Knowe of Ramsay and Knowe of Yarso, red deer bones, some charred, dominated the assemblage. Butchery evidence confirms that these animals were not the remains of living animals seeking shelter. It is therefore unnecessary to invoke an argument that red deer could not have entered the cairn naturally (Morris, 2005, p10, Ritchie, 2004, pp97-98). Whole carcasses were transported into the cairns, so deer were culled or died within reasonable carrying distance or sourced elsewhere and transported by boat to the shore below the cairns and carried up-slope. Seabirds in the cairns may also be from the shore area, another possible wild food source.

The red deer ageing data suggests, in the case of Knowe of Ramsay at least, that animals were acquired at different times of the year and importation of carcasses was not a one-off event. The data also highlight that although adult deer were dominant, other age classes were represented. In the original description of young and adult red deer bones were recovered from most cells at Knowe of Ramsay (Platt, 1936). At Knowe of Yarso twenty-two animals were adults, including older adults, four young and the rest unidentified (Platt 1935). This age of death pattern perhaps does not indicate a mass slaughter of a herd, when a larger proportion of fawn, juvenile and sub-adults might be expected. The only evidence of how these animals may have died is a skull fragment with a vertical crack running through the parietal bone, possibly resulting from a blow to the head.

Fires were lit in both Knowe of Ramsay and Knowe of Yarso but charring on red deer bones was rare, suggesting these bones had not been used as a source of fuel and may have been marked by incidental burning (Costamagno et al., 2004). Internally cairns were dark and if either a ceremony or butchering/cooking took place then fire would have assisted by producing light as well as heat. There were no traces of burning on red deer bones examined at the NMS Collection Centre from Blackhammer, Rowiegar, Quoyness, Holm of Papa Westray North and Lairo. In addition, there is no published record of burning within cairns at Cuween, apart from the west cell which had traces of fire (Charleston 1902) or at Isbister (Barker, 1983), Unstan and Wideford Hill (Davidson and Henshall, 1989). At Quanterness cairn there was sporadic evidence of burning or charring of bones (Clutton-Brock, 1979) and it is thought that “mourners light a fire in the main chamber using heather and brushwood and food would be prepared” which could then be eaten or left for the dead”(Renfrew 1979, p168).

Various options on red deer arrival in cairns is as follows:

- Offerings/ sacrifices or remains of feasts conducted at Late Neolithic interments or occasions when ancestor remains were revisited (Barker, 1983, p143, Clutton-Brock, 1979, p114, Hedges, 1983, p269, Renfrew 1979, p156, Richards et al., 2013, Sharples, 1984, p113)
- Midden material, with associated animal bone fragments, carried into cairns for some purpose, although arguments against this have been outlined (Henshall, 2004, p89) and the LON midden material examined contained only small numbers of red deer bones
- Refuges for either hunters or displaced settlers after the belief system associated with deposition of community dead were no longer potent. V.G.Childe suggested red deer bones from the upper layers of his Skara Brae settlement excavation may have been remains of feasts after settlement abandonment (Childe, 1931, p62). It is possible that displaced people, perhaps with no access to domestic stocks, were using the cairns as shelters and subsisting on red deer, wildfowl and shellfish
- Remains from non-subsistence hunting, for example trophy, weapon practice, or “rites of passage” (Boyle, 2006, p19)

More detailed radiocarbon date analysis would be required to explore these proposals. There is already evidence of later animal bone deposits in Orkney Neolithic tombs, for example at Quanterness, Mainland, a horse bone was dated to 988-1261 cal AD (Hedges et al., 1995) and at Blackhammer, Rousay, one cattle 3rd phalanx deposited in the upper layers of cell 1 or cell 2 was radiocarbon dated to 1890-1770 cal BC, a later Bronze Age date (Sheridan, 2005, p182).

It is difficult to deduce why red deer bones were so dominant in only two of the cairns in Orkney for which detailed records of animal bone deposits are available. It is unlikely that the red deer were given unimpeded range on Rousay since there is evidence of domesticated animal bone in the cairn deposits and a settlement at Rinyo (Childe and Grant, 1939). Red deer have been recorded as swimming up to 7km in Scotland (Whitehead, 1993) a distance far greater than the width of channels separating Rousay to Mainland and other adjacent islands. The deer could have therefore migrated to and from other Orkney habitats so it is unlikely that they absent from other areas of Orkney. So, either the people using these two cairns had a commitment for use of red deer for funerary or initiation ceremonies, an affiliation that distinguished themselves from users of other cairns in Rousay and other locations in Orkney, or the ruins of these cairns were deemed particularly suitable for butchering red deer carcasses by hunters or displaced people.

### 11.6.7 Red deer antlers

Antler may have been a useful resource for manufacture of antler tools (Grigson et al., 1981, p196) and it is possible to speculate that this may have been an incentive to the possible introduction and management of red deer herds in Orkney. It is possible that red deer herds were not eradicated from Orkney during the Neolithic, Chalcolithic and Iron Age because of the importance of antler, even though red deer would have competed with cattle and sheep grazing, the highest niche overlap being in spring (Putman, 1996) and may also have marauded newly sprouting cereals.

Recovery of antlers adjacent to cattle in the foundation course, Structure 9, the collection of antlers at Holm of Papa Westray North cairn and shed antler fragments in other cairns may indicate both a practical, but possibly also a belief-driven role, for this resource. A study of red deer introduced to Sardinia in the Late Neolithic period deduced that they had been introduced for symbolic rather than economic reasons (Vigne, 1999, pp312-313). The importance of antler in Late Neolithic Orkney may therefore have been under-estimated, because its lower density than longbone resulted in low recovery and/or poor identification rates for small fragments. This suggestion contrasts with the view of the earlier excavator at

LON who states that “the absence of antler tools in any quantity suggest that the deer were being regularly exploited for food and skins” (Clarke and Sharples, 1985, p77).

Red deer antlers, predominately shed, have been recovered from ceremonial settings, or as special depositions in ditches and mines, at many British Neolithic sites (Clark, 1952, pp48-49, Clutton-Brock, 1984, Grigson, 1999, p206, Legge, 2008, p550, Piggott, 1954, Pollard, 1995, Serjeantson, 2011, p40, p77, Sharples, 2000, p109, Thomas, 2013, p380, pp412-413). For example, at the Late Neolithic site at Woodhenge, Wiltshire, there appeared to be deposits of bundled antler picks in the base of a ditch which may have been intentionally covered after deposition and 25% of the post-holes of the monuments six rings contained antler fragments (Pollard, 1995, p145, p147). At Durrington Walls in the Late Neolithic a cluster of fifty-seven antler picks were left on the base of the terminal ditch (Thomas, 2013, p413). It is therefore possible that red deer antlers in Late Neolithic Orkney may have had a symbolic as well as a utilitarian value. C. Tilley has argued that red deer fulfilled a symbolic role in the Neolithic in Scandinavia based on the use of red deer bones for tools and decorative objects and the deposition of unworked antlers in burials. He speculated that the fertility symbolism of annual antler regrowth may have been an important behind these archaeological phenomena (Tilley, 1996).

## 11.7 LON mammal bone deposits

### 11.7.1 General

LON mammal bone deposits in middens and infill contexts examined were dominated by cattle and sheep, with cattle contributing the largest quantities of meat to the settlers’ diet. The skull deposits from Structures 9 and 18 therefore reflect herds and flocks maintained at the site, but cattle skulls were deposited preferentially. LON mammal exploitation appears to reflect a mature, stable, non-experimental husbandry regime. Detailed analysis of eight 10cm spits from midden material from Context 7302 reflects no change over the period when this material was deposited, although some material in this midden may have been redistributed or cultivated after initial deposition.

The dominance of “domestic” mammals reflects the pattern from Early/Mid Neolithic monumental and non-monumental sites in southern Britain with cattle, sheep/goat and pig comprising 97% of archaeozoological material recovered from causewayed enclosures, mortuary monuments, settlements and other sites. At causewayed enclosures and mortuary sites cattle dominated by NISP, with pig and sheep in equal second place, but at settlements, cattle NISP dominate, with pig the next most abundant species (Schulting, 2013, p316, p318, table 16.2, Serjeantson, 2011, pp16-17, figs 2.3-2.6). Unlike Orkney, sheep are not represented in significant numbers until the Bronze Age (Serjeantson, 2011, p29, Tinsley and Grigson, 1981, p225) possibly because forests still dominated the landscape in the Neolithic period (Clark, 1947a, p136).

Dominance of cattle and sheep in Orkney may therefore have been a response to the topography, soil, vegetation and climate (Barrett, 2011, p83, Clark, 1952, p121) and poor representation of pigs due to lack of woodland feeding and their destructive behavior in open pasture (Clarke, 1998, p16, McCormick and Buckland, 2003, p91). Certainly in the 16th to 19th century it was considered important to curtail rooting activities of semi-wild Orkney pigs on pasture and arable land (Fenton, 1978, p496, Heddle quoted in Buckley and Harvie-Brown, 1981, p90) but lack of tree cover and strong winds did not seem to present difficulties to these animals. Pigs are omnivores, eating almost any material of organic origin efficiently and converting one-fifth of what they consume into food for human consumption, occupy different feeding niches from sheep and cattle and reproduce quickly (Crosby, 2004, p173) so it would be surprising if at least a few domestic pigs were not kept as “living refuse disposal units” even if not allowed free range in Neolithic Westray (Fenton, 1978, p496).

Over ninety percent of cattle, sheep, red deer and pig bones recovered from the eight areas under study at LON were incomplete. Intact bones were predominately phalanges, carpals and tarsals. No meat bearing cattle bones were complete, but some sheep long bones and mandibles remained intact. Medium bone fragment weights for each area were low when compared with weights of unbroken bones, indicating high levels of fragmentation. Most cattle and sheep long bones had spiral breaks in the diaphysis, indicating they may have been broken just after the animals’ deaths either for cooking purposes, to extract marrow and/or produce blanks for tool manufacturing. The evidence therefore suggests that domesticated mammals culled at LON were carefully exploited.

The LON mammal bone representation was similar to the earlier Mid Neolithic settlement in Orkney, Knap of Howar, showing no evidence, even at this earlier stage of the Neolithic, of experimental agriculture. Sufficient understanding of environmental constraints (Conolly et al., 2012) may have been known to incoming farmers prior to full settlement. This relative stability of husbandry contrasts with changes in material culture over the Mid/Late Neolithic in Orkney, for example the emergence of Grooved ware pottery and progression from cairns to monumental architecture. It has been suggested, based primarily on lipid analysis from pottery shards from Barnhouse Neolithic settlement, Mainland, that consumption of cattle products was associated with Grooved ware pottery (Jones and Richards, 2003, p48), but cattle were the dominant species at Knap of Howar, a site where Unstan ware pottery was in use, although some pottery shard features may be related to Grooved ware (Clarke, 2003, p86, Ritchie, 1983).

## 11.7.2 Age of death of LON domestic mammals

### 11.7.2.1 General

Results from LON cattle and sheep “age of death” profiles and other Orkney Neolithic settlements sites are consistent. The pattern appears to have been established from the Mid Neolithic onwards, and was also observed at the Early Neolithic site of Runneymede in southern England (Serjeantson, 2006, p118, table 9.4). The analysis assumes that cattle were born at, or adjacent to the settlements, but intriguingly an earlier alternative interpretation was that Scottish Neolithic cattle were semi-wild and “inhabitants found it easier to slay the young than old animals” (Ritchie, 1920, p59). Research on birth seasonality from stable isotope measurements ($\delta\ ^{18}O$) of teeth indicates that sheep had strong seasonality of birth at Knap of Howar, Papa Westray, perhaps because of harsh climatic conditions (Balasse and Tresset, 2007, p82).

### 11.7.2.2 Cattle

A large proportion of LON cattle bones were from individuals who died in their first year of life. The extensive culling of calves below the age of six months and a larger proportion of females within the surviving adult population at some southern English Neolithic and Early Bronze Age sites led A. Legge to argue that this profile represented a dairying economy (Legge, 1981, Legge et al.1992). The cattle profiles from other Orkney excavations have also been evoked as evidence for dairying (Serjeantson and Bond, 2007a, 2007b) but, alternatively, could be associated with fodder shortages (McCormick, 1992, 1998) since more than one explanation can be attached to similar “age of death” profiles (Greenfield, 2010, p34, Halstead and Isaakidou, 2011, p64).

Many researchers believe it probable that at least some milk was extracted from cattle and sheep from the onset of domestication, even if only as a substitute for human mother’s milk (e.g. Gerbault et al., 2013, p985, Greenfield, 2010, p33). Examination of milk residues on pottery confirms that milk processing has been undertaken from the 7th millennium BC in the Near-East and by 4th millennium BC in Britain and Scandinavia (Copley et al., 2009, Craig et al., 2011, Evershed et al., 2008, Isaksson and Hallgren, 2012). However the presence of ruminant milk residues on pottery cannot give insight into the scale of dairying (Halstead and Isaakidou, 2011, p65, McCormick, 2012, p108). It is possible that dairying was not an important element of the livestock management strategy from the beginning of the Neolithic in continental Europe, as suggested by J.-D. Vigne and D. Helmer (2007), particularly since their method of adjustment for culling profiles has been challenged (Brochier, 2012, Greenfield, 2010, p30, p44).

Examination of milk residues cannot identify the ruminant species involved (Greenfield, 2010, p34). An immunological detection method of the most abundant protein in milk (αcasein) using indirectly labelled antibodies was used during a survey of milk residues from Iron Age sites on the Western Isles of Scotland to establish the species involved in the production of milk (in this case cattle) (Craig et al., 2005), although a recent review stated that this method has been largely abandoned (Gerbault et al., 2013, p984). Milking is confirmed by at least the 3rd millennium BC at Tell al-Ubaid, southern Mesopotamia by a detailed temple frieze of stone, bronze and bitumen illustrating dairying, with cattle realistically depicted (Clark, 1977, p74), one of a many friezes representing animals during this period.

In general, the examination of dairying introduction and intensification during the Neolithic can be examined using three complementary criteria (i) culling profiles (ii) dairy fat residues held in pores of pottery (iii) retention of lactase persistence into adulthood. The presence of ceramic perforated vessels, possibly for use in cheese-making, may also be relevant, but few have been recovered, and none from Neolithic Orkney to date (Bogucki, 1984, 1988, p89).

In Neolithic Orkney analysis of pottery residues from the Mid Neolithic site of Barnhouse, Mainland indicated the possible presence of cattle milk on four pottery shards using fatty acid composition and potential cattle "marker" analysis (Jones et al., 2005). More recently, a survey of sites from north-western Europe, using a suite of lipid biomarkers and stable carbon isotope signatures on pottery residues included material from the following secondary expansion of the Neolithic and Late Neolithic settlement and cairn sites in Orkney (i) Pool, Sanday (ii) Braes o'Habreck, Wyre (iii) Knowes of Trotty, Mainland (iv) Stonehall, Mainland (v) Wideford Hill, Mainland (v) Quanterness, Mainland (Neolithic secondary expansion) and (i) Pool, Sanday (ii) Ness of Brodgar, Mainland (iii) Skara Brae, Mainland (iv) Stonehall, Mainland (v) Crossiecrown, Mainland (vi) Links of Noltland, Westray (Late Neolithic). The results revealed an overwhelming presence of dairy products associated with Orkney Neolithic pottery in both periods under examination (Cramp et al., 2014).

Milk sugar, lactose, is broken down to make it digestible by a human enzyme called lactase. The activity of this enzyme is down-graded after weaning apart from a proportion of population (32% worldwide) which have inherited lactose persistence (LP) and today in areas of northern Europe LP can reach more than 90% (Itan et al., 2010). In northern Europe there was an upsurge in the LP trait during the Neolithic period, and the increase was so rapid that it is unlikely to be genetic drift alone and must have been influenced by natural selection (Gerbault et al., 2013, pp985-986). Evidence suggests that positive selection for LP in central Europe coincided with the start of the Neolithic Linearbandkeramik (LBK) culture and was associated with large quantities of cattle remains at these sites. This strongly suggests that an ability to ingest dairy products was an advantage although the specific benefits are not known. It may be associated with (i) helping assimilate calcium in a diet that lacked the breadth of earlier non-intensive agricultural diets (ii) supplement vitamin D in low light intensity areas where UVB light is not sufficient to convert dehydocholesterol to vitamin $D_3$ (iii) another form of food storage (Cramp et al., 2014, Gerbault et al 2013). Detailed LP analysis for Orkney has not yet been published, and this would be of great value for considering routes taken for the colonisation of Orkney by Neolithic peoples.

Based on evidence of cattle “age of death” profiles, milk residues and the uptake of LP in early other northern European sites, it is probable that the Neolithic LON settlers milked some cows. This would produce a better conversion rate of grass (indigestible to humans) to food than raising calves for meat (Legge et al., 1992, pp86-90). Calves may have been suckled by cows until grazing productivity declined, at which point those in excess to herd requirements might have been culled (Serjeantson and Bond, 2007a, p224).

It is of interest that LON cattle neonatal and calf bones were butchered, showing that at least a proportion of these dead animals were exploited, not just removed for possible dairying purposes.

#### 11.7.2.3 Sheep

The “age of death” profiles of LON sheep at LON appears to be consistent with out-take for meat and not intensive dairying or wool production despite sheep being easier to milk without the presence of their lambs (Balasse, 2003). No evidence for spinning or weaving wool has been identified from Neolithic sites in Orkney to date. However, the primitive breeds from Neolithic Orkney would have shed fleece (Ryder, 1981) that could have been felted. A description of Soay sheep, another primitive breed states “their hair is long…neither like the wool of sheep or goat” (Hector Boece, 1520, Scotorum Historiae, quoted in Lever, 2009, p 313). In Europe there is no evidence or sheep being raised for wool until after the Neolithic period with full specialisation only appearing around two thousand years ago (Greenfield, 2010, p36, Ryder, 1983).

#### 11.7.2.4 Pig

The LON sample for pig “age of death profiles” is small but the pattern unexpected since older animals predominate; it might be anticipated that since pigs produce litters more than once per annum then large number of piglets would be culled in order to control stocking rates. It is possible that bones of young piglets might have undergone taphonomic destruction; although foetal/neonatal bones were recovered at the Iron Age site of Brest Ness, Westray (Fraser, unpublished) and teeth might be expected to survive in LON middens. Alternatively, it is possible that pigs were not kept at the settlement and the presence of their bones attributable to imports or hunting, although, as stated above, it would have been advantageous to keep at least a few pigs tethered at the settlement.

### 11.7.3 Pathology of LON mammals

#### 11.7.3.1 General

The number of pathological specimens from LON was similar to Barton Court Villa but higher than seven other British archaeological sites (greater than 300 NISP) (Siegel, 1976, pp357-358, table 2). In addition, the proportion of LON cattle pathological specimens was higher than the 0.02% prevalence of pathology on cattle bone fragments from 51 central European and south-west Asian pre-historic sites (Bartosiewicz and Gál, 2013, p151). Sheep bones displayed a range of pathologies but the pattern differed from cattle, with less pathology associated with feet bones and more with forelimbs, particularly ulna/radii. Very few LON pig bones were recovered but pathology was noted from this small sample. One red deer had a hindlimb displaying symptoms of spavin. The most advanced cases of pathological change were from otter bones, as was the case in the earlier D. Clarke's LON excavation and at the Iron Age site of Brest Ness, Westray (Armour-Chelu, 1992, Fraser unpublished).

Overall, however, there was no severe or extensive pathology noted on LON domestic mammal bones, but this may have been due to judicious culling. The small number of skeletal abnormalities aligned with results of other Orcadian Neolithic sites and did provide clear evidence of genetic isolation or in-breeding for domestic mammals within Westray. Evidence for healed trauma was also rare, but dislocated epiphyseal junctions are of interest, possibly caused by congenital, genetic or environment factors. There was little evidence of non-specific infections.

The under-estimation of dental hypoplasia at LON in this study signals that a specialised study should be undertaken. Presence of hypoplasia that was noted does, however, indicate some disturbance in tooth formation for all three domestic species, potentially periods of illness or reduced availability of food.

The prevalence of subchondral cystic lesions on the articular facets of cattle, sheep, red deer and pig bones at LON reflects results from other Neolithic and Iron Age sites in Orkney. More data is required to determine if this is a localised symptom or occurs throughout British and continental European Neolithic sites.

#### 11.7.3.2 Possible cattle traction at LON

An extensive study of proximal phalanges (741) of Neolithic domestic cattle from southern Scandinavia and proximal phalanges of aurochs (243) suggested that pronounced exostosis may be a symptom of natural ageing of cattle skeletons, but lipping and extension of proximal articular surfaces is not commonly associated with ageing. Neolithic cattle had lipping and extension on proximal phalanges, aurochs did not, perhaps signifying that these symptoms were associated with use of cattle for traction (Johannsen, 2006). Lipping and extension of 1st and 2n cattle phalanges were noted at LON, which perhaps suggests that these animals were used for traction. However, it is important not to assume that there was only one cause for local bone lesions and also it is impossible to know what level or intensity of traction took place at the site (Bartosiewicz and Gál, 2013, p150, Isaakidou, 2006, p104).

The introduction of cattle to pull ploughs, sledges or carts would have been a major technological innovation and is sometimes referred to as part of the "Secondary Products Revolution (Sherratt, 1981), although introduction of traction animals may have actually been "a phase in which pre-existing trends were accelerated and accentuated" (Whittle, 1996, p142). The transfer of labour to cattle would have freed up time for other activities (Bogucki, 1988, p176, 2011, p112) turning domestic animals into tools "predicated on knowledge of biology, ecology, physiology, temperament and intelligence of target species" (Shipman, 2010, p525).

There is no artistic evidence of traction or burials of pairs of draft cattle in Europe before the 4th millennium BC and no written records until the 2nd millennium BC (Bartosiewicz and Gál, 2013, p9, Bogucki, 2011, p112, Clark, 1957, p226, Isaakidou, 2006, p95, Johannsen, 2005, p44, Pollex, 1999, Sherratt, 1981, Whittle, 1996, p141). A small bovine copper figure from Liskovskà Cave, Slovakia, is possibly the oldest representation of animal traction, belonging to the first half of the 4th millennium BC (Anati and Gomes, 2013, p114). However, D. Serjeantson considers cattle would have been used for sledges, travois, carts or ploughs during the Late Neolithic in England and may have moved stones for monument building (Serjeantson, 2011, p20).

Four different origin and diffusion patterns have been outlined for animal traction uptake in Europe (Anati and Gomes, 2013, p162, fig 120), but all include the arrival of this technology on the Central European coast by 3500BC, with M Volsteen's model also indicating uptake in Normandy, France and A. Anati and M.V. Gomes model, indicating uptake on North Sea, English Channel and Western Atlantic coasts by this period. If these models, based on reviews on archaeological data, are appropriate, then it is possible that Mid/Late Neolithic communities in Britain would have been exposed to the concept of cattle being deployed for traction.

Earlier publications suggest that if cattle were used for traction during the Neolithic at British sites the impact would be reflected in the pathology of forelimbs (Armour-Chelu and Clutton-Brock, 1985, Higham et al., 1981, p354). However, later publications have emphasised the strain to the pelvis and hindfeet since pelvis and hind limbs provides much of the power for forward propulsion (Bartosiewicz et al., 1997, p54, table 8, Bartosiewicz and Gál, 2013, p151, fig 128, Isaakidou, 2006).

Although the study of traces of traction on bone material is still an emerging discipline (Bogucki, 2011, p107) based on pathologic lesions observed of LON cattle pelves, and other pelves from Neolithic sites in Orkney, and the lipping and extensions on the articulated surfaces of LON tarsals and phalanges (not allocated to thoracic or pelvic extremities) it is tentatively suggested that some LON cattle were involved in traction. Other evidence such as pathological lesions of cervical vertebrae or eburnation of the pelvic acetabulum and femur caput were absent at LON, but recorded at other Orcadian Neolithic sites.

The hypothesis that cattle were used for traction in Neolithic Orkney is supported by an examination of an almost complete cattle post-cranial skeleton from the Neolithic midden at Tofts Ness, Sanday. This skeleton had highly developed muscle insertions on long bones, arthritic changes to some long bones and foot elements, arthritic features on cervical vertebrae and the asymmetry of sections of the ventral column, leading J. Bond suggested that this animal may have been used for traction (Bond, 2007b, p200).

If LON cattle were used for traction then harnessing the physical contribution from cattle may have conferred status to owners in an Orcadian society increasingly involved with monumental construction. It is possible, as displayed in Egyptian tomb paintings, that both males and female cattle were used sporadically for traction, females alternating traction duties with production of calves, although today the role of draught animal falls mainly to castrates (Johannsen, 2011). The cattle abandoned on Swona in the third quarter of the 20th century were described as triple purpose animals (beef, milk, draught) and this may also have been the pattern of stock-keeping in the prehistoric period (Hall and Moore, 1986). Use of traction would create even closer relationships between cattle and their owners, through training and operation, perhaps another reason to commemorate cattle after death by retention of their skulls.

### 11.7.4 Size of LON mammals

#### 11.7.4.1 Cattle

Results indicate that there was a clear reduction in cattle stature between the Late Neolithic and Iron Age period in Orkney, and if the Late Bronze Age site of Bay of Skaill is considered, then this change occurred during the Orkney Chalcolithic or Early/Mid Bronze Age period. Inspection of profiles of size index scale graphs demonstrates that this change cannot be attributed solely to a change of representation of males, females and castrates in the herds.

Overall the measurements from cattle recovered from the Mid Neolithic and Late Neolithic period are consistent. The mean value for “GLl” astragalus for the previous LON excavation by D. Clarke, for fourteen specimens is actually closer to the Knap of Howar mean than the present LON excavation (68.8, 68,5 and 67.3mm respectively). Measurements from selected southern English Early and Late Neolithic sites shows similar bone dimensions, although the mediums for these sites are slightly lower than those from Orkney. Very few LON bone measurements approached published male aurochs dimensions, although a few measurements from both LON and Knap of Howar were larger than the “standard” Ullerslev female aurochs. A small number of LON bones overlapped with the published range of than female aurochs/male domesticated cattle aurochs and one skull deposited in the foundation course, Structure 9 had dimensions associated with a male aurochs.

There may have been a preference to maintain cattle with large stature and horns with a “*primigenius*” spiral during the Neolithic, perhaps to retain a resemblance to their wild progenitor, the aurochs. The reduction in cattle stature by the Iron Age is not unique to Orkney but also recorded at sites in England and Europe at the end of the second millennium BC (Serjeantson, 2011, p19) and was part of a widespread phenomenon.

This change may have been related a different role for cattle in society, so, for example, instead of prestige being associated with owning aurochs-like cattle perhaps the amount of milk a cattle herd produced came to represent wealth and status, as was the case in early medieval Ireland (Lucas, 1989). Cattle selected for docility and high milk yields led to the inheritance of these, and perhaps also associated traits such as size diminution, within several dozen generations (Morey, 2010, pp199-201). Alternatively poorer grazing through overstocking or climate change impacting on length of growing season and/or production of winter fodder may have led to this reduction in cattle stature. It is noted there was a possible deterioration of climate with increased humidity in northern Scotland during the Chalcolithic/Bronze Age periods (Cunliffe, 2012, p253, Tipping and Tisdall, 2004, p76, Whittington and Edwards, 2003, p21).

There is insufficient data to examine how cattle stature at LON compared with other Neolithic sites in Scotland, including those of northern Scotland, Western Isles and Caithness because, although some animal bone reports have been published, such as Scord of Brouster, Shetland (Noodle, 1986) and Northton, Western Isles (Finlay, 2006) few measurements are available. It is therefore difficult to deduce if stature of mammals in Orkney is typical of other areas of Scotland and/or Ireland and, consequently, to speculate on the route travelled by these animals “*en route*” to Orkney. It is of note that some Orcadian Neolithic cattle bone measurements were larger than those from sites in southern England since there may have been more favourable conditions in this area, with more wooded and sheltered browsing and grazing in southern England and longer growing seasons. This difference does not appear to be caused by different proportions of females and males/castrates in the population based on distribution of results from size-scale index graphs. However changes in cattle stature can occur over a few generations, so this information cannot be used without additional strands of evidence to claim that Orkney Neolithic cattle were not from the same founder populations as these of southern English Neolithic cattle.

#### 11.7.4.2 Sheep

The measurements from sheep bones confirm that the LON sheep resembled the modern northern sheep breeds considered relict populations from flocks that arrived with the early farmers to Orkney. Stature diminishes between the Neolithic and Iron Age period but the changes are less pronounced as those for cattle. However it also appears that the dimensions of sheep bones from the Mid Neolithic site of Knap of Howar are smaller than those from the Late Neolithic site at LON. Based on stable isotope analysis on teeth, it has been suggested that the earliest sheep living at Knap of Howar did not consume seaweed, and that this zoo-technical innovation post-dated arrival of flocks in Orkney (Balasse and Tresset, 2009, p82). Other explanations are possible; including introduction of new stock during the Late Neolithic, or that Westray provided optimal grazing to the flocks during this period.

#### 11.7.4.3 Pig

Measurable pig bones at LON do not indicate these pigs were wild boar unless they had undergone some level of diminution though living on islands. There may have been a slight reduction in stature between the Neolithic and the Iron Age but an overlap of ranges means that a greater number of measurements would be required to test this statistically.

#### 11.7.4.4 Red Deer

Red deer in Neolithic Orkney were of smaller stature than contemporary mainland Scotland red deer. Size index scale graphs may allude to a slight reduction in stature between the Orcadian Late Neolithic period and Iron Age. The difference however, it not as marked as the diminution in stature of cattle between the two periods. The only bone with a large range of measurements at the Late Neolithic LON and Iron Age Howe were astragali (with measurements from the LON red deer deposit from the earlier exaction added) 26 and 43 “GLl” measurements (means of 48.6 and 47.3mm respectively) were not significantly different using the Student’s t-test, implying that any reduction in stature is not proven.

Although the question of whether red deer were farmed or carefully controlled has been raised (e.g. Smith, 1994, p145 Sharples, 2000, p113) the small stature does not suggest that red deer were receiving substantial supplementary feeding in Late Neolithic in Iron Age Orkney.

## 11.8 Arrival of mammals in Orkney

### 11.8.1 Domestic species

Domestic animals must have been imported into Orkney, and, given the difficulties of moving domestic animals by boat, including requirements for food and water, it has been proposed that the immediate point of departure might be Caithness in the north-east mainland of Scotland (ScARF Panel Report). It is not known if these north of Scotland communities and their domestic herds and flocks arrived originally along the "Western Seaways" or from movement along the coasts of eastern Britain. If deliberate cross-Pentland sea crossings occurred, rather than "drift" sailing, then a high degree of sea-faring expertise would have been required.

Orkney can be viewed from mainland Scotland and colonisation by farmers may have been prompted by its extensive grazing areas, including recently formed machair plains. The equitable maritime climate may also have been attractive, reducing the requirement for winter feeding. The Orkney archipelago would not have been regarded as "marginal" or "an extremity" during the British and Irish Neolithic period (Noble, 2006, p28) since travelling by sea craft would have been easier than making progress on foot through dense or scrubby forests, marshy areas or over mountains (Cooney, 2004, p147). An additional advantage in Orkney would have been the productivity of seaweed, although this may not have been recognised initially (Balasse and Tresset, 2003).

It is probable that only low numbers of Mesolithic people were visiting or living in the Orkney Islands prior to arrival of domesticated stock and cereals, partly because Mesolithic finds are sparse (although coastal sites may have been lost to rising sea levels) (Saville, 2000, p98, 2004, p5,Wickham-Jones, 2006, pp23-24). Moreover, if the general figure of hunter-gatherer territory of 25km$^2$ per person is used (Budiansky, 1992, p115) then the Orkney Islands would have supported less than fifty people. However, the marine resources around the coasts of Orkney may have permitted greater density than this. It is not known whether the relationship between Mesolithic people and Neolithic farmers was one of integration or hostility, but their skills both in obtaining wild resources and sea-faring might have been valuable to early settlers. It is certainly the case that from an early stage of colonisation, Neolithic farmers constructed cairns, possibly as territorial markers to stake their claim to land in Orkney.

The cattle and sheep introduced into Orkney meant that the farmers had a means of converting grasses, inedible to humans, into meat (Crosby, 2004, p26, Diamond, 2005, p88, Simmons, 1993, p66). Productivity is improved if both sheep and cattle are run together on pasture as their dietary requirements differ. Sheep can graze pasture successfully after cattle have eaten long grasses as close as they are able (Putman, 1995, p16, Putman and Moore, 1998, Osbourne, 1984, Jarman, 1972, p138).

There may also have been a link between colonisation at higher latitudes and the occurrence of dairying (Clark, 1952, p372), with introduction of cows in milk producing a reliable supply of food both as milk and stored food in the form of cheese for early settlers. The riskiest stage of colonisation is when the first small group reach an uninhabited, or relatively uninhabited, island (Keegan and Diamond, 1987, p77). It is therefore possible, based on Orkney pottery residues and age of death profiles of cattle, that dairying was adopted from the earliest arrival of settlers, and may have contributed to their successful establishment in Orkney. The extensive coastline of Orkney would also have provided fish and shellfish resources to support any initial shortfall in provisions and in subsequent years of subsistence uncertainty (Bogucki, 1988, p215, Montgomery et al., 2013). Colonisation might have occurred over a number of years, starting perhaps with targeted scouting parties, followed by summer residence with some stock, then crop planting/summer residence before full colonisation (Case 1969, Fiedel and Anthony, 2003, p156). The move to Orkney may have been prompted by pressure on resources in northern Scotland (Brookbank and Strasser, 1991), settlement fissuring (Bogucki, 1988, p217) and/or as discussed above, an increase in knowledge on management of domesticates to produce secondary products.

A gradual exploration and scouting of Orkney would have allowed a “domestic package” modified for local environmental conditions to be introduced (Manning et al, 2013, Rowley-Conwy and Layton. 2011), although cultural requirements would also be of importance. Based on cattle and sheep representation, age profiles and sizes, it appears that herds in Mid and Late Neolithic Orkney had similar profiles, regardless of whether they were managed on the largest island in Orkney, Mainland, or other islands such as Sanday and Westray, suggesting similar farming strategies between communities in different islands.

Importation of domesticates would have altered the physical landscape of Orkney through grazing, production of midden material for garden plots, inhibition of tree or scrub regeneration and possible destabilisation of machair. This, in combination with still rising sea levels, would have led to changing landscapes, but animal husbandry, in terms of sheep and cattle remains in middens, remained relatively constant over the Orkney Neolithic period. The changes in domestic stock representation and size by Iron Age may therefore be associated not only with environmental changes but also sociocultural preferences. Unlike human colonisation of many islands, the introduction of domestic stock, commensals (and possibly wild mammals) to Orkney would have led to an increase in the faunal biodiversity of depauperate Orkney.

A simplified food web for Orkney is shown in *Figure 9 (excludes raptors and compresses routes from micro/macro-algae).)*

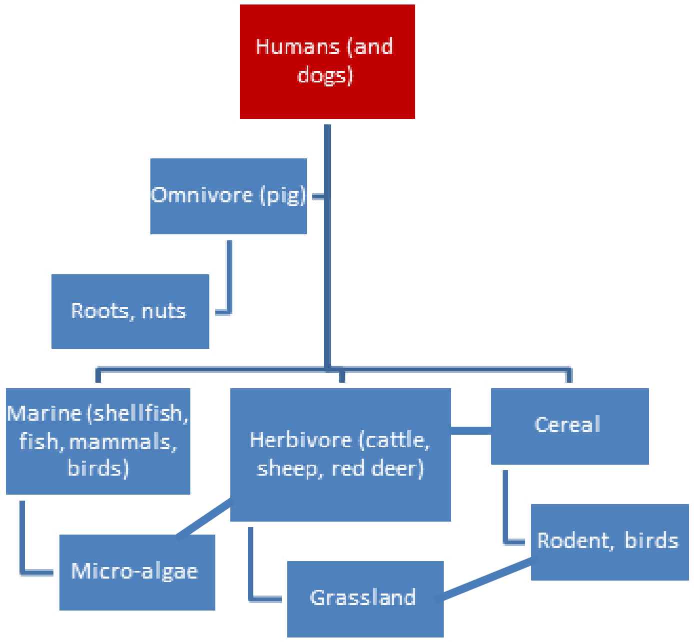

**Figure 9: Simplified food web for Neolithic Westray**

### 11.8.2 Orkney Neolithic domestic cattle mtDNA

Thirteen cattle samples at LON had four different matrilineages present, three of which belong to the main European haplogroup for domesticated cattle “T3”. The “T3 haplotype 1” is ubiquitous in Neolithic cattle populations in Europe. However, “T3 haplotype 2” has been reported infrequently but identified in both LON cattle skulls and cattle bones and as well represented as “T3 haplotype 1”. “T3 haplotype 3” is rare (Elsner et al., unpublished). The range of dates for “T3 1 haplotypes” is 3012-2348 cal BC and for “T3 2 haplotypes” 3082-2349 cal BC, so the “T3 2 haplotype” does not appear to be a later arrival. The date for the only “T3 3 haplotype” is 2880-2626 cal BC, so this bone, recovered from midden is not intrusive. For details of radiocarbon dates see *Appendix 2.*

It is of great significance that Late Neolithic cattle herds in Orkney carried the matrilineal genetic signatures for three domestic “T3” haplotypes. If the first farmers to Orkney imported a small founder herd of cattle, this range must have been present in the herd from which this founder herd was selected, with all three haplotypes incorporated into the small colonising herd. The more plausible explanation is that there may have been more than one introduction of cattle herds into Westray and Papa Westray over the Neolithic period.

Ideally, the number of cattle and sheep introduced into Orkney to allow maximum tolerable rate of inbreeding of 1% per generation translates into an effective population of about fifty for each species. If fewer individuals per species were introduced the population may have lost genetic viability by passing through bottlenecks, although this may not be too damaging if the population expanded quickly (Whittaker and Fernandez-Palacois. 2007, pp253-254). Evidence from mtDNA analysis of cattle indicates there was more than one introduction of cattle into Westray, suggesting that Neolithic settlers recognised the dangers of arriving with the minimum “one pregnant female carrying a male foetus” and that the introduction of cattle may have been a protracted process.

A feature of the successful initial colonisation to Orkney may have access to other groups living in northern mainland Scotland during demographic or subsistence crisis (Brookbank and Strasser, 1991, pp238-239, Steele and Rockman, 2003, p142) although other contacts, and possibly small numbers of livestock, may have travelled further, with perhaps the presence of the Orkney vole from mainland Europe and material evidence of contact with the Boyne Valley in eastern Ireland during the Late Neolithic bearing testament to this (ScARF Panel Report).

### 11.8.3 Cattle skull with hg “P” haplotype in Orkney

Modern cattle are descended from animals domesticated in the Near East (Bollongino et al., 2006). MtDNA evidence indicates that, although mating between local aurochs and domesticated cattle occurred in central and northern Europe (Achilli et al., 2008, p 158) this interbreeding was rare (Bollongino et al., 2006, 2012, Edwards et al., 2007, Elsner et al, unpublished, Schibler et al., 2014). Biometrical and ageing evidence to date for British Neolithic domestic cattle demonstrate an external origin, with very limited, or entirely absent, hybridisation (Viner, 2011, p344). One suggested reason for enforced separation between domestic cattle and aurochs is that large calves fathered by aurochs bulls could have presented a danger to the cow during gestation or birth (Legge, 2010, p32). Separation may also have had a social dimension, allowing control over the bloodline and retaining a genealogical knowledge of the herds (Robb, 2013, p406).

The discovery of a cattle skull at LON with the “P” haplogroup generally associated with European aurochs is therefore important. There is no evidence based on non-duplicated isotope results, that hg “P” followed a different grazing pattern from the other LON cattle, or was imported from a more forested, or wetter environment. One possibility is that aurochs had either colonised or been introduced to Orkney after the LGM. If, however, F4459, the cattle skull with hg “P”, was domesticated, the origin of this mtDNA incorporation into domestic stock at some point before domesticated cattle’s arrival in Orkney would be exceptional based on current research results indicating incorporation of a female aurochs into the domestic herds in continental Europe or Britain.

M. Armour-Chelu considered whether large cattle bones at the earlier LON excavation (1979-81), indicated the presence of (i) aurochs (ii) recently domesticated population of aurochs (iii) hybridization between domestic cattle and aurochs. This was based on her observation that ten cattle metacarpal bone dimensions, and fifty-eight 1st phalanges (plus other small groups of bone measurements) had a higher upper range of values than those from southern England Neolithic sites. She argued against the presence of an aurochs population in Westray and, if hybridization did occur, it must have been prior to importation into Orkney (Armour-Chelu, 1992 pp166-172).

During the 19th century large cattle bones from Orkney prehistoric sites were attributed to aurochs, for example at Skara Brae, Mainland (Lairg, 1867, Petrie, 1867). In contrast, although making reference to the large size of some cattle specimens, 20th and 21st century Orkney Neolithic archaeological reports allocate cattle bones to domesticated cattle, introduced into Orkney by Neolithic farmers (e.g. Barker, 1983, Bond, 2007, Clarke, 1998, Clutton-Brock, 1976, MacCormick, 1984, Nicholson and Davies, 2007, Noddle, 1978, 1983, 1997, Platt, 1934, 1937, Watson, 1931).

The exceptions were, firstly, at Quanterness cairn, Mainland where J. Clutton-Brock states that “the remains of ox were probably all from domesticated cattle. The only bone that could be questioned is a scapula (No 1539) which is marginal in size between a small *Bos primigenius* (the extinct wild ox) and a large domestic ox” (Clutton-Brock, 1979, p120). At Knap of Howar, Papa Westray, M. Platt states “some fragments exceed in size the corresponding bones of the present day ox and approach closely the dimensions of those of the European bison, now extinct (Platt, 1937, p818). Finally, during a selection for radiocarbon analysis from the Neolithic cairn of Knowe of Rowiegar, R. Chaplin states “proximal end and part shaft of *Bos* radius. A very substantial animal, possibly wild rather than domestic” (Switsur and Harkness in Renfrew, 1979, p72).

### 11.8.4 Possible arrival of non-domesticated mammals to Orkney

Red deer herds have been resident in mainland Scotland from the early Holocene up to the present day and in Orkney from at least the Late Neolithic to the Viking period. Aurochs have also been recorded from mainland Scotland in the Mesolithic, Neolithic and Bronze Age period (Kitchener, 1998, Kitchener and Bonsall, 1999, Kitchener et al., 2004, Ritchie, 1920). Extinction of aurochs in Britain occurred during the Bronze Age, with the most recent radiocarbon-dated aurochs bones being from Charterhouse Warren Farm, Somerset, 3245 BP in England (*1529-1498 cal BC*) (Yalden, 1999, pp107-109,  table 4.2) and Galloway 3315 BP (*1626-1546 cal BC*) in Scotland (Kitchener et al., 2004, table 5.1 p75). There would therefore be aurochs and red deer living in mainland Scotland during the Late Neolithic.

If aurochs were present in Orkney, the three options for their arrival would be:

- Transported by boat as dead stock (or just skulls)
- Transported by boat as live stock
- Natural colonisation of Orkney prior to the landbridge with mainland Scotland being fully breached.

A few cattle post-cranial bones recovered from LON and Knap of Howar, Papa Westray, exceeding some published values for Danish aurochs, may reduce the likelihood of only curated aurochs skulls being imported for special deposition. However, the larger LON cattle measurements show no clear evidence of being outliers, so future mtDNA analysis is required on some large post-cranial cattle bones to resolve this question.

Human introduction of live aurochs during the Neolithic cannot be ignored, but the capture and transportation of an adult aurochs seems improbable in view of their size, strength and historically documented ferocity. Encountering an unprotected calf or calves, which could be transported, would have been an unusual event. This method of introduction is, however, offered as the explanation for the presence of red deer in Orkney (Clutton-Brock, 1979, p113) and the Western Isles (Serjeantson, 1990, Mulville, 2010, p44). There is also evidence of human-assisted red deer introduction into Ireland during the Neolithic, based on a multi-disciplinary analysis using mtDNA, craniometric analyses and radiocarbon dating (Carden et al., 2012, Montgomery et al., 2014 p157). In addition, clear precedents exist for the introduction of deer and other wild species to Mediterranean islands by colonising Neolithic farmers along with their domestic livestock (Blondel and Vigne. 1993, p135, Conolly et al., 2011, p543, Schule, 1993, Vigne, 2011, Vigne et al., 2009, 2011).

It is plausible that Neolithic farmers would want to import red deer, both for antler production and as a back-up food supply, although marauding of cereal crops must have been of concern. However, introduction of aurochs to Orkney, with similar products to those of domesticated cattle seems less compelling unless a desire to hunt these mammals was of cultural importance. Lack of forest in Orkney would not have been a detriment to aurochs survival because recent research indicates preference to low-lying flat ground to woodland (Hall, 2008).

An alternative is that Mesolithic hunter-gatherers may have already introduced red deer (and aurochs?) to Orkney prior to the arrival of Neolithic farmers. These hunter-gathers would have owned boats capable of facilitating this importation. Some palaeoecological evidence at Catta Ness, Shetland, suggests that during the 7500 to 5400 BP period there was a change of dominance from herbs and ferns to heathland and mire plants perhaps indicating the presence of a large herbivore on the island (assumed to be red deer) and their extinction at the end of this period, although this hypothesis is not accepted by all researchers from either an ecological (e.g. Tipping, 1994, p17, 2004, p162) or behavioural point of view (Woodman, discussion in Saville, 2004, p162). A. Saville raises the interesting point that if microliths recovered as surface finds in Orkney are from the Mesolithic period, does this imply there were terrestrial mammals available for hunting (Saville, 2000, p98).

When wild herbivores are introduced into a new territory with abundant food supply their population would expand until constrained by some factor. So, for example, four red deer introduced to Melsetter, Mainland, Orkney in the mid-19th century expanded to a population of thirteen or fourteen over twenty years, before all but one being killed because “they were so much annoyance about the crofters crops” (Buckley and Harvie-Brown, 1891, p82). These red deer “throve perfectly” (ibid), as did a later 20th century herd of managed red deer introduced into to Westray, an enterprise only discontinued because of a commercial considerations (H. Moore pers. comm.).

Wolf, the main predator of red deer, may not have been present on Westray because this species did not migrate into Orkney, or if it did arrive naturally or was introduced by humans, did not thrive because of the restrictive territory of the island. This species remained on the Scottish mainland until 1749 (McCormick and Buckland, 2003, p87). Eagles, the other red deer predator, predominately remove weak fawns and would make little impact on a population (Clutton-Brock and Albon, 1989, Clutton-Brock et al., 1982).

A third option is that aurochs, red deer, and other wild mammals recorded in Neolithic Orkney such as fox, otter and pine marten (Clutton-Brock, 1975/76, 1979, McCormick and Buckland, 2003) entered Orkney unaided. However, if aurochs and other wild species did colonise Orkney prior to the last British glaciation episode (LGM) proxy climatic evidence indicates that these populations would have been eliminated during this event (Ballantyne, 2004, Clark et al., 2012, Hughes et al., 2014), so any such colonisation must have been after the LGM.

Immediately after the LGM, during the Late Glacial Interstadial, non-Arctic mammals migrated north from refuges in continental Europe, when Britain was still attached to northern Europe (and Orkney connected to mainland Scotland) due to the lower sea levels associated with continued water storage within northern hemisphere ice sheets (Lambeck et al., 1995, p445, fig 3e, Shennan et al., 2000 p312). Bones from large mammals such as elk, giant deer (*Megaloceros giganteus*), wild horse, red deer, reindeer, mammoths *(Mammuthus primigenius*) and aurochs have been recovered in Britain dating from this period (Hedges et al., 1998, Stuart, 1982, Yalden 1999) but no aurochs bones identified from northern Scotland.

During the colder Loch Lomond Stadial (Younger Dryas) of approximately 11000 to 10000 BP which followed this warm Late Glacial Interstadial there was widespread replacement of boreal shrubs and woodlands by scrub and tundra communities (Lowe and Walker, 1997 p346) with the only ungulates considered able to survive these conditions being reindeer and wild horse (Yalden, 1999 p50). However, a date of 10900 to 10200 cal BP (9430 +/- 65 BP) for an antler/cranium portion from a giant deer dredged from the River Cree, Dumfries and Galloway (Kitchener and Bonsall, 1999, p8, table 1) suggests this species may also have been present in Scottish during the Loch Lomond Stadial. Additionally, a red deer tooth from Wookey Hole, Somerset, in southern England dated at 10460+/- 90 BP, prompted R.M. Jacobi to state “red deer is now also firmly dated to the Younger Dryas Stadial” (Hedges et al., 1998 p 229).

The Loch Lomond Stadial (Younger Dryas) ended abruptly. Temperatures comparable with present day were reached by c 9800 to 9500 BP (Ballantyne, 2004, Golledge, 2010, Lowe and Walker 1999, Whittingham and Edwards, 2003). Since it is improbable that warm-adapted ungulate populations survived in Orkney during the Loch Lomond Stadial, notwithstanding the more recent evidence of giant deer and red deer presence in mainland Britain during this period, the only opportunity for natural colonisation for aurochs or red deer to Orkney would be dispersal to northern Scotland from either Europe or British southern refuges before the landbridge between Orkney and mainland Scotland breached. Evidence of sea levels is summarized in *Chapter 1* and indicates this colonisation unlikely.

Notwithstanding, swimming/islet hopping over a narrower post-glaciation Pentland Firth by wild species cannot be fully ruled out since in mainland Scotland aurochs and red deer were present in the Mesolithic, Neolithic and Bronze Age period (Kitchener, 1998, Kitchener and Bonsall, 1999, Kitchener et al., 2004, Ritchie, 1920). The oldest radiocarbon dated Scottish aurochs bone is from Fife at 9170 +/-70 BP (10350-9980 cal BP) overlapping with the later dates projected for the Loch Lomond Stadial (Kitchener and Bonsall, 1999, p8, table 1, Kitchener et al., 2004).

Until recently, the thirty-five Scottish mainland aurochs bone find- sites were located in southern, central and eastern Scotland (Kitchener, 1998, p70, fig 10, Smith, 1872). In 2012 three cattle bone fragments recovered from a rock-shelter in An Corran. Staffin, Skye, Western Isles were radiocarbon dated to 7595+/- 50; 7555 +/- 45; 7525 +/- 45 BP. Although these bones were originally considered to be from domesticates, the radiocarbon dates now reveal they are probably small aurochs (Bartosiewicz in Saville et al., 2012). The An Corran aurochs find is important because firstly, it extends the known distribution of aurochs in Scotland. Secondly it may indicate an aurochs presence on a Scottish island prior to the Neolithic period, either by natural colonisation or importation by Mesolithic sea-farers.

### 11.8.5 Variation in aurochs and red deer stature

#### 11.8.5.1 Aurochs

Although some LON cattle bone size lie between the published Danish results for male domesticated cattle and female aurochs, with only one skull possibly being from a male aurochs, there is increasing evidence that some European aurochs were smaller than the measurements from this standard work. In addition, diminution of aurochs size from central to northern Europe is recorded and Orkney is located at the recorded northern limit of distribution ($58^{o}$ N) for aurochs during the Holocene (Kyselý, 2008).

A reduction in European aurochs size between the Pleistocene to the Holocene is accepted (Chaix and Arbogast, 1999, Degerbøl and Fredskild 1970, Grigson, 1969). During the Holocene, although some relatively small aurochs specimens were recorded in Denmark, it was considered that when this material was combined with examples from north-west Germany and England there was no evidence that aurochs decreased in size between the Mesolithic and Bronze Age (Degerbøl and Fredskild 1970, Grigson, 1969, 1978, Lasota-Moskalewska and Kobryń, 1990). Any range of measurements within Europe sites during this period attributed to sexual dimorphism (Bartosiewicz, 1984, Degerbøl and Fredskild 1970, Grigson, 1969, 1978, Legge, 2010).

In Britain a study of one of the largest collections of aurochs bones from the early Mesolithic site of Star Carr, Yorkshire, England appeared to highlight the presence of small and large aurochs (Fraser and King 1954). However, a review of the material highlighted that some bones attributed to aurochs were from elk (*Alces alces*) and if these bones were removed the range of aurochs bone measurements was as expected for a species exhibiting strong sexual dimorphism (Legge and Rowley-Conway, 1988, Legge, 2010).

Nevertheless, there is some evidence that geographical location may influence the size of European aurochs, with central European specimens larger than those from Scandinavia and northern Europe (Lasota-Moskalewska and Kobryń, 1990). An examination of aurochs from Germany, Poland and Denmark and Britain during the early Holocene, 10000 to 5500 cal BC identified that this group were larger than those from more southern sites of south France, Portugal, Spain and Italy (Wright and Viner-Daniels, 2015, p14). Hungarian aurochs were also noted as being smaller than those of northern Europe (Bökönyi and Bartosiewicz, 1987).

Recently some European aurochs with small measurements have been identified. The post-cranial bones of a female aurochs from the River Tjonger Valley, Netherlands dated 6690+/-40 BP (*5680-5520 cal BC*) had a derived withers height of 134cm, lower than the range generally attributed to female aurochs of 141-156cm. and within the range for domesticated cattle of 103-135cm (Prummel and Niekus, 2011, p1458). At Rosenhof, Northern Germany, cattle were mtDNA tested and results revealed that all Neolithic cattle had mtDNA lineages typical of domesticated cattle originating in the Near East, whereas aurochs and a group of Mesolithic small cattle previously thought to be possible early domesticates, all carried the mtDNA for aurochs (Scheu et al., 2008). This may indicate that distinction between aurochs and domesticate cattle based on stature is a less reliable guide that was previously assumed.

#### 11.8.5.2 Red deer

Bones of red deer in Neolithic Orkney were smaller than early Holocene Scottish mainland red deer, apart from three exceptions, and comparable in size to present day red deer herds inhabiting the island of Islay, Western Isles. There is also evidence of small stature of red deer in the Western Isles during the Mesolithic period (Grigson and Mellars, 1987). In the historic period the small stature of red deer was recorded in the 16th century from the Western Isles “abundante of little deiris” in Rum and “mony deir but not great of quantitie” in Lewis (Munro 1549/1999, p319, p337).

#### 11.8.5.3 Island rule

A possible explanation for the smaller stature of red deer (and aurochs?), in Orkney is the “island rule” which defines the changes in size of island animals when compared with those from adjacent species-rich continental communities. This rule states that smaller animals will tend towards gigantism and larger animals towards dwarfism (or nanism) although, it should be noted, in some cases, these trends are analogous or at least equivocal (Case, 1978, Damuth, 1993, p748, Foster, 1964, pp32-34, fig 2.3, Lomolino, 2005, Whittaker and Fernandez-Palacois 2007, p186).

Dwarfism may occur in island larger ungulates though (i) inability to obtain adequate resources, due to inter and intra-specific competition (ii) no possibility of migrating to better feeding grounds (iii) absence of a full array of predators (Klein, 1970, Lister, 1995, Lomolino, 2005, MacArthur and Wilson. 2001 p151, Whittaker and Fernandez-Palacois 2007, Schule, 1993, p403). Dwarfism can vary with the island area, degree of isolation and presence/absence of competitors (Lomolino, et al., 2010, p37). To this could be added the lack of shelter from the strong prevailing winds in Orkney, which would increase heat loss and contribute to retarded growth. This island effect may be the reason for the smaller stature of Neolithic Orkney red deer.

Herbivores such a red deer and aurochs may have evolved their larger size in mainland communities in response to smaller individuals from their community being preyed upon and/or to outcompete smaller, more specialised herbivorous competitors and once these constraints were removed tended to converge on the hypothetical optimal size for that group, perhaps investing more energy into fat storage and reproduction (Clutton-Brock et al., 1982, Lomolino et al., 2010, p37).

#### 11.8.5.4 Overview

In order to answer the question on origin of MtDNA genetic material from aurochs in one LON cattle skull, further analysis and sex determination is required for skull F6718 and a sample of post-cranial cattle bones with measurements exceeding published male domestic cattle dimensions. However the possibility exists that aurochs and red deer were present on Orkney prior to the arrival of Neolithic farmers and these animals were hunted as prized trophies (Ray and Thomas, 2003, p42) or, in the case of aurochs, amalgamated with domestic herds, something that may have been more practical if their stature was already reduced. The recovery of aurochs bones from Skye, Western Isles may be another example of where aurochs, as well as red deer, were introduced to islands, although the logistics of introducing viable populations for either species appears difficult and could perhaps only have involved transport of juvenile specimens.

# 12 Conclusion

Cattle skulls in LON Structure 9, with mandibles removed, were carefully placed into midden material lying below the inner and outer foundation course, with horn cores orientated downwards into the midden material and skull maxilla and occipital bones upwards. Two sheep skulls were also part of the deposition. The skulls had been carefully placed with most horn cores facing outwards and had no practical function, their purpose perhaps to “animate” or defend the building. The cattle and sheep skulls from LON Structure 18, also detached from mandibles, were placed as blocking material in the passageway between two rooms, again symbolic deposits. Skulls would have represented a small loss of resource from butchered mammals, particularly if horn sheaths and tongues were removed but these depositions indicate that mammals in Neolithic Orkney had more than an economic role in the community.

Although cattle skulls dominated both deposits, the presence of sheep skulls and one red deer skull suggests that they could also fulfilled symbolic roles. Since both male and female cattle skulls were present there appears to be no focus on bulls. After deposition the skulls would no longer be visible, so their presence could only have been retained in the memory of participants or by oral tradition. The role of hidden deposits may have parallels with other hidden artwork or votive deposits in Neolithic Orkney. There is no artistic representation of cattle, or other domestic animals, in Neolithic Orkney so the LON skull depositions are the only evidence that these mammals played an important role in belief systems.

Varied numbers of bones recovered from each skull, the lack of loose teeth associated with skulls where no maxilla bones were present and better internal condition of skull bones suggests that at least some skulls were curated prior to final deposition. There is no evidence that skulls had been placed on posts, hung on walls, or used as masks but some may have been displayed in niches within structures. Further radiocarbon analysis will help determine if the skulls were from specimens that died during different time periods.

The deposition must have marked the end of a long chain of relationships and events between the mammals represented by the skulls and the Orkney Neolithic communities (i) breed/acquire (ii) nurture (iii) cull/butcher (iv) consume (v) convert skulls to objects (vi) curate and deposit. Predominately adults and older adult skulls were deposited and it is probable that their removal from the herd involved ceremonial processes and feasting. The LON skull deposition included one cattle specimen carrying maternal genetic material of an aurochs and another skull which may also be from an aurochs.

There was no selection of specific post-cranial bones for deposition with skulls in wall core material, Structure 9, apart from cattle pelves (and three red deer antlers) or in the blocking material in Structure 18, apart from a cattle scapula. Wall core material deposited over the Structure 9 foundation course deposit and midden underlying it was, however, dominated by butchered cattle post-cranial bones, either because sheep were less significant in the LON settlers' diet when these contexts were formed, or the material was associated with an area where secondary butchering or storage of cattle bones occurred. The location of Structure 9, separated, and to the north of, the enclosed structure complex in LON Area 5, might indicate that the structure had a dedicated function but there is no evidence of special treatment or deposition of mature cattle within the building.

Examples of cattle skull deposition/display; complete cattle skeletons honoured by special burials; and artistic representations of bucrania have been identified from sites throughout the Near East, continental Europe and Britain from the Pre-Pottery Neolithic onwards, even before aurochs were domesticated. This indicates that cattle, in particular, were integral to social/belief systems of communities for thousands of years prior to the excavation of cattle skull deposits in Late Neolithic Orkney. It is notable, however, that the nature of these representations and depositions varied between different areas and different time periods, perhaps indicating that it was the idea, rather than a prescribed ritual that was transmitted. It is of interest that sheep skulls were also considered suitable for special deposition in Orkney, perhaps suggesting a focus or relationships, ceremony or feasts rather than with only one species of mammal.

It is possible that during the Neolithic period these mammals were not regarded as separate and subordinate to man, but as part of their community (Kristiansen and Larsson, 2005, p320) The cattle, in particular, were of large stature, with horn cores that had beginnings of a *Bos primigenius* spiral, and it is possible to speculate that these characteristics were as important to the LON community as these mammals ability to provide meat and other primary or secondary products. However, since all symbols are products of primary developments that are now obscure "interpretations of their meanings is a matter of conjecture" (Mundkur, 1988, p175)

The LON cattle skull foundation and passageway depositions are unique within published Neolithic site records in Britain but it is possible that similar deposits exist but are still hidden or have been misallocated. There are examples of special use of cattle skulls in Orkney, however for closing deposits at the Orkney ceremonial site of Ness of Brodgar and the earlier excavation at LON.

Human skulls were afforded a particular status during the Orkney Mid Neolithic and represented collective rather than individual burials, so the concept of a cache of skulls representing ancestors was familiar to Neolithic communities in Orkney and may have informed the use of cattle and sheep skulls as symbolic objects. No partial or complete cattle skulls were deposited at Neolithic cairn sites, however, denying the possibility that skulls of humans and cattle were interchangeable in the belief system of early Orkney settlers, a suggestion made for Neolithic barrow sites in south of England.

Red deer bones have been recovered from three different locations in Neolithic Orkney (i) midden material at settlements (ii) cairns (iii) articulated or semi-articulated deposits within rubble infill or above settlement middens. Since all elements red deer skeletons and all age groups were represented it is probable that red deer lived on Orkney and not the remains of selective import of meat joints and antler.

The current LON excavation supports, and adds to, the evidence of deposition of complete or semi-complete articulated red deer skeletons recovered in D. Clarke's previous LON 1979-81 excavation. Tooth eruption data from younger red deer indicates time of death as late winter/early spring. Unlike the cattle and sheep skull deposits, the red deer skeletons were not integrated within LON structures, but recovered in rubble/sand overlying abandoned structures during the Late Neolithic/Early Chalcolithic period. It is probable these red deer died or were slaughtered close to the LON settlement and possible explanations for their presence are more ambiguous than those for LON cattle and sheep skulls. The red deer skeletons could be the remains of spring slaughter to prevent marauding newly sprouted crops, active culling of juveniles/males to manage the herd numbers or natural deaths from late winter/early spring starvation. Prestige hunting appears unlikely since the deer would have been in poor condition. Skins may have been of value, and stretching skins is one possible explanation for the numerous ulnae bones with broken distal diaphyses recovered adjacent to one skeleton. Alternatively the deposits were ritualistic, mammals perhaps slaughtered for a special event, with potential resources slighted.

The red deer bone in Orkney Neolithic cairns may have been the remains of sacrifices or feasts for ancestors, remains of meals from hunting expeditions, or less probably associated with midden material transported into cairns. Red deer bones in settlement midden material were not numerous, but some LON bones appear to show evidence of butchery, so meat, fat and sinews may have been exploited.

Antler would have been an important renewable resource prior to the advent of metal and its importance may have been under-estimated. Antler deposited in the foundation course, Structure 9, antler bundles from the cairn of Papa Westray North and antler fragments from other Orkney Neolithic cairns may indicate both a practical, but possibly also a belief-driven role, for this resource.

LON mammal bone deposits in middens and infill contexts examined were dominated by cattle and sheep, with cattle contributing the largest quantities of meat to the settlers' diet. The skull deposits from Structures 9 and 18 therefore reflect herds and flocks maintained at the site, but cattle skulls were deposited preferentially. LON mammal exploitation, at least half a millennium after the first arrival of domesticates, reflects a mature, stable, non-experimental husbandry regime. The mammal bone representation at LON was similar to the earlier Mid Neolithic settlement in Orkney, Knap of Howar, showing no evidence, even at this earlier stage, of experimental agriculture.

A large proportion of LON cattle bones were from individuals who died in their first year of life. Evidence of "age of death", milk residues and the uptake of LP in early other northern European sites, suggests it probable that the Neolithic LON settlers milked some cows. In contrast, the "age of death" profile of sheep at LON appears consistent with out-take for meat and not intensive dairying or wool production. The LON sample for pig "age of death profiles" is small but the patterns unexpected since older animals predominate. The possibility that pig were not bred at LON must be considered even although it is suggested that cattle, sheep and pigs form a "characteristic" British Neolithic domestic mammal group. It would be of interest to determine whether lack of pig bones was characteristic of other Irish or northern British sites.

Overall no severe or extensive pathology were noted on LON domestic mammal bones, but this may have been due to judicious culling. However, based on pathologic lesions observed of LON cattle pelves and lipping and extensions on the articulated surfaces of tarsals and phalanges, it is tentatively suggested that some LON cattle were involved in traction. Pathology noted on non-domesticated species included evidence of spavin from a red deer

There was a clear reduction in cattle stature between the Late Neolithic and Iron Age period in Orkney, and if the Late Bronze Age site of Bay of Skaill is considered, then this change occurred during the Orkney Chalcolithic or Early/Mid Bronze Age. No LON cattle bone measurements approached published male aurochs apart from one skull deposited in Structure 9, but a small number of LON bones than could be female aurochs or domesticated male cattle. There may have been a preference to maintain cattle with large stature and horns with a "*primigenius*" spiral during the Neolithic, perhaps to retain a resemblance to their wild progenitor, the aurochs. The subsequent reduction in cattle stature by Iron Age may be related to their changed role in belief systems, or alternatively, the possible impact of environmental deterioration at the end of the Neolithic period.

Red deer in Late Neolithic Orkney were generally of smaller stature than contemporary mainland Scotland red deer, so diminution of stature had occurred prior to this period. LON sheep resembled modern northern sheep breeds considered relict populations from flocks that arrived with early farmers to the Northern Isles. Stature diminishes between the Neolithic and Iron Age period but the changes are less pronounced as those for cattle. However it also appears that the dimensions of sheep bones from the Mid Neolithic site of Knap of Howar are smaller than those from the Late Neolithic site at LON and this requires further investigation.

Domestic cattle and sheep must have been imported. The equitable maritime climate and extensive grazing areas may have been attractive to colonisers, reducing the requirement for winter feeding. In addition, the extensive coastline of Orkney could provide fish and shellfish to support food shortfalls. There may even have been a link between colonisation at higher latitudes and the occurrence of dairying. It is of great significance that LON cattle herds carried the matrilineal genetic signatures for three domestic “T3” haplotypes. This may indicate that there was more than one introduction of cattle herds into Westray and Papa Westray over the Neolithic period, demonstrating that networks were maintained by the community over time.

Importation of domesticates would have altered the physical landscape of Orkney through grazing, production of midden material for garden plots, inhibition of tree or scrub regeneration and possible destabilisation of machair. This, in combination with still rising sea levels, would have led to changing landscapes, but animal husbandry, in terms of sheep and cattle remains in middens, remained relatively constant over the Orkney Neolithic period. Changes in domestic stock representation and size by Iron Age may be associated not only with environmental changes but sociocultural preferences. Unlike human colonisation of many islands, the introduction of domestic stock, commensals (and possibly wild mammals) to Orkney would have led to an increase in the faunal biodiversity of depauperate Orkney.

The discovery of a cattle skull at LON with the “P” haplogroup generally associated with European aurochs is important. There is no evidence based on non-duplicated isotope results, that hg “P” followed a different grazing pattern from the other LON cattle, or was imported from a more forested, or wetter environment. If this mammal was domesticated, the origin of this mtDNA incorporation into domestic stock at some point before domesticated cattle's arrival in Orkney would be exceptional.

Aurochs have been recorded from mainland Scotland in the Mesolithic, Neolithic and Bronze Age period, so another possibility is that at least two aurochs skulls were imported from mainland Scotland for special deposition. Human introduction of live aurochs is another possible explanation, and has been offered as an explanation for the presence of red deer in Orkney, the Western Isles and Ireland. It is plausible that Neolithic farmers would want to import red deer, both for antler production and as a back-up resource but the introduction of aurochs seems less compelling unless these mammals were of cultural importance. Alternatively, Mesolithic hunter-gatherers may have already introduced red deer (and aurochs?) to Orkney prior to the arrival of Neolithic farmers since these communities would have owned boats capable of facilitating such an importation.

A third option is that aurochs, red deer, and other wild mammals recorded in Neolithic Orkney such as fox, otter and pine marten, entered Orkney from mainland Scotland unaided immediately after the abrupt ending of the Loch Lomond Stadial at approximately 10000 BP. There is evidence that red deer in Late Neolithic Orkney already exhibited smaller stature than Scottish mainland red deer, so it is possible that if aurochs were living on Orkney, the recorded northern limit of their distribution, they would also smaller than their mainland counterparts. There is increasing evidence that geographical location may influence stature of European aurochs, with central European specimens larger than those from Scandinavia and northern Europe. Recently some European cattle with small measurements have been identified using mtDNA analyses to be aurochs indicating that distinction between aurochs and domesticate cattle based on stature is a less reliable guide that was previously assumed. The "island rule", which may apply to Neolithic Orkney mammal communities, which leads to smaller mammals tending towards gigantism and larger animals towards dwarfism (or nanism), so further research is  required to investigate whether post-cranial bones at the uppermost range for domestic males could be aurochs.

Evidence from LON mammal bones indicates a thriving Late Neolithic community successfully organising their domestic cattle herds and sheep flocks and exploiting red deer for antler and other resources. Cattle and sheep provided primary products, and in the case of cattle, also secondary products, and also fulfilled a role in their belief systems. The role of red deer more ambiguous and pigs do not appear to be important for either sustenance or ceremonies.

The following suggestions are made for further study

- Detailed morphological comparison with Neolithic faunal remains from LON and those of Northton, Western Isles (material held at NMS Collection Centre) and from Caithness cairn sites.

- Investigation of LON Bronze Age material to try to produce a more accurate time-scale for size diminution of cattle between the Neolithic and Iron Age in Orkney

- Further mtDNA and sex determination of LON cattle skulls F6718 and F4459 plus a sample of post-cranial bones exceeding published dimensions of Neolithic domestic cattle. In addition investigation on whether hg “P” recovered from Irish or mainland Scotland cattle.

- Study of otters in Neolithic, Bronze Age and Iron Age sites in Orkney and comparison with present day populations, with particular reference to morphology and incidence of pathological lesions.

- Study of possible sheep stature diminution between Orkney Mid and Late Neolithic sites

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# 14 Appendices

## 14.1 Appendix 1: Neolithic sites in Orkney

## Orkney cairns

| Cairn | NGR | Mammal Species | Mammal Skulls | Reference |
|---|---|---|---|---|
| Blackhammer | HY 414 276 | cattle, red deer, sheep | sheep mandibles | Platt, 1937a |
| Burray | ND 489 988 | dog; seven skeletons including skulls | animal skull with horns | Davidson and Henshall, 1989 |
| Calf of Eday | HY 578 386 | Otter | partial otter skull | Platt, 1937b |
| Cuween | HY 363 127 | cattle, dog | twenty-four dog skulls | Charleson, 1901/02 |
| Holm of Papa Westray North | HY 504 522 | cattle, dog, otter, pig, red deer, sheep | some cattle and sheep skull frgs | Harman, 2009 |
| Isbister | ND 470 845 | cattle, dog, otter, pig, rabbit, red deer, seal, sheep | cattle skulls | Barker, 1983, Jones and Richards, 2003 |
| Knowe of Ramsay | HY 400 280 | cattle, red deer, sheep | | Platt, 1936 |
| Knowe of Rowiegar | HY 373 297 | cattle, sheep | sheep skull | Davidson and Henshall, 1989 |
| Knowe of Yarso | HY 404 279 | cattle, dog, red deer, sheep | red deer and sheep mandibles | Platt, 1935 |
| Midhowe (Neolithic) | HY 372 304 | cattle, red deer (antler only), sheep | | Platt, 1934 |
| Pierwall Quarry | HY 439 490 | cattle, otter, pig, pine-marten, red deer, sheep | sheep and pine martin skull frgs | McCormick, 1984 |
| Point of Cott | HY 465 476 | cattle, dog, otter, red deer, sheep | cattle, dog and sheep skull frgs | Halpin, 1997 |
| Quanterness | HY 412 129 | cattle, dog, fox, horse, otter, pig, rabbit, red deer, sheep | one dog mandible, fox, otter, pig, skull frgs, otter skull frgs, sheep mandibles and loose maxillary teeth | Clutton Brock, 1979 |
| Quoyness | HY 676 378 | cattle, red deer, sheep | sheep skull in cist (lamb) | Davidson and Henshall, 1989, Zeuner, 1952 |
| Unstan | HY 228 117 | cattle, dog, pig, red deer, sheep | | Davidson and Henshall, 1989 |
| Vesta Fiold | HY 242 221 | cattle, fox, cf pine marten, sheep | one cattle maxillary fragment four sheep mandible frgs | Richards et al, 2013 |
| Wideford Hill | HY 409 121 | cattle, horse, pig, red deer, sheep | | Davidson and Henshall, 1989 |

## Orkney settlements

| Settlements | NGR | Mammal Species | Mammal Skulls | Reference |
|---|---|---|---|---|
| Knap of Howar | HY 483 518 | cattle, sheep, pig, dog, seal, otter, whale | | Noddle, 1983, Platt 1937c |
| Skara Brae | HY 231 187 | cattle, sheep, pig, whale, red deer | cattle skulls | Childe, 1931, Clarke, 1998, Noddle, 1978, Watson, 1931, |
| Pool | HY 619 378 | cattle, sheep/goat, pig, red deer, whale | cattle skull | Bond, 2007 |
| Tofts Ness | HY 757 464 | cattle, sheep, pig, red deer, dog, seal, otter, whale | | Nicholson and Davies, 2007 |
| Rinyo | HY 440 322 | cattle, sheep, whale, red deer antlers | | Childe and Grant, 1939, 1947 |
| Barnhouse | HY 307 127 | cattle, sheep/goat, pig | | King, 2005 |

## Orkney Ceremonial sites

| Monuments | NGR | Mammal Species | Mammal Skulls | Reference |
|---|---|---|---|---|
| Stones of Stenness | HY 306 125 | wolf/dog, cattle, sheep | | Clutton-Brock, 1975/76 |
| Ness of Brodgar | HY 303 129 | cattle, red deer, sheep | cattle skull | Mainland et al, 2014 |

## 14.2 Appendix 2: Radiocarbon dates for LON (determined by SUERC on behalf of Historic Scotland)

| **LON Context** | **EASE Code** | **SUERC Code** | **GU Code** | **Sp** | **Bone** | **C14 date** | **cal BC 95.4%** | **cal BC 68.2%** |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| 9123 | 2013A | 51170 | 32936 | Cattle | $P^3$ | 3973+/-35 | 2578-2349 | 2566-2466 |
| 9116 | 2013B | 51171 | 32937 | Cattle | $M_3$ | 4236+/-36 | 2916-2694 | 2905-2764 |
| 9123 | 2013C | 51172 | 32938 | Cattle | $M^1$ | 4256+/-35 | 2923-2704 | 2911-2874 |
| 9116 | 2013D | 51173 | 32939 | Cattle | $P_2$ | 4228+/-35 | 2911-2681 | 2900-2762 |
| 9116 | 2013E | 51174 | 32940 | Cattle | $M^2$ | 4299+/-35 | 3012-2879 | 2927-2884 |
| 9116 | 2013F | 51175 | 32941 | Cattle | $P^3$ | 4217+/-35 | 2905-2678 | 2894-2712 |
| 9129 | 2013G | 51176 | 32942 | Cattle | $M_1$ | 3970+/-35 | 2577-2348 | 2566-2464 |
| 9021 | 2013H | 51180 | 32943 | Cattle | radius proximal | 4039+/-35 | 2835-2472 | 2618-2539 |
| 9031 | 2013I | 51181 | 32944 | Cattle | radius, proximal | 4158+/-35 | 2880-2626 | 2871-2678 |
| 9021 | 2013J | 51182 | 32945 | Cattle | $M^3$ | 4158+/-35 | 2880-2626 | 2871-2678 |
| 9028 | 2013K | 51183 | 32946 | Cattle | m/t fragment | 4338+/-35 | 3082-2893 | 3011-2904 |
| 9116 | 2013L | 51184 | 32947 | Cattle | humerus fragment | 4064+/-35 | 2853-2486 | 2833-2497 |
| 9166 | 2013M | 51185 | 32948 | Cattle | phalanx | 4188+/-35 | 2891-2639 | 2884-2698 |
| 9681 | 2013N | 51186 | 32949 | Cattle | m/t distal | 4270+/-35 | 3008-2711 | 2911-2881 |
| 9134D | 2013O | 51190 | 32950 | Red | femur, distal | 3980 +/-35 | 2580-2349 | 2566-2469 |
| 9681 | 2013P | 51191 | 32951 | Red | phal2 | 4076+/-35 | 2859-2491 | 2835-2501 |
| 9031AD | 2013Q | 51192 | 32952 | Sheep | Calc | 4112+/-35 | 2871-2573 | 2853-2587 |
| 7302 | SF 515 | 27899 | 20906 | Cattle | phalanx | 4030+/-30 | 2630-2470 | 2580-2485 |
| 7302 | SF507 | 27900 | 20907 | Sheep | Vert | 4105+/-30 | 2870-2570 | 2850-2570 |
| 9016 | SF2418 | 27902 | 20909 | Cattle | Calc | 4070+/-30 | 2860-2490 | 2840-2490 |
| 9009 | SF2225 | 27903 | 20910 | Sheep | Vert | 4185+/-30 | 2890-2660 | 2880-2700 |

## 14.3 Appendix 3: Methods for mtDNA

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### Methods

DNA extraction followed the User Developed Protocol: “Purification of total DNA from compact animal bone using the DNeasy® Blood & Tissue Kit” (Qiagen, Basel, Switzerland) for less than 100 mg, in double reactions for each sample. One mock control was performed per eight samples. All extracts were washed twice with water (molecular biology grade, Eppendorf, Allschwil, Switzerland) using 30 kD filter units (Amicon/Millipore, Zug, Switzerland). The final eluate was 200 µl.

Three targets of the mt d-loop covering nucleotide positions 15’903-16’023, 16’041-16’152, and 16’185-16’312 (*Bos taurus* reference sequence (BRS) V00654, Anderson *et al.* 1982) were PCR amplified in 25 µl volumes containing 1.5 U AmpliTaq Gold, 1x GeneAmp 10x PCR Gold Buffer (150 mM Tris-HCl, 500 mM KCl, pH 8.0) and 2 mM $MgCl_2$ (all Applied Biosystems, Hombrechtikon, Switzerland); 0.4 mM dNTP Mix (Promega, Dübendorf, Switzerland); 0.2 µM of each primer; 20 µg/µl BSA (bovine serum albumin, Roche, Basel, Switzerland), and 3-9 µl template DNA on a Mastercycler ProS (Eppendorf, Allschwil, Switzerland). The cycling conditions were: 12 min initial denaturation, followed by 50 cycles of denaturation at 95 °C for 40 sec, annealing at 52-58 °C for 30 sec, and extension 72 °C for 30 sec, with a final extension of 60 sec at 72 °C. Non-template controls were performed alongside all amplifications. Successful PCR amplification was monitored on a 3% agarose gel, cut from the gel and purified with MinElute Gel Extraction Kit (Qiagen, Basel, Switzerland). PCR products were premixed with elongated sequencing primers (Binladen *et al.* 2007) and Sanger sequenced by Microsynth (Balgach, Switzerland).

Sequences were edited and aligned by eye with BioEdit (Hall 1999). A Median Joining Network (MJN, Bandelt *et al.* 1999) was constructed with the software Network (fluxus-engineering.com). The sequence alignment was shortened to nucleotide positions 16’042-16’152 and 16’185-16’262 to include as many published sequences of ancient *Bos taurus* and *Bos primigenius* as possible resulting in a total of 382 sequences. *Bos* database entries were taken from Troy *et al.* 2001; Anderung *et al.* 2005; Salamon *et al.* 2005; Beja-Pereira *et al.* 2006; Bollongino *et al.* 2006; Edwards *et al.* 2007; Pruvost *et al.* 2007; Bollongino *et al.* 2008; Scheu *et al.* 2008; Campana *et al.* 2010; Bollongino *et al.* 2012; Gravlund *et al.* 2012; Cai *et al.* 2014, Anderung *et al.* unpublished, Campana *et al.* unpublished, and Scheu *et al.* unpublished.

### Authenticity

Established standards in aDNA research at the Integrative Prehistory and Archaeological Science (IPAS) were adhered to (e.g. Schlumbaum *et al.* 2010, Elsner *et al.* submitted). In detail: All ancient DNA work (pre-PCR) was performed in dedicated, physically separated laboratories for sample preparation, DNA extraction and PCR setup in a different building than the post-PCR laboratory following a strict one-way policy. Experiments were performed freshly showered and wearing dedicated freshly washed clothes. Gloves and sleeves were changed regularly. Bones and teeth were cut in an acrylic glass box equipped with an UV-lamp and a vacuum cleaner to remove bone dust. After each working step, surfaces were cleaned with soap and commercial bleach (Javel-Wasser, Migros, Zurich, Switzerland) and UV-radiated for at least 30 min. Diamond-cutting disks were cleaned in ethanol to avoid corrosion. Mixer mill beakers were cleaned with soap, quartz and 30 min bleach incubation. PCR was set up in a laminar flow work station equipped with an UV lamp. Surfaces and tools were cleaned with soap, bleach and ethanol and UV-irradiated after processing of each sample or working step. Consumable plastic ware was UV-irradiated prior to use. We did not perform sample preparation, extraction and PCR on the same day. No modern cattle or pig DNA was analysed in the post-PCR laboratory and none of the co-workers had contact with living cattle or pigs. Each target was validated with two independent extractions and three to four PCR products.

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## 14.4 Appendix 4: Ferriter's Cove- review of published evidence

Seven cattle bones, plus a sheep incisor tooth, were recovered from a late Mesolithic occupation site, Ferriter's Cove Co. Kerry in south west Ireland. Two cattle bones from this deposit were radiocarbon dated. The first bone was from a deposit located on a wave-cut platform and dated to 5550 +/- 70BP (OxA 3896). The other was a charred bone from a bulk sample with an earlier date of 8775 5825+/- 50 BP (OxA 8775), excluded from the recent extensive and thorough evaluation of Mesolithic/Neolithic dates in "Gathering Time", because of risk of contamination from exogenous carbon (Cooney et al., 2011, p629). Cattle bone OxA 3896 is considered to be the earliest dated domesticated animal bone from Britain and Ireland (Sheridan 2010, p92).

Cattle bones recovered from Ferriter's Cove were fragmented and poorly preserved with identification based on the examination of long bone diaphysis portions. The exception was the charred metatarsal proximal fragment from the bulk sample (McCarthy, 1999). Reporting of the seven cattle bones from Ferriter's Cove has been inconsistent. In the interim report from the site, the main text describes the recovery of seven cattle bones (Woodman and O'Brien, 1993 p28) but in the "Faunal Remains Appendix" two bone elements were attributed to red deer* (species identification uncertain), and no elements to cattle. In a later publication on the Quaternary Fauna of Ireland the radiocarbon dated cattle bone OxA 3896 was described as a cattle ulna (lower forelimb) Ulna E263 (Woodman et al 1997, p 139; Table 6 P138). However, in a publication two years later the seven recovered cattle bones were described as two tibia fragments, two radius fragments, two unidentified long bone diaphysis fragments and a lateral proximal metatarsal fragment, with no reference to the aforementioned ulna (McCarthy, 1999, p89). The radiocarbon dated bone, OxA 3896, was now described as a cattle tibia (Woodman and McCarthy, 1999); this is also the bone description presented in the analysis of Irish Mesolithic/Neolithic dates (Cooney et al, 2011 p628, Table 12.9).

The discovery of the Ferriter's Cove cattle bones has encouraged some researchers to suggest that there was an early, but short-lived, colonisation of south-west Ireland from western France the 5th millennium BC (Sheridan, 2003, 2010, Tresset, 2002, 2003). Another possibility is that the cattle bones represented evidence of a Mesolithic/Neolithic interface before the establishment of a Neolithic society, a hypothesis proposed by other archaeologists (e.g. Case, 1969, Woodman, 2000, Woodman and McCarthy, 2003, p34, Zvelebil and Lillie, 2000). The Mesolithic communities have proven sea-faring abilities (Garrow and Strut 2011, McGrail, 2010, Van de Noort, 2011, p 137) and contact through coastal voyaging could have introduced livestock from continental Europe (Robb, 2013, p164).

The underlying assumption for these arguments is that cattle bones at Ferriter's Cove were from domestic animals. If the bones came from wild aurochs, red deer or another large mammal they would still have been imported by sea, sourced from either mainland Britain or continental Europe, but not necessarily from regions were domestic stock-keeping was practised. Current evidence indicates that the bones could not have been from indigenous large mammals since elk, red deer and aurochs bones have not been recovered from Irish sites in the Late Glacial period (Woodman et al, 1997, p153, fig 7). Red deer only appeared to in Ireland during the Neolithic (Woodman et al, 1997 p152/53, Yellen 1999, p218). This observation is reinforced by recent mDNA, radiocarbon and craniometric analyses of red deer that indicate that, post glaciation, this species was reintroduced by humans during the Neolithic period and that Britain, Ireland's nearest landmass, played a vital role in their establishment (Carden et al., 2012).

The cattle bones from Ferriter's Cove were allocated to domestic cattle, not aurochs, because they were considered too small to be from aurochs (Woodman and McCarthy, 2003 p 33). However, recent evidence of diversity of size ranges in aurochs bones (Bökönyi and Bartosiewicz 1987, Prummel and Niekus, 2011, Scheu et al., 2008) including records of specimens with significantly smaller estimated withers height than earlier published measurement tables for aurochs and domestic cattle (e.g. Degerbøl and Fredskild 1970, Grigson, 1969) suggests that this assumption is open to challenge.

In addition to the cattle bones from Ferriter's Cove a mammal long bone diaphysis fragment, initially identified as a cattle bone, from a shell midden, Sutton Co. Dublin, was dated 6660 +/-80 BP (OxA 3691). This led the Quaternary Faunas Project to suggest that this bone may have been "a bear bone, a more "archaeologically acceptable" explanation" (Woodman and McCarthy, 2003 p 35, Woodman et al 1997, p155).

"Gathering Time" with regard to Ferriter's Cove cattle bones stated "whether the bones are sufficiently diagnostic to make certain they were from domesticated animal(s) is a question that should be raised from re-examination and re-confirmation" (Cooney et al., 2011 p 632). A non-destructive and inexpensive collagen analysis could confirm the bones Ferriter's Cove were cattle (Buckley et al, 2013). The same test for the earlier Sutton shell midden bone could also check the identification of brown bear based on an assumption that this was the only large terrestrial mammal living in Ireland during the Mesolithic. If the bones from Ferriter's cove are from cattle then mDNA analysis could assist with the determination on whether the bones carried the aurochs or domesticated cattle haplotypes.

## 14.5 Appendix 5: Sequence of skull deposition, Structure 9

**NORTH**

| | | | | |
|---|---|---|---|---|
| | sheep skull F6852 | | F6728 | |
| | red deer antler F4469 | | F4262 | |
| | F4468 | | F4261 | |
| | F6699 | | cattle pelvis (L&R) F4260 | |
| | F4466 | | F4259 | |
| | F4462 | | F4258 | |
| | F4461 | | F4257 | |
| | F4460 | | F4256 | |
| **WEST** | F4459 | | F4255 | **EAST** |
| | F6692 | | red deer antler | |
| | F4458 | | F4254 | |
| | F6694 | | cattle pelvis (2*L) F7924 | |
| | F6693 | | sheep skull F6721 | |
| | | | cattle pelvis R | |
| | | | F4253 | |
| | | | F6717 | |
| | | | F7750 | |
| | | | F6718 | |
| | | | F6701 | |
| | | | F4917 | |
| | | | F4521 (single horn core) | |
| | | | F6700 | |
| | | | F6716 | |
| | | **SOUTH** | | |

## 14.6 Appendix 6: Fragmentation of non-conserved LON (Links of Noltland) Structure 9 cattle skulls

| SKULL | weight (g) | no of fragments | length of largest fragment (mm) | ave weight of fragment (g) |
|---|---|---|---|---|
| 6728 | 83 | 98 | n/a | 0.8 |
| 4255 | 110 | 88 | 230 | 1.2 |
| 7750 | 265 | 15 | 134 | 17.6 |
| 6717 | 297 | 137 | 98 | 2.2 |
| 6701 | 354 | 10 | 139 | 35.4 |
| 4262 | 366 | 72 | 101 | 5.1 |
| 4261 | 376 | 142 | 128 | 2.7 |
| 6699 | 424 | 171 | 141 | 2.5 |
| 6718 | 486 | 166 | 114 | 2.9 |
| 4460 | 676 | 237 | 111 | 2.9 |
| 6700 | 716 | 196 | 138 | 3.7 |
| 4257 | 756 | 283 | 130 | 2.7 |
| 4917 | 817 | 20 | 195 | 40.9 |
| 4459 | 846 | 204 | 106 | 4.1 |
| 4259 | 1090 | 285 | 240 | 3.8 |
| 4468 | 1105 | 136 | 250 | 8.1 |
| 6693 | 1121 | 315 | 91 | 3.6 |
| 6718 | 1260 | 221 | 220 | 5.7 |
| 4462 | 1460 | 365 | 125 | 4.0 |
| 4917 | 1701 | 242 | 230 | 7.0 |
| 4254 | 1739 | 243 | 220 | 7.2 |
| 4253 | 2877 | 310 | 270 | 9.3 |

## 14.7 Appendix 7: Maxillary teeth from Structure 9 cattle skulls

| **SKULL** | **R/L** | **$P^2$** | **$P^3$** | **$P^4$** | **$dp^2$** | **$dp^3$** | **$dp^4$** | **$M^1$** | **$M^2$** | **$M^3$** |
|---|---|---|---|---|---|---|---|---|---|---|
| 4256 | L | | | | | | | | | P |
| 4256 | R | | P | P | | | | P | P | P |
| 4262 | R | | E | E | | | | P | P | |
| 4459 | L | | P | P | | | | P | P | P |
| 4459 | R | | P | P | | | | P | P | P |
| 4462 | L | P | P | P | | | | P | P | P |
| 4462 | R | | P | P | | | | P | P | P |
| 4460 | L | U | U | U | | | | P | P | P |
| 4460 | R | U | U | U | | P | P | P | P | P |
| 6693 | L | | P | P | | | | P | P | P |
| 6693 | R | | | P | | | | P | P | P |
| 6699 | | | | | | | | | U | |
| 4257/4258 | L | P | P | P | | | | P | P | P |
| 4257/4258 | R | P | P | P | | | | P | P | P |
| ass 4462 | L | | | P | | | | | | |

**KEY: L = left, R = right, P = present, U= unerupted, E= erupting**

## 14.8 Appendix 8: Age estimates from maxillary teeth Structure 9 cattle

| **SKULL** | **Andrews (1982)** | **Simonds (1854)** | **Silver (1969) modern** | **Sisson and Gross-man (1975) (*in Grigson 1982*** | **Higham (1967)** | **Halstead (*in Grigson 1982*)** | **Note** | **Age** |
|---|---|---|---|---|---|---|---|---|
| 4254 | | >30-36m | >24-30m | >24-30m | >40m | G | M3 pillar in wear | OA |
| 4256 | | >30-36m | >28-36m | >30-36m | >40-50m | | | A/OA |
| 4262 | | >24 <36m | >15-18m<18-30m | >12/18 <18/30m | >18-24< 40m | | | SA |
| 4458 | | >30-36m | >28-36m | >30-36m | >50m | G | M1,2, 3 pillars in wear | OA |
| 4459 | | >30-36m | >28-36m | >30-36m | >50m | F | M3 pillar not in wear | A |
| 4460 | | >30 <36m | >24-30m< 36m | 24-30m | 30-33m | C | M1 pillar just in wear | SA |
| 4461 | | >30-36m | >28-36m | >30-36m | 40-50m | | | A |
| 4462 | | >30-36m | >28-36m | >30-36m | 40-50m | | Only M1 pillar in wear | A |
| 6692 | | >30-36m | >28-36m | >30-36m | >50m | F | M1,2 pillars in wear M3 pillar not in wear | A |
| 6693 | | >30-36m | >28-36m | >30-36m | >50m | G | | A/OA |
| 6694 | >16<20m | approx 15m | 15-18m | 12-18m | 15-17m | | no dentine wear on M2 | J |
| 6699 | >14 <20m | approx 15m | >5-6m<12-18m | >5-6m<12-18m | 15-17m | | | J |
| 6718 | | | >28-36m | >30-36m | | | | A/SA |

## 14.9 Appendix 9: Combined age estimates for LON (Links of Noltland) Structure 9 cattle skulls

| SKULL | Teeth | Suture | h/c texture (not tip) Armitage (1982) | perlins on eye (Grigson, 1976) | perlins of h/c (Grigson, 1976) |
|---|---|---|---|---|---|
| | | | | | |
| 4253 | A (alveoli) | OA | A/OA | A/OA | A/OA |
| 4254 | OA | A/OA | A | A/OA | A |
| 4255 | | | SA? | | |
| 4256 | A/OA | A/OA | A/OA | | A/OA |
| 4257/8 | A | | A | | |
| 4259 | | | A | | A/OA |
| 4261 | | A/OA | A | | |
| 4262 | SA | | | | |
| 4458 | OA | A/OA | A/OA | | A/OA |
| 4459 | A | | A/OA | | |
| 4460 | SA | | | | |
| 4461 | A | | | | |
| 4462 | A | | A | | |
| 4466 | | | | | |
| 4468 | | A/OA | A/OA | | A/OA |
| 4917 | | A/OA | A/OA | | |
| 6692 | A | | | | |
| 6693 | A/OA | A/OA | A | | |
| 6694 | J | | | | |
| 6699 | J | J | | | |
| 6700 | | | SA | | |
| 6701 | | | YA | | |
| 6716 | | | | | |
| 6717 | | | SA | | |
| 6718 | SA/A | A | YA/A | | |
| 6728 | | | | | |
| 7750 | | A | | | |

## 14.10 Appendix 10: LON Structure 18 cattle skulls Minimum Number of Individuals (MNI)

| Context | SKULL | MNI |
|---|---|---|
| 9880 | 19851 | 1 |
| 9880 | 19853 | 1 |
| 9880 | 19854 | 1 |
| 9880 | 19863 | 1 |
| 9880 | 19874 | 1 |
| 9880 | 19875 | 1 |
| 9880 | 19876 | 1 |
| 9880 | 19880 | 2 |
| 9880 | 19882 | 2 |
| 9880 | 19884 | 2 |
| 9880 | 19895 | 2 |
| 9880 | 19896 | 1 |
| 9880 | 19897 | 2 |
| 9880 | 19898 | 3 |
| 9880 | 19904 | 1 |
|  |  |  |
| 9898(niche) | 19946 | 1 |
| 9898(niche | 19948 | 1 |
|  |  |  |
| Total | 17 | 24 |

## 14.11 Appendix 11: LON Structure 18 cattle skulls weight and maximum fragment length

| SKULL | weight (g) | Length of longest fragment (mm) |
|---|---|---|
| 19898b | 47.6 | 86.7 |
| 19898a | 55 | 113.6 |
| 19895a/b | 96.8 | 139.0 |
| 19882b | 99.5 | 82.4 |
| 19948 | 124 | 85.4 |
| 19897b | 126.3 | 152.0 |
| 19946 | 221.3 | 149.5 |
| 19864 | 249.4 | 150.0 |
| 19904 | 287 | 149.5 |
| 19897a | 320.1 | 185.0 |
| 19896 | 322.6 | 174.0 |
| 19875 | 360.8 | 170.0 |
| 19882a | 430.6 | 137.6 |
| 19876 | 458.1 | 230.0 |
| 19853 | 476.7 | 225.0 |
| 19895a | 506.9 | 170.0 |
| 19898a/b | 528.2 | 137.4 |
| 19874 | 572.2 | n/a |
| 19863 | 609.2 | n/a |
| 19880a | 717.5 | 270.0 |
| 19880b | 778.5 | n/a |
| 19884a/b | 830.3 | 250.0 |
| 19851 | 911.2 | 139.6 |

## 14.12 Appendix 12: Age estimates for Structure 18 cattle skulls

| SKULL | Teeth | Suture | h/c texture (not tip) Armitage (1982) |
|---|---|---|---|
| 19851 | A | A/OA | |
| 19853 | | OA | |
| 19854 | | A/OA | A/OA |
| 19864 | A | OA | |
| 19875 | A | A/OA | |
| 19874 | | A/OA | A/OA |
| 19876 | | A/OA | SA/A |
| 19879 | | | |
| 19880 | | A/OA | |
| 19881 | | A/OA | |
| 19884 | A/OA | A/OA | SA/A |
| 19896 | A | OA | |
| 19904 | | A | J |
| 19946 | | J | Calf |
| 19882a | | Calf | |
| 19882b | | J | J |
| 19895a | | A | A |
| 19895b | | | |
| 19897a | | OA | |
| 19897b | | SA | |
| 19898 | | A/OA | |

## 14.13 Appendix 13: Bone weight for cattle, sheep, large mammal and medium-sized mammal in eight LON areas studied (g)

| Bone weight (g) | Cattle | Sheep | Large mammal (including cattle) | Medium size mammal (including sheep) |
|---|---|---|---|---|
| Midden below St 9 | 3038 | 408 | 4312 | 604 |
| Floor St 9 | 1760 | 571 | 2980 | 786 |
| Wall core St 9 | 8277 | 1184 | 10310 | 1574 |
| Above St 9, Midden 9031 | 10099 | 4222 | 15062 | 5851 |
| Midden 7302 | 38380 | 19952 | 53307 | 28774 |
| Infill to kiln, St 10 | 4166 | 1639 | 5568 | 2070 |
| Midden ~7302 (a) | 4824 | 2064 | 5110 | 2270 |
| Midden ~7302 (b) | 1866 | 655 | 2649 | 812 |

## 14.14 Appendix 14: Bone weight for sheep and cattle NISP from spits in context 7302 (g)

| Spit 7302 | Cattle (g) | Sheep (g) |
|---|---|---|
| 1 | 1990 | 1567 |
| 2 | 10539 | 5208 |
| 3 | 12433 | 6748 |
| 4 | 8994 | 2661 |
| 5 | 2264 | 1656 |
| 6 | 875 | 786 |
| 7 | 1073 | 754 |
| 8 | 212 | 195 |

## 14.15 Appendix 15: Number of complete sheep and cattle bones in eight LON areas studied

| | Cattle complete | Cattle NISP | Sheep complete | Sheep NISP |
|---|---|---|---|---|
| Midden below St 9 | 12 | 244 | 9 | 174 |
| Floor St 9 | 13 | 142 | 13 | 153 |
| Wall core St 9 | 18 | 1265 | 12 | 368 |
| Midden 9031, above St 9 | 53 | 1023 | 76 | 1298 |
| Midden 7302 | 286 | 3013 | 411 | 4953 |
| Infill to kiln, St 10 | 9 | 268 | 18 | 355 |
| Midden ~7302 (a) | 22 | 202 | 25 | 189 |
| Midden ~7302 (b) | 6 | 175 | 7 | 153 |

## 14.16 Appendix 16: Burnt bone weights (identified and non-identified) in eight LON areas studied (g)

| | Burnt | Total | % |
|---|---|---|---|
| Midden below St 9 | 1744 | 7128 | 24 |
| Floor St 9 | 827 | 4229 | 19 |
| Wall Core St 9 | 410 | 12599 | 3 |
| Midden 9031 | 2214 | 21884 | 10 |
| Midden 7302 | 4881 | 81377 | 6 |
| Infill to kiln, St 10 | 639 | 8127 | 8 |
| Midden ~7302 (a) | 45 | 7379 | 1 |
| Midden ~7302 (b) | 254 | 3641 | 7 |

## 14.17 Appendix 17: All bone fragments (identified and non-identified) from six of eight LON areas studied level of burning by weight (g)

| | **light burn** | **slight burn** | **charred** | **local calcined** | **dom calcined** | **calcined** |
|---|---|---|---|---|---|---|
| Midden below St 9 | 184.3 | 187.3 | 484.9 | 520.2 | 203.8 | 163.1 |
| Floor St 9 | 289 | 108.2 | 205.5 | 137.5 | 61.1 | 49.9 |
| Wall Core St 9 | 48 | 30.1 | 174 | 38.6 | 32.6 | 86.1 |
| Midden above St 9, 9031 | 50 | 160 | 854.8 | 550.3 | 231.2 | 367.2 |
| Midden 7302 | 350 | 939 | 1235 | 1024 | 688 | 612 |
| Infill to kiln, St 10 | 128.6 | 137.7 | 124.7 | 155.8 | 38.5 | 53.4 |

## 14.18 Appendix 18: LON (Links of Noltland) bone density calculations

The opportunity to identify a bone to element and/or species is at least partly related to the bone's structural density (equivalent to volume of bulk density). More precisely, since the primary component of bone is hydroxyapatite has a constant density of 3.1-3.2 the structural densities are based on the amount of space between the bony tissues (Shipman, 1981, p23). Bones involved in locomotion are subject to greater stresses in the living animal resulting in greater density than other bones (Bartosiewicz and Gál, 2013, p12).

Various techniques for measuring bone density exist, the simplest being that of water displacement. Most techniques do not take into account the annual variability of bone density, for example, when male deer are growing antlers or when female animals are gestating or lactating (Chen et al, 2009, p694). Differences due to diet, age and activity level are also usually not measured (Horwitz and Smith, 1990, Ioannidou, 2003).

L. Lyman undertook the first comprehensive survey using photon densitometry to measure bone structural densities on selected locations of post-cranial skeletal bones (Lyman, 1994 figs 7.4-7.6, pp240-245) and tabulated his and other researchers' results (Lyman, 1994, Table 7.6 pp 246-248, Kreutzer, 1992, table 2, pp278-281). Methods by different researchers vary. For example, Kreutzer used a dual energy X-ray densitometer, rather than the single bean photo densitometer used by L. Lyman and also calculated thickness of bone at the scan site differently. The table produced by L. Lyman included sheep and bison but not domesticated cattle or wild red deer. The measurements were taken from a small number of modern specimens, such as three partial sheep skeletons, one partial pronghorn antelope and twelve bison (Lyman, 1982, 1984, Kreutzer, 1992, p275). The inherent weakness of the early tables was that it was not possible to calculate the size of marrow cavities within long bone shafts (Kreutzer, 1992, p283) which led to underestimates of the density of long bones, particularly mid-shaft portions (Lam et al., 1995).

Since L. Lyman's table was published, photon densitometry calculations have become more sophisticated with results now adjusted for shape and the thickness of the scanned bone, for example, for a large sample of ninety-one modern Shetland sheep (Symmons, 2002, 2004, 2005). This approach has resulted in a greater range of values, for example, L. Lyman's sheep bone site T13 has a bone density of 0.59, R. Symmons' equivalent is 0.501 with a range of 0.280 to 0.630 (Lyman, 1994, table 7.6, p246, Symmons, 2005, table 3, p1695).

A simpler approach to addressing bone survivorship was adopted by M. Stiner (2002, 2004). This involved placing bones into nine categories and allocating each category an averaged density value from L. Lyman's tables. For example all feet bones are allocated 0.4, upper hind limb bones 0.5.This method loses a great deal of information. Even the scan sites on an individual bone do not convey the full extent of the bone density within that bone, so amalgamating results from scan sites from several bones of different sizes and shapes will not serve as reliable analogues (Symmons, 2004, p719). Additionally limb bone shaft fragments, not included in M. Stiner's calculation, cannot be excluded from analysis if limb bone abundances in assemblages are to be estimated (Pickering et al, 2003, p1480, Lam et al, 1999, p358).

Another method for examining bone density is to use of CT scanners (quantitative computed tomography) which take into consideration bone cavity and the thickness of cortical bone. R. Symmons argues that it is probable that CT produces more reliable results but it is very expensive and therefore cannot be used for a large number of skeletons (Symmons, 2005, p1692). Using the same bone scan site as published by L. Lyman, the CT method gives a value for seven caprine for scan site T13 of 1.238, SD 0.019, much higher than the values attributed to sheep by photon densitometry of 0.59 and 0.501(Lam et al., 1998, table 1, p563, Lyman, 1994, table 7.6, p247, Symmons, 2005, Table 3, p1695).

When CT scanning measurements were undertaken on four ungulate species the results indicated that there was a strong correlation between bovid, cervid and equid bone density. The variation between some bison and deer bone densities noted in earlier photon densitometry studies may have been due to different methodologies (Kreutzer, 1992, p 291, Lam et al, 1999, p354, Lyman, 1994, table 7.6, p 246-249). The correlation has been used as one of the justifications for using one species' bone density published measurements for other species recovered from the same archaeological investigations (Marciniak, 2005, p109, Orton, 2012, p323).

This correlation is of interest because, in theory, the maximum stress on bone is proportional to its linear dimension, and as this increases, elements of the skeleton must become relatively more massive because the material, bone, does not change (Currey, 1970, p9). The colloquial expression "elephants are not scaled-up mice" derived from essays by the early 20th century zoologist J. B. S. Haldane perhaps captures this allometric cube-squared relationship between size and weight. In addition, bulk density can vary between species due to differences in locomotion and deportment and use of horns/antlers (Currey, 1984, Kreutzer, 1992, p273), which would be the case for species such as cattle and red deer. The species used by Y. Lam and his colleagues for cervids, bovids and equids were four wildebeest, four reindeer, two Burchell's zebras and two Przewalski horses, all of which will preferentially use flight as a means of protection from carnivores, rather than stand and charge.

Density values for these species, labelled $BMD_2$ for bones with an internal cavity, generated density values lower than the CT density published for caprines by the same lead author

(Lam et al., 1998, table 1, p563, Lam et al., 1999, table 1, p381-383). The mean T13 value was 1.238 for caprines (1998), 1.07 for equids, 1.12 for wildebeest and 1.13 for reindeer 1.13 (1999). In both surveys the equipment and software were the same, the only difference being that the caprine bones were immersed in water, the other species scanned in air and adjustments made to convert them to the equivalent values as if they had been scanned in water.

## 14.19 Appendix 19: Condition of cattle, sheep and red deer bones by weight (g). Designation based on surface condition of bone and excludes teeth and axial fragments.

| **Cattle (weight, g)** | **Excellent** | **Good** | **Fair** | **Poor** |
|---|---|---|---|---|
| Midden 7302 | 361 | 24150 | 3641 | 294 |
| Midden above St 9 | 59 | 3659 | 207 | 214 |
| Wall core St 9 | 175 | 2346 | 3447 | 365 |
| Below St 9 | 0 | 1443 | 503 | 160 |

| **Sheep (weight, g)** | **Excellent** | **Good** | **Fair** | **Poor** |
|---|---|---|---|---|
| Midden 7302 | 109 | 12898 | 1583 | 138 |
| Midden above St 9 | 5 | 2118 | 604 | 31 |
| Wall core St 9 | 0 | 361 | 132 | 39 |
| Below St 9 | 0 | 239 | 65 | 7 |

| **Red deer (weight, g)** | **Excellent** | **Good** | **Fair** | **Poor** |
|---|---|---|---|---|
| Midden 7302 | 0 | 713 | 101 | 36 |
| Midden above St 9 | 0 | 126 | 85 | 12 |
| Wall core St 9 | 0 | 54 | 98 | 0 |
| Below St 9 | 0 | 386 | 110 | 14 |

## 14.20 Appendix 20: Distribution of LON (Links of Noltland) cattle, sheep and red deer by weight

| Weight (g) | Cattle | Sheep | Red | Total ID |
|---|---|---|---|---|
| Midden 7302 | 38380 | 19952 | 866 | 60017 |
| Midden 9031 | 10099 | 4222 | 329 | 15132 |
| Wall core St 9 | 8277 | 1184 | 396 | 9977 |
| Midden below St 9 | 3038 | 408 | 536 | 3391 |

## 14.21 Appendix 21: Size Index Scale: dimensions used in calculations

### Width/depth

| **Bone** | **Dimension** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|---|
| Astr | Bd | * | * | * | * |
| Fem | DC | * | * | * | * |
| Fem | Bd | * | * | * | * |
| Hum | Bd |  |  | * |  |
| Hum | BT | * | * |  | * |
| M/c | Bp | * | * | * | * |
| M/c | Bd | * | * | * | * |
| M/t | Bp | * | * | * | * |
| M/t | Bd | * | * | * | * |
| Rad | Bp | * | * | * | * |
| Rad | Bd | * | * | * | * |
| Scap | GLC | * | * | * | * |
| Tcen | GB | * | * | * | * |
| Tib | Bp | * | * | * | * |
| Tib | Bd | * | * | * | * |

### Length

| **Bone** | **Dimension** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|---|
| Astr | GLl | * | * | * | * |
| Pat | GL | * | * | * | * |
| Calc | GL | * | * | * | * |
| M/c | GL |  |  | * |  |
| M/t | GL |  |  | * |  |
| Rad | GL | * |  |  |  |

## 14.22 Appendix 22: Individual cattle bone and teeth measurements (mm) from Orkney Neolithic and Iron Age sites: LON (Links of Noltland, Late Neolithic); KOH (Knap of Howar, Mid Neolithic); Howe (Iron Age); BNKS (Brest Ness, Iron Age)

| Cattle astragalus GLl (mm) | LON | KOH | HOWE | BNKS |
|---|---|---|---|---|
| No | 36 | 9 | 101 | 13 |
| Mean | 67.6 | 68.5 | 58.4 | 59.6 |
| SD | 3.5 | 3.0 | 4.1 | 2.3 |
| Min | 59.9 | 65.0 | 47.0 | 55.5 |
| Q1 | 65.7 | 65.9 | 57.0 | 58.5 |
| Median | 68.3 | 68.3 | 59.0 | 59.9 |
| Q3 | 69.4 | 70.3 | 61.0 | 61.2 |
| Max | 77.4 | 72.6 | 74.0 | 62.8 |
| Bottom | 65.7 | 65.9 | 57.0 | 58.5 |
| 2QBox | 2.6 | 2.4 | 2.0 | 1.4 |
| 3Qbox | 1.1 | 2.0 | 2.0 | 1.3 |
| Whisker- | 5.8 | 0.9 | 10.0 | 3.0 |
| Whisker+ | 8.0 | 2.3 | 13.0 | 1.6 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| Cattle astragalus Bd (mm) | LON | KOH | HOWE | BNKS |
|---|---|---|---|---|
| No | 39 | 10 | 92 | 11 |
| Mean | 42.8 | 43.6 | 37.0 | 37.7 |
| SD | 3.7 | 3.1 | 3.2 | 2.6 |
| Min | 36.9 | 39.7 | 30.0 | 32.2 |
| Q1 | 40.0 | 41.0 | 35.0 | 36.5 |
| Median | 42.1 | 43.2 | 37.0 | 38.1 |
| Q3 | 45.0 | 45.7 | 38.0 | 39.5 |
| Max | 50.1 | 48.4 | 48.0 | 41.0 |
| Bottom | 40.0 | 41.0 | 35.0 | 36.5 |
| 2QBox | 2.1 | 2.2 | 2.0 | 1.6 |
| 3Qbox | 2.9 | 2.5 | 1.0 | 1.4 |
| Whisker- | 3.1 | 1.3 | 5.0 | 4.3 |
| Whisker+ | 5.1 | 2.7 | 10.0 | 1.5 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Cattle 1$^{st}$ phalanx GLpe(mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---:|---:|---:|---:|
| No | 84 | 20 | 156 | 67 |
| Mean | 60.9 | 61.3 | 53.6 | 54.5 |
| SD | 3.9 | 2.7 | 3.0 | 3.3 |
| Min | 50.0 | 50.0 | 47.0 | 47.4 |
| Q1 | 58.2 | 59.9 | 51.0 | 52.4 |
| Median | 60.5 | 61.7 | 53.0 | 54.0 |
| Q3 | 63.2 | 62.6 | 55.3 | 56.3 |
| Max | 69.6 | 68.6 | 63.0 | 65.9 |
| Bottom | 58.2 | 59.9 | 51.0 | 52.7 |
| 2QBox | 2.3 | 1.8 | 2.0 | 1.6 |
| 3Qbox | 2.7 | 0.9 | 2.3 | 2.3 |
| Whisker- | 8.2 | 9.9 | 4.0 | 5.0 |
| Whisker+ | 6.4 | 6.0 | 7.7 | 9.6 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Cattle 1$^{st}$ phalanx Bd (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---:|---:|---:|---:|
| No | 86 | 28 | 100 | 67 |
| Mean | 29.8 | 29.4 | 26.3 | 26.9 |
| SD | 2.6 | 2.6 | 2.3 | 2.2 |
| Min | 25.2 | 24.7 | 20.0 | 21.7 |
| Q1 | 28.0 | 27.8 | 25.0 | 25.4 |
| Median | 29.6 | 29.6 | 26.0 | 27.0 |
| Q3 | 31.5 | 30.8 | 27.0 | 28.1 |
| Max | 37.1 | 35.4 | 36.0 | 32.9 |
| Bottom | 28.0 | 27.8 | 25.0 | 25.4 |
| 2QBox | 1.6 | 1.8 | 1.0 | 1.6 |
| 3Qbox | 1.9 | 1.2 | 1.0 | 1.1 |
| Whisker- | 2.8 | 3.1 | 5.0 | 3.7 |
| Whisker+ | 5.6 | 4.6 | 9.0 | 4.8 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Cattle mandibular $dp_4$ length (mm)** | **LON** | **KOH** | **BNKS** |
|---|---|---|---|
| Count | 72 | 55 | 21 |
| Mean | 34.4 | 34.6 | 29.9 |
| SD | 1.9 | 1.7 | 2.3 |
| Min | 28.0 | 31.2 | 25.0 |
| Q1 | 33.4 | 33.6 | 28.2 |
| Median | 34.4 | 34.6 | 30.2 |
| Q3 | 35.3 | 35.8 | 31.2 |
| Max | 38.1 | 38.8 | 33.7 |
| Bottom | 33.5 | 33.5 | 29.5 |
| 2Q box | 1.0 | 1.0 | 2.0 |
| 3Q box | 0.9 | 1.2 | 1.0 |
| Whisker- | 5.4 | 2.4 | 3.2 |
| Whisker+ | 2.8 | 3.1 | 2.5 |
| Offset | 0.5 | 1.5 | 2.5 |

| **Cattle mandibular M3 length (mm)** | **LON** | **BNKS** | **Danish aurochs** |
|---|---|---|---|
| Count | 36 | 10 | 47 |
| Mean | 38.1 | 35.7 | 47.1 |
| SD | 2.9 | 2.7 | 3.1 |
| Min | 31.1 | 31.4 | 40.5 |
| Q1 | 36.5 | 34.5 | 44.9 |
| Median | 38.4 | 35.1 | 47.1 |
| Q3 | 39.7 | 36.6 | 48.7 |
| Max | 44.2 | 41.0 | 52.3 |
| Bottom | 36.5 | 34.5 | 44.5 |
| 2Q Box | 1.8 | 0.5 | 2.3 |
| 3Q Box | 1.4 | 1.6 | 1.6 |
| Whisker- | 5.4 | 3.1 | 4.4 |
| Whisker+ | 4.5 | 4.4 | 3.7 |
| Offset | 0.5 | 1.5 | 2.5 |

## 14.23 Appendix 23: Cattle astragalus GLl means and range (mm) for LON (Links of Noltland) and three other Orkney Neolithic/Bronze Age settlements

| **Site** | **Period** | **Mean GLl (mm)** | **Max GLl (mm)** | **Min GLl (mm)** | **No** | **Source** |
|---|---|---|---|---|---|---|
| LON | Late Neo | 67.6 | 77.4 | 59.9 | 36 | |
| LON (1979/81) | Late Neo | 68.8 | 73.7 | 64.7 | 14 | Armour-Chelu, 1992 |
| Skara Brae | Late Neo | 68.5 | 77 | 60 | 99 | Noddle in Bond, 2007 |
| Pool | Neo | 66.6 | 71.9 | 61.8 | 18 | Nicholson and Davies, 2007 |
| Bay of Skaill | Late BA | 59.3 | 63 | 55 | 20 | Noddle, 1997 |

## 14.24 Appendix 24: Cattle measurements from LON (Links of Noltland), KOH (Knap of Howar) and aurochs (aurochs measurements from Degerbøl and Fredskild, 1970)

| Cattle 1st phalanx GLpe (mm) | LON | KOH | Danish Bos prim |
|---|---|---|---|
| No | 84 | 20 | 11 |
| Mean | 60.9 | 61.3 | 73.0 |
| SD | 3.9 | 2.7 | 4.3 |
| Min | 50.0 | 50.0 | 68.0 |
| Q1 | 58.2 | 59.9 | 69.0 |
| Median | 60.5 | 61.7 | 74.0 |
| Q3 | 63.2 | 62.6 | 75.5 |
| Max | 69.6 | 68.6 | 81.0 |
| Bottom | 58.2 | 59.9 | 69.0 |
| 2QBox | 2.3 | 1.8 | 5.0 |
| 3QBox | 2.7 | 0.9 | 1.5 |
| Whisker- | 8.2 | 9.9 | 1.0 |
| Whisker+ | 6.4 | 6.0 | 5.5 |
| Offset | 0.5 | 1.5 | 2.5 |

| Cattle astragalus GLl (mm) | LON | KOH | Danish Bos prim |
|---|---|---|---|
| No | 36 | 9 | 85 |
| Mean | 67.6 | 68.5 | 85.5 |
| SD | 3.5 | 3.0 | 4.8 |
| Min | 59.9 | 65.0 | 74.0 |
| Q1 | 65.7 | 65.9 | 81.0 |
| Median | 68.3 | 68.3 | 85.0 |
| Q3 | 69.4 | 70.3 | 89.0 |
| Max | 77.4 | 72.6 | 97.0 |
| Bottom | 65.7 | 65.9 | 81.0 |
| 2QBox | 2.6 | 2.4 | 4.0 |
| 3QBox | 1.1 | 2.0 | 4.0 |
| Whisker- | 5.8 | 0.9 | 7.0 |
| Whisker+ | 8.0 | 2.3 | 8.0 |
| Offset | 0.5 | 1.5 | 2.5 |

| **Cattle metacarpal Bd (mm)** | **LON** | **HOWE** | **Danish Bos prim** | **Danish Neo/BA domesticates** |
|---|---:|---:|---:|---:|
| No | 25 | 32 | 38 | 23 |
| Mean | 65.0 | 53.0 | 78.1 | 64.7 |
| SD | 5.1 | 4.1 | 7.4 | 6.8 |
| Min | 56.5 | 48.0 | 66.0 | 48.0 |
| Q1 | 59.9 | 50.0 | 70.3 | 62.3 |
| Median | 65.4 | 52.0 | 81.0 | 66.0 |
| Q3 | 69.4 | 54.0 | 84.4 | 70.0 |
| Max | 74.4 | 63.0 | 88.0 | 73.0 |
| Bottom | 59.9 | 50.0 | 70.3 | 62.3 |
| 2QBox | 5.5 | 2.0 | 10.7 | 3.7 |
| 3QBox | 4.0 | 2.0 | 3.4 | 4.0 |
| Whisker- | 3.4 | 2.0 | 4.3 | 14.3 |
| Whisker+ | 5.0 | 9.0 | 3.6 | 3.0 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

## 14.25 Appendix 25: Individual cattle bone measurements (mm) from Orkney Neolithic (LON, Links of Noltland and KOH (Knap of Howar) and southern England sites (Windmill Hill (Early Neolithic), Hambleton Hill (Late Neolithic), Runneymede settlement (Mid Neolithic), Durrington Walls (Late Neolithic)

| Cattle astragalus GLl (mm) | Windmill Hill | Hambleton Hill | Runnymede | Durrington Walls | LON | KOH |
|---|---|---|---|---|---|---|
| No | 22 | 13 | 14 | 13 | 36.0 | 9 |
| Mean | 65.6 | 66.1 | 66.9 | 64.6 | 67.6 | 68.5 |
| SD | 1.4 | 3.9 | 5.3 | 4.4 | 3.5 | 3.0 |
| Min | 64.0 | 60.8 | 60.0 | 58.0 | 59.9 | 65.0 |
| Q1 | 65.0 | 64.2 | 64.3 | 61.0 | 65.7 | 65.9 |
| Median | 65.0 | 66.2 | 66.5 | 65.0 | 68.3 | 68.3 |
| Q3 | 66.8 | 68.4 | 68.0 | 67.0 | 69.4 | 70.3 |
| Max | 69.0 | 73.0 | 82.0 | 72.0 | 77.4 | 72.6 |
| Bottom | 65.0 | 64.2 | 64.3 | 61.0 | 65.7 | 65.9 |
| 2QBox | 0.0 | 2.0 | 2.3 | 4.0 | 2.6 | 2.4 |
| 3Qbox | 1.8 | 2.2 | 1.5 | 2.0 | 1.1 | 2.0 |
| Whisker- | 1.0 | 3.4 | 4.3 | 3.0 | 5.8 | 0.9 |
| Whisker+ | 2.3 | 4.6 | 14.0 | 5.0 | 8.1 | 2.3 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 | 5.5 |

| Cattle humerus BT (mm) | Windmill Hill | Hambleton Hill | Durrington Walls | LON | KOH |
|---|---|---|---|---|---|
| No | 35 | 54 | 66 | 15 | 10 |
| Mean | 75.4 | 73.5 | 74.7 | 77.4 | 79.7 |
| SD | 5.1 | 5.4 | 6.7 | 4.1 | 5.7 |
| Min | 70.0 | 66.5 | 66.0 | 72.4 | 70.6 |
| Q1 | 72.0 | 69.3 | 70.0 | 74.9 | 75.7 |
| Median | 73.0 | 72.2 | 74.0 | 75.9 | 80.2 |
| Q3 | 77.0 | 76.2 | 78.0 | 79.7 | 84.5 |
| Max | 90.0 | 88.2 | 103.0 | 86.6 | 87.0 |
| Bottom | 72.0 | 69.3 | 70.0 | 74.9 | 75.7 |
| 2QBox | 1.0 | 2.9 | 4.0 | 1.0 | 4.5 |
| 3Qbox | 13.0 | 4.0 | 4.0 | 3.8 | 4.3 |
| Whisker- | 2.0 | 2.8 | 4.0 | 2.5 | 5.1 |
| Whisker+ | 13.0 | 12.0 | 25.0 | 6.9 | 2.5 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 |

Data from Serjeantson, 2011, p21, Fig 2.9, Cleal et al, 1995, p570, Table 8.27, Grigson, 1965, Table VII).

## 14.26 Appendix 26: Individual sheep bone measurements (mm) from Orkney Neolithic and Iron Age sites: LON (Links of Noltland, Late Neolithic); KOH (Knap of Howar, Mid Neolithic); Howe (Iron Age); BNKS (Brest Ness, Iron Age). Modern Shetland sheep data from 67 unimproved modern Shetland ewes, rams and castrates (Davis, 1996, p596, table 2, Popkin et al., 2012)

| **Sheep astragalus GLl (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** | **Modern Shetland** |
|---|---|---|---|---|---|
| No | 148 | 61 | 163 | 112 | 68 |
| Mean | 27.7 | 26.1 | 25.8 | 25.6 | 27.3 |
| SD | 1.2 | 1.1 | 1.5 | 1.5 | 1.3 |
| Min | 24.7 | 23.9 | 20.0 | 22.0 | 23.3 |
| Q1 | 26.8 | 25.1 | 25.0 | 24.7 | 26.3 |
| Median | 27.6 | 26.1 | 26.0 | 25.6 | 27.4 |
| Q3 | 28.6 | 26.7 | 27.0 | 26.7 | 28.3 |
| Max | 30.6 | 28.5 | 30.0 | 30.5 | 30.0 |
| Bottom | 26.8 | 25.1 | 25.0 | 24.7 | 26.3 |
| 2QBox | 0.8 | 1.0 | 1.0 | 0.9 | 1.1 |
| 3QBox | 1.0 | 0.6 | 1.0 | 1.1 | 0.9 |
| Whisker- | 2.1 | 1.2 | 5.0 | 2.7 | 3.0 |
| Whisker+ | 2.0 | 1.8 | 3.0 | 3.8 | 1.7 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 |

| **Sheep astragalus Bd (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** | **Modern Shetland** |
|---|---|---|---|---|---|
| No | 152 | 61 | 150 | 98 | 68 |
| Mean | 18.0 | 16.8 | 17.2 | 16.5 | 18.6 |
| SD | 0.9 | 0.6 | 1.1 | 1.1 | 1.1 |
| Min | 15.9 | 15.7 | 15.0 | 13.5 | 15.9 |
| Q1 | 17.4 | 16.4 | 16.0 | 15.9 | 17.8 |
| Median | 18.0 | 16.8 | 17.0 | 16.5 | 18.8 |
| Q3 | 18.6 | 17.2 | 18.0 | 17.0 | 19.3 |
| Max | 20.3 | 18.5 | 20.0 | 18.7 | 21.1 |
| Bottom | 17.4 | 16.4 | 16.0 | 15.9 | 17.8 |
| 2QBox | 0.6 | 0.4 | 1.0 | 0.6 | 1.0 |
| 3QBox | 0.6 | 0.4 | 1.0 | 0.5 | 0.5 |
| Whisker- | 1.5 | 0.7 | 1.0 | 2.4 | 1.9 |
| Whisker+ | 1.7 | 1.3 | 2.0 | 1.7 | 1.8 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 |

| **Sheep humerus Bd (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|
| No | 59 | 46 | 106 | 87 |
| Mean | 28.8 | 27.0 | 27.1 | 26.6 |
| SD | 2.1 | 1.6 | 2.0 | 2.1 |
| Min | 24.4 | 24.2 | 23.0 | 21.9 |
| Q1 | 27.8 | 25.7 | 26.0 | 25.3 |
| Median | 28.5 | 27.0 | 27.0 | 26.5 |
| Q3 | 29.8 | 27.8 | 29.0 | 27.8 |
| Max | 35.6 | 32.1 | 32.0 | 32.4 |
| Bottom | 27.8 | 25.7 | 26.0 | 25.3 |
| 2QBox | 0.7 | 1.3 | 1.0 | 1.3 |
| 3QBox | 1.3 | 0.8 | 2.0 | 1.3 |
| Whisker- | 3.4 | 1.5 | 3.0 | 3.4 |
| Whisker+ | 5.9 | 4.3 | 3.0 | 4.7 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Sheep radius Bp (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|
| Count | 49 | 31 | 67 | 43 |
| Mean | 29.6 | 28.1 | 26.7 | 27.4 |
| SD | 1.9 | 1.7 | 2.0 | 2.4 |
| Min | 24.1 | 25.4 | 21.0 | 23.6 |
| Q1 | 28.0 | 27.2 | 26.0 | 26.0 |
| Median | 29.9 | 28.0 | 27.0 | 26.8 |
| Q3 | 31.0 | 29.2 | 28.0 | 28.0 |
| Max | 32.8 | 32.4 | 32.0 | 34.6 |
| Bottom | 28.0 | 27.2 | 26.0 | 26.0 |
| 2QBox | 1.9 | 0.8 | 1.0 | 0.8 |
| 3QBox | 1.1 | 1.2 | 1.0 | 1.2 |
| Whisker- | 3.9 | 1.8 | 5.0 | 2.4 |
| Whisker+ | 1.8 | 3.2 | 4.0 | 6.6 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Sheep tibia Bd (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|
| No | 26 | 26 | 67 | 42 |
| Mean | 25.5 | 24.2 | 23.4 | 23.6 |
| SD | 1.7 | 1.1 | 1.3 | 1.4 |
| Min | 21.8 | 22.4 | 21.0 | 21.2 |
| Q1 | 24.5 | 23.4 | 23.0 | 22.6 |
| Median | 25.5 | 24.0 | 23.0 | 23.7 |
| Q3 | 26.6 | 24.8 | 24.0 | 24.6 |
| Max | 28.4 | 26.8 | 27.0 | 27.4 |
| Bottom | 24.5 | 23.4 | 23.0 | 22.6 |
| 2QBox | 1.0 | 0.6 | 0.0 | 1.0 |
| 3QBox | 1.1 | 0.8 | 1.0 | 0.9 |
| Whisker- | 2.7 | 1.0 | 2.0 | 1.4 |
| Whisker+ | 1.8 | 2.0 | 3.0 | 2.8 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Sheep 1st phalanx GLpe (mm)** | **LON** | **KOH** | **HOWE** | **BNKS** |
|---|---|---|---|---|
| Count | 99 | 48 | 230 | 199 |
| Mean | 36.2 | 33.7 | 32.5 | 32.7 |
| SD | 1.8 | 1.6 | 1.8 | 1.7 |
| Min | 32.0 | 30.3 | 28.0 | 27.9 |
| Q1 | 35.0 | 32.8 | 31.0 | 31.5 |
| Median | 36.1 | 33.9 | 33.0 | 32.6 |
| Q3 | 37.5 | 34.6 | 34.0 | 33.5 |
| Max | 40.3 | 37.7 | 37.0 | 38.0 |
| Bottom | 35.0 | 32.8 | 31.0 | 31.5 |
| 2QBox | 1.1 | 1.1 | 2.0 | 1.1 |
| 3QBox | 1.4 | 0.7 | 1.0 | 0.9 |
| Whisker- | 3.0 | 2.5 | 3.0 | 3.6 |
| Whisker+ | 2.8 | 3.1 | 3.0 | 4.5 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 |

| **Sheep mandibular $dp_4$ length (mm)** | **LON** | **BNKS** |
|---|---:|---:|
| Count | 98 | 45 |
| Mean | 18.2 | 16.3 |
| SD | 1.2 | 1.4 |
| Min | 15.2 | 14.0 |
| Q1 | 17.2 | 15.1 |
| Median | 18.3 | 16.3 |
| Q3 | 19.1 | 17.3 |
| Max | 20.3 | 19.1 |
| Bottom | 17.3 | 15.7 |
| 2Q Box | 1.1 | 1.2 |
| 3Q Box | 0.8 | 1.0 |
| Whisker- | 2.0 | 1.1 |
| Whisker+ | 1.2 | 1.8 |
| Offset | 0.5 | 1.5 |

| **Sheep mandibular $M_3$ length (mm)** | **LON** | **BNKS** |
|---|---:|---:|
| Count | 83 | 14 |
| Mean | 21.1 | 19.7 |
| SD | 1.1 | 1.7 |
| Min | 18.7 | 16.2 |
| Q1 | 20.3 | 18.9 |
| Median | 21.1 | 19.4 |
| Q3 | 22.0 | 21.1 |
| Max | 23.5 | 21.7 |
| Bottom | 20.4 | 19.4 |
| 2Q Box | 0.8 | 0.5 |
| 3Q Box | 0.8 | 1.7 |
| Whisker- | 1.6 | 2.7 |
| Whisker+ | 1.6 | 0.6 |
| Offset | 1.5 | 0.5 |

## 14.27 Appendix 27: Red deer astragalus measurements GLl (mm) from Orkney Neolithic and Iron Age sites: LON (Links of Noltland, Late Neolithic), KOY (Knowe of Yarso, Neolithic cairn). Howe (Iron Age)

| Red deer astragalus GLl (mm) | LON | KOY | Howe |
|---|---|---|---|
| No | 20 | 10 | 43 |
| Mean | 49.6 | 49.2 | 47.3 |
| SD | 2.9 | 3.2 | 2.8 |
| Min | 44.9 | 45.1 | 39.0 |
| Q1 | 47.7 | 46.7 | 46.0 |
| Median | 49.7 | 49.2 | 47.0 |
| Q3 | 51.6 | 50.9 | 49.0 |
| Max | 54.9 | 54.2 | 53.0 |
| Bottom | 47.7 | 46.7 | 46.0 |
| 2Qbox | 2.0 | 2.5 | 1.0 |
| 3QBox | 1.9 | 1.7 | 2.0 |
| Whisker- | 2.8 | 1.6 | 7.0 |
| Whisker+ | 3.3 | 3.3 | 4.0 |
| Offset | 0.5 | 1.5 | 2.5 |

## 14.28 Appendix 28: mtDNA results

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| **Context** | **Find No** | **Laboratory No** | **Skeletal Element** | **mtDNA haplogroup** |
|---|---|---|---|---|
| 9123 | 4257/58 | ORK 1 | $P^3$ | T3 |
| 9116 | 4917 | ORK 2 | $M_3$ | T3 |
| 9116 | 6693 | ORK 3 | $M^1$ | T3 |
| 9116 | 4462 | ORK 4 | $P^2$ | T3 |
| 9116 | 4460 | ORK 5 | $M^2$ | T3 |
| 9116 | 4459 | ORK 6 | $P^3$ | P |
| 9129 | 8442 | ORK 7 | $M_1$ | T3 |
| 9021 | n/a | ORK 8 | $M^3$ | T3 |
| 9021 | n/a | ORK 9 | Radius proximal | T3 |
| 9031 | n/a | ORK 10 | Radius proximal | T3 |
| 9017 | n/a | ORK 11 | 1st Phalanx (ant) | n/a |
| 9028 | n/a | ORK 12 | M/t distal | T3 |
| 9116 | Assoc. sk 4462 | ORK 13 | Humerus distal | n/a |
| 9166 | n/a | ORK 14 | 1st Phalanx (ant) | T3 |
| 9681 | 17528 | ORK 15 | M/t distal | T3 |
| 9681 | 17206 | ORK 16 | M/t distal | n/a |

## 14.29 Appendix 29: Comparison of $\delta^{13}C$‰ and $\delta^{15}N$‰ values between LON and English Neolithic and Neolithic/Bronze Age domesticated cattle. *Source Lynch et al., 2008*

| **$\delta^{13}C$‰** | **LON** | **English Neo/BA** | **English Neo only** |
|---|---:|---:|---:|
| No | 15 | 35 | 21 |
| Mean | -21.3 | -22.3 | -22.3 |
| SD | 0.3 | 0.7 | 0.4 |
| Min | -21.7 | -24 | -23 |
| Q1 | -21.6 | -22.7 | -22.7 |
| Median | -21.3 | -22.5 | -22.5 |
| Q3 | -21.1 | -21.7 | -22 |
| Max | -20.4 | -20.6 | -21.6 |
| Bottom | -21.7 | -24 | -23 |
| 2Q | -0.3 | -0.2 | -0.2 |
| 3Q | -0.2 | -0.8 | -0.5 |
| Whisker- | -0.1 | -1.3 | -0.2 |
| Whisker + | -0.7 | -1.1 | -0.4 |
| Offset | 0.5 | 1.5 | 2.5 |

| **$\delta^{15}N$** | **LON** | **English Neo/BA** | **English Neo only** |
|---|---:|---:|---:|
| No | 15 | 21 | 35 |
| Mean | 6 | 5 | 5.4 |
| SD | 0.9 | 0.6 | 0.9 |
| Min | 4.7 | 3.2 | 3.2 |
| Q1 | 5.3 | 4.7 | 4.8 |
| Median | 6.0 | 5.2 | 5.4 |
| Q3 | 6.7 | 5.6 | 5.9 |
| Max | 7.4 | 6.1 | 7.7 |
| Bottom | 5.3 | 4.7 | 3.2 |
| 2Q | 0.7 | 0.5 | 0.6 |
| 3Q | 0.7 | 0.4 | 0.5 |
| Whisker- | 0.6 | 1.5 | 1.6 |
| Whisker + | 0.7 | 0.5 | 1.8 |
| Offset | 0.5 | 1.5 | 2.5 |

## 14.30 Appendix 30: Comparison of δ$^{13}$C‰ and δ$^{15}$N‰ isotopes between LON and "Gathering Time|" Neolithic cattle *Source Hamilton and Hedges, 2011*

| **δ$^{13}$C‰** | **LON** | **Chalk Hill** | **Etton** | **Windmill Hill** | **Abington** |
|---|---|---|---|---|---|
| No | 15 | 16 | 7 | 17 | 19 |
| Mean | -21.3 | -21.8 | -21.9 | -22.3 | -22.1 |
| SD | 0.3 | 0.6 | 0.3 | 0.3 | 0.5 |
| Min | -20.4 | -21.0 | -21.3 | -21.8 | -21.0 |
| Q1 | -21.1 | -21.3 | -21.7 | -22.0 | -21.8 |
| Median | -21.3 | -21.5 | -21.9 | -22.3 | -22.2 |
| Q3 | -21.6 | -22.5 | -22.0 | -22.5 | -22.5 |
| Max | -21.7 | -22.8 | -22.2 | -23.0 | -23.2 |
| Bottom | -21.3 | -21.5 | -21.9 | -22.3 | -22.2 |
| 2Q Box | -0.2 | -0.2 | -0.2 | -0.3 | -0.4 |
| 3Qbox | -0.3 | -1.0 | -0.1 | -0.2 | -0.3 |
| Whisker- | -0.7 | -0.3 | -0.4 | -0.2 | -0.8 |
| Whisker+ | -0.1 | -0.3 | -0.2 | -0.5 | -0.7 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 |

|  | **LON** | **Chalk Hill** | **Etton** | **Windmill** | **Abington** |
|---|---|---|---|---|---|
| No | 15 | 16 | 7 | 17 | 19 |
| Mean | 6.0 | 5.4 | 5.7 | 4.7 | 5.8 |
| SD | 0.9 | 0.5 | 0.9 | 0.5 | 0.5 |
| Min | 4.7 | 4.3 | 4.6 | 4.3 | 5.2 |
| Q1 | 5.3 | 5.1 | 5.1 | 4.5 | 5.4 |
| Median | 6.0 | 5.4 | 5.6 | 4.7 | 5.6 |
| Q3 | 6.7 | 5.8 | 6.4 | 5.2 | 6.1 |
| Max | 7.4 | 6.3 | 7.0 | 5.9 | 7.3 |
| Bottom | 5.3 | 5.1 | 5.1 | 4.5 | 5.4 |
| 2Q Box | 0.7 | 0.3 | 0.5 | 0.2 | 0.2 |
| 3Qbox | 0.7 | 0.4 | 0.8 | 0.5 | 0.5 |
| Whisker- | 0.6 | 0.8 | 0.5 | 0.2 | 0.2 |
| Whisker+ | 0.7 | 0.5 | 0.6 | 0.7 | 1.2 |
| Offset | 0.5 | 1.5 | 2.5 | 3.5 | 4.5 |

## Cattle Skull Data Records:
## Individual cattle skulls from Foundation Course, Structure 9

This is a series of individual sheets for each cattle skull showing a general diagrammatic representation of skull regions present in the recovered skull and a photograph of the skull “in situ”. The diagrams were adopted from A. von den Driesch (1976, figure 8, pp29-30). Photographs © G. Wilson apart from Skulls 4466, 4462 and 6699.

# Cattle skull F4259

East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4257/B

Notes:

Adjacent to pelvis

# Cattle skulls F4257/8

## East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4256 and F4259

Horncores interlocked

Notes:

Two sets of horncores intermingled, only one set of toothrows

Flints and stone tool adjacent to skull

## Cattle skull F4256
East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F4255 and F4257

Horncore interlocked with F4255

Notes:

1st phalanx recovered from palette, another under skull

Orange clay/degraded pottery below skull

Treated and lifted by conservator

## Cattle skull F4254
East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F4255 and cattle pelvis F7924

Notes:

Proximal fused humerus portion and proximal fused femur portion adjacent to skull, red deer below skull

L occipital condyle hacked?

## Cattle skull F4261
East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F4262 and cattle pelvis F4260

Notes:

Cattle longbone diaphysis above skull

## Cattle skull F4262
East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4261

Notes:

Dorsal upwards (only skull with this arrangement)

No evidence of pole-axing

## Cattle skull F4255
### East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Horncore interlocked with horncore of F4256.

Notes:

Cattle rib and longbone diaphysis frgs and 1st and 2nd phalanges adjacent to skull

## Cattle skull F4253
### East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6717 and F6721

Notes :

Stone covering R occipital

Chert, pottery and cattle pelvis frg adjacent to skull

## Cattle skull F4460
### West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4459

Notes :

Flint adjacent to skull

## Cattle skull F4468

### West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Skull flattened

Adjacent to sheep skull F6852

Notes :

Red deer antler and flint adjacent to skull

Cattle 1st phalanx under skull

## Cattle skull F4917
East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6716 and F6700

R horncore under stone

Notes :

Flint recovered adjacent to skull

Cattle mandible frg and mandibular M3 under skull

## Cattle skull F6700
East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

E/SE-W/NW Orientation

Adjacent to F6716 and F4917

L horncore underneath anterior of F4917

Notes :

Flint and pottery frg recovered adjacent to skull

Sheep distal tibia, proximal m/c and vole humerus adjacent to skull

## Cattle skull F6716

East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6700 and F4917

Treated and lifted by conservator

Notes :

Flint, cattle distal radius with part of ulna attached, cattle mandible frg, incl M3, sheep radius frg adjacent to skull

# Cattle skull F4918
East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4917

Very fragmented

Notes :

Cattle astragalus adjacent to skull

# Cattle skull 6693

## West Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6692 and F6694

Crushed by overlying stones

Notes :

Cattle distal femur and 2 flints adjacent to skull

Sheep astragalus lying on palette

## Cattle skull 6694
West Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

SE-NW Orientation

Adjacent to F6922 and F6693

Treated and lifted by conservator

Notes :

Rib lying on premaxilla

Stone lying on palette

# Cattle skull 6699
## West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Poor condition

Adjacent to F4466

Notes :

Loose molar tooth to N of skull

Cattle distal radius and humerus adjacent to fragmented skull

# Cattle skull 6692
## West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4458

Treated and lifted by conservator

Notes :

Otter thoracic vertebra adjacent to skull

## Cattle skull F4458

West Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6692

Treated and lifted by conservator

Notes :

One horncore at a different angle from the other. Bird humerus, large bird, adjacent

Tip of R horncore resting on clay

## Cattle skull F6701
East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F4917 and F 7750

Notes :

Oyster shell, and 2 flints adjacent to skull

# Cattle skull F6718
## East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F6718 and F4253

R horncore underneath F6718

Notes :

Cattle mandible frg adjacent to skull

# Cattle skull F6717
## East Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F6718 and F4253

R horncore underneath F6718

Notes :

Cattle mandible frg adjacent to skull

## Cattle skull F4459
West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Adjacent to F 4458

Notes :

Horncore curved over stone

Two Skaill knives and flint adjacent to skull

# Cattle skull F4462
## West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Horncores bent

Adjacent to F4461

Notes :

Unfused cattle 1st phalanx in palette

Distal cattle radius adjacent to skull

# Cattle skull F4461
## West Foundation, Structure 9

Posterior

Basal

Dorsal

Left

Right

Position:

Abutting premaxilla of F4460, interlocking horns with F4462

Notes :

Cattle radius distal frg and 2 carpals adjacent to skull

Treated and lifted by conservator

# Cattle skull F4466
## West Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Large skull, fragmentary

Notes :

Distal cattle femur adjacent to skull

# Cattle skull F7750
## East Foundation, Structure 9


Posterior


Basal


Dorsal


Left


Right

Position:

Adjacent to F6701with horncores interlocking

Notes :

Probably placed in foundation after 6701

Cattle mandible frg associated with skull