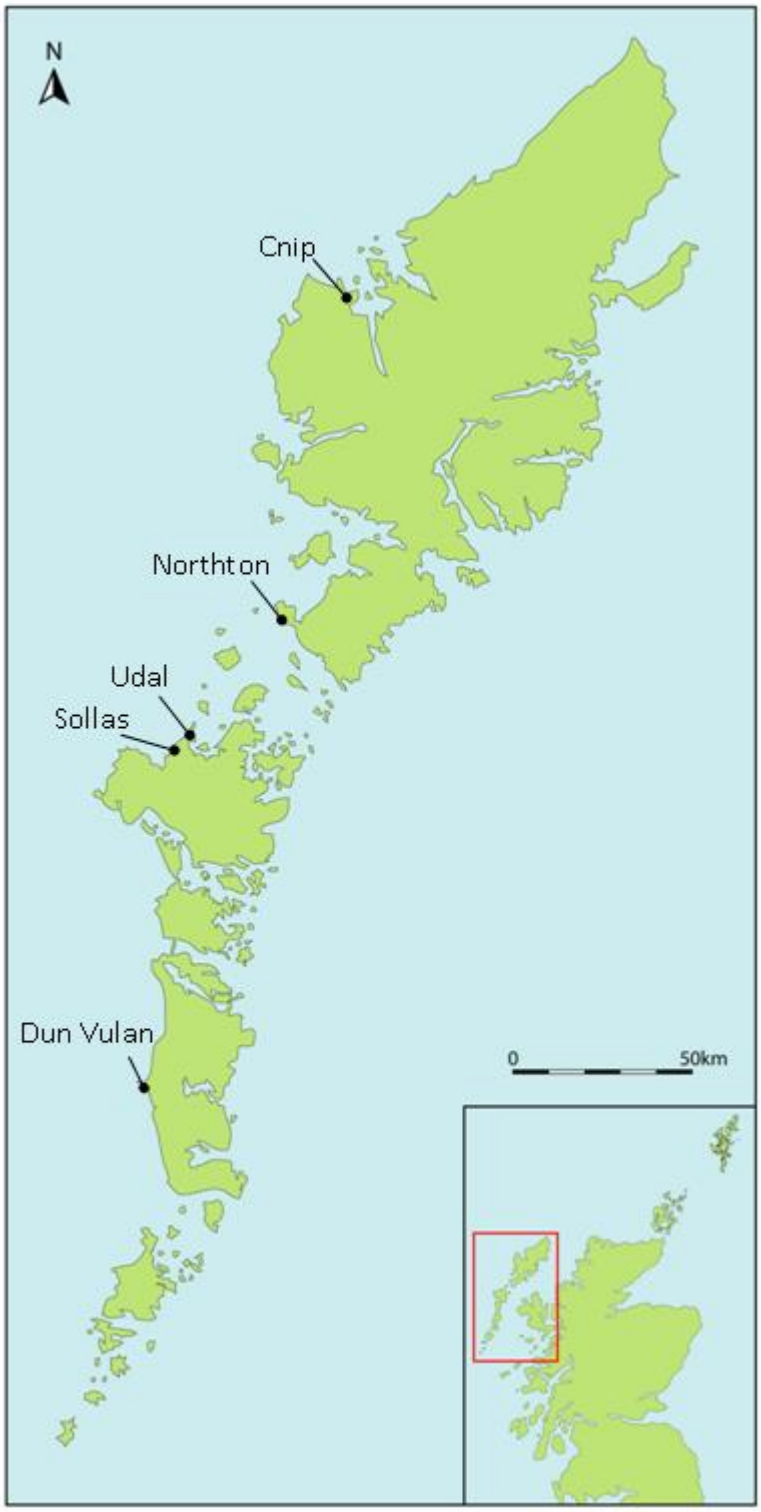

Figure 5.1 Map of the Western Isles showing sites included in this study. (Illustration by D. Bashford).

Western Isles

Five sites were examined from the Western Isles and their locations are shown in figure 5.1. Dun Vulan is a broch site on the west coast of South Uist (Parker Pearson & Sharples 1999). A small amount of other structural remains were found surrounding the broch, the principal feature of which was the 'platform'. The broch is thought to have been constructed in the late 2nd or 1st century BC but very little animal bone material is attributed to these deposits. The majority of animal bone material came from two main areas, the area adjacent to the broch where midden accumulations date to 1st-4th centuries AD and the 'platform' which provided the largest sample of animal bone dating to 2nd-6th centuries AD (*ibid*. and sections by Mulville therein).

The site of Sollas is located on the north coast of North Uist in the Vallay area (Campbell 1991). Two potential wheelhouses were excavated at the site. The first of these (Wheelhouse A) had undergone a great deal of modification and had been robbed of much of its stone; this is the earlier of the two and likely dates to the 1st century AD or possibly earlier (*ibid*.). Wheelhouse B was more certainly identified as a wheelhouse structure. This is an interesting structure, with a large number of ritual pits containing animal remains found below its occupation levels (*ibid*.). This wheelhouse had also undergone a number of modifications, many of which were thought to be related to defending against a series of sand-blow events and it seems likely that the site was eventually abandoned due to catastrophic sand-blow (*ibid*.). Radiocarbon dates date the early use of this structure to the 1st or 2nd centuries AD

and archaeomagnetic dating of the last use of the hearth suggested that it was not used later than the 2nd century AD (*ibid*.).

The Udal is also located in North Uist, not far from Sollas. This was a multiperiod site located on the machair. Little has been published about the site but Armit (1992) gives some detail. The main feature of the site is a wheelhouse structure but there are also pre-Norse cellular buildings as well as Norse and later structures present (*ibid*.: 51). Little dating evidence is available but the phase designated as Late Wheelhouse or 'squatter' is dated to the 1st century AD (*ibid*.: 68); with the earlier wheelhouse occupation thought to date to the later part of the 1st millennium BC (*ibid*.: 72). There are also some bone measurements available for the Neolithic period from the Udal but there is no absolute dating evidence available for this period at the site.

The site of Northton is located in the western part of Harris and the main focus of the site is Neolithic and Beaker period activity (Simpson *et al*. 2006). Deposits at the site include inhumation burials, midden deposits and a number of stone structures. Neolithic deposits date to the late 4th to early 3rd millennium BC and those from the Beaker period date to the early 2nd millennium BC (*ibid*.); however, no bone measurement data was available from the Beaker deposits. Later deposits were also excavated but these were found to be a mix of Bronze Age, Iron Age and later material (*ibid*.) and although bone measurements were available they were not used in this analysis due to mixing of the deposits.

The final site examined for the Western Isles is that of Cnip located on the west coast of Lewis. This wheelhouse site showed excellent structural and stratigraphic preservation (Armit 2006). The first phase dates to the 1st century BC or possibly earlier, and relates to the building of two wheelhouses. One of these was incomplete and allowed detailed examination of construction methods, indicating that the level of skill required for building these structures was of a similar standard to that required for broch building (*ibid*.). The second phase dated to the 1st century AD and involved modifications to the main wheelhouse including the addition of an ancillary structure (*ibid*.); the majority of bone measurement data came from this phase. The final phase dates from AD 100-250, when the modified wheelhouse was replaced by a rectilinear domestic building, a structure thus far unique in Atlantic Scotland (*ibid*.). Following this the site was eventually abandoned, like Sollas, due to catastrophic sand-blow (*ibid*.).

Northern Isles – Orkney

A total of nine sites were examined from Orkney, spread across four islands; their locations are shown on figure 5.2. Four were located on Mainland. Skaill is a multi-period site located on the east coast with a sequence of settlement from the Late Bronze Age through to the Post Medieval period (Buteux 1997). The earliest evidence for human activity comes from a soil horizon containing extensive ard marks and dating to c. 1000-700 BC (*ibid*.). Iron Age occupation is attested to by the presence of a large roundhouse. It is not known when this was constructed, but there was occupation in the 3rd-6th centuries AD and evidence of numerous alterations;

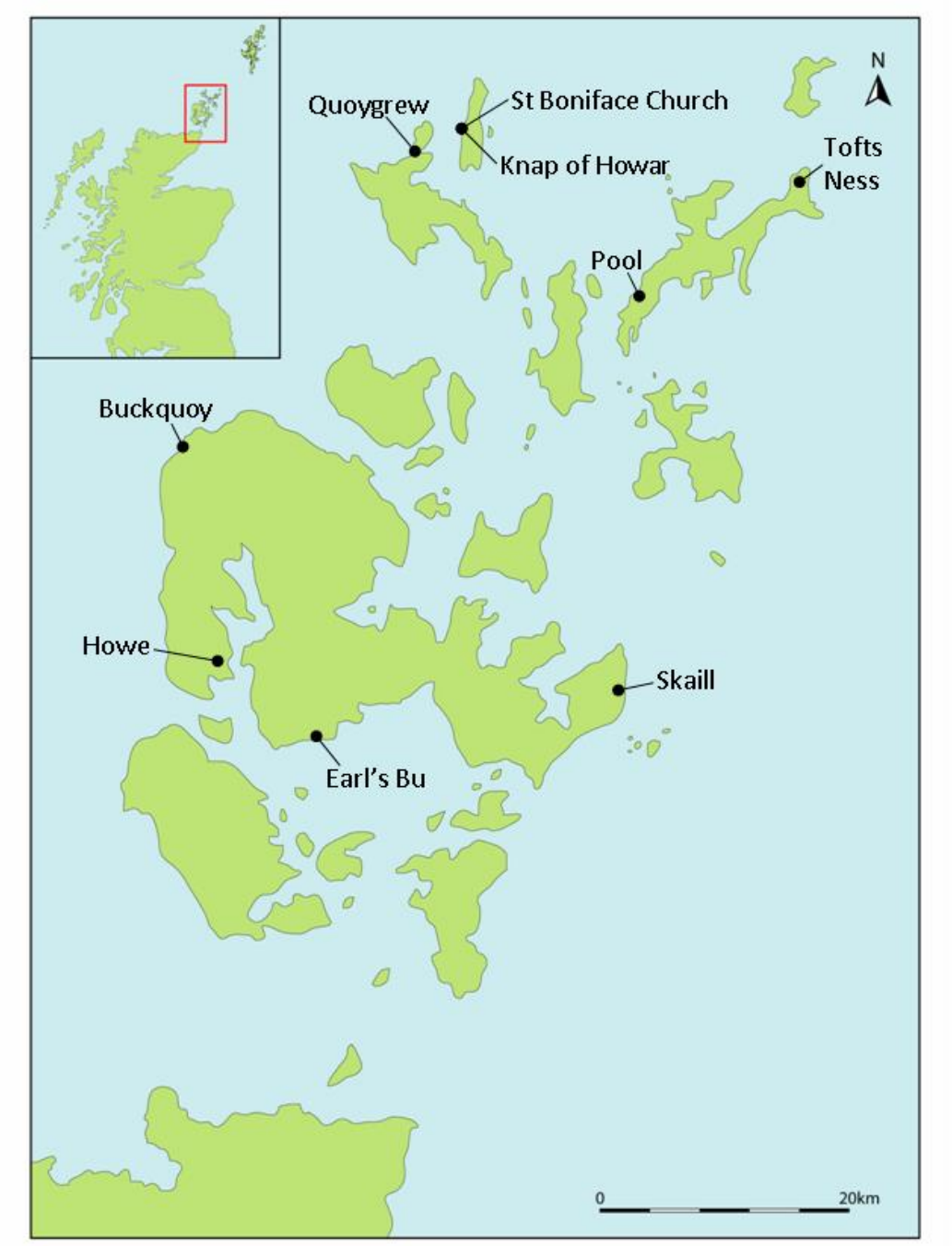

Figure 5.2 Map of Orkney showing sites included in this study. (Illustration by D. Bashford).

occupation probably continued until the 7th or 8th centuries (*ibid*.). Norse period settlement was represented by a sequence of five buildings, dating from the 8th or 9th centuries through to the 11th century, and overlaying these Norse remains was a

medieval hall dating to the 12th century but remaining in use for a long period of time (*ibid*.). The last occupation at the site was marked by a 17th century barn and corn drying kiln (*ibid*.).

The site of Earl's Bu is located on the north side of Scapa Flow in Orphir Bay (Batey *et al*. 1993; Morris *et al*. 1994). The site is a unique Norse horizontal mill, the fill of which was made up of a large quantity of midden material that represents domestic waste from the adjacent Late Norse hall. The midden material and nearby hall date to the 11th-15th centuries AD and some have thought that the hall belonged to the Earls Paul and Harald noted in the Orkneyinga Saga; but this is not necessarily the case (Morris *et al.* 1994). The mill itself had a fairly brief lifespan as the material upon which it sits was also Scandinavian in character (*ibid*.); however, it is the Late Norse fill that is of interest to this project.

Howe is a multi-period site located near to Stromness, whose occupation continued from the Neolithic through to the Late Iron Age or Pictish period (Ballin Smith 1994). Eight phases of occupation were identified; the first two of which relate to Neolithic mortuary practices. Phases 3 and 4 date to the Early Iron Age, from the 8th-4th centuries BC and comprise scant structural evidence and the cutting of an enclosure ditch (*ibid*.). During Phase 5 a large roundhouse was built and occupied in the 4th-3rd centuries BC. Phase 6 saw the building of the broch overlaying the roundhouse and although there was no direct dating evidence its place in the stratigraphic sequence dated it to the 2nd-1st centuries BC (*ibid*.). Phase 7 made up the largest part of the site in terms of archaeological information available: the second phase of broch

occupation, this shows several episodes of collapse and rebuild dating to the 1st-4th centuries AD (*ibid*.). The final phase of Howe is a Late Iron Age farmstead dating to the 4th-7th or 8th centuries AD (*ibid*.).

The final site on the Orkney mainland is that of Buckquoy, located on the north side of the Bay of Birsay and dating from the 7th to the 10th centuries (Ritchie 1977). The first two phases are the early and late Pictish farmstead, for which absolute dates were not available but artefactual material dated to the 7th and 8th centuries, with the structures being of a typically Pictish cellular form. The following three phases belong to the Norse farmstead, of which the remaining evidence (it is thought some of the settlement was lost to coastal erosion) suggests three, chronologically separate, farm buildings (*ibid*.). The final phase is a single 10th century Norse grave (*ibid*.). Again there is no absolute dating evidence for the Norse phases but artefactual material from the burial and the preceding Pictish deposits suggests that the majority of the occupation took place within the 9th century (*ibid*.).

The site of Quoygrew is located at Rackwick on the island of Westray and is described as a settlement site and fish midden with deposits dating from the 9th/10th centuries to the 17th century (Barrett 2005). Midden deposits were divided into three phases. Phase 1 dates to the 9th-10th centuries, and Phases 2 and 3 (from which come most of the bone measurement data) date to the 11th-13th centuries (Milner *et al*. 2007).

St Boniface Church is a multi-period site located on the west coast of the island of Papa Westray (Lowe 1998). A total of nine occupation phases were identified,

beginning with early funerary activity and settlement in the 3rd to mid 2nd millennium BC (Phases 1 & 2) which was followed by a wind-blown sand event. Occupation recommenced during the Bronze Age in the late 2nd millennium BC, identified by the presence of three structures containing occupation and infill deposits (*ibid*.). Phase 5, an unenclosed roundhouse settlement dating to the mid 1st millennium BC, is designated as Late Bronze Age/Early Iron Age (*ibid*.). Phase 6 relates to the cutting of a ditch and the enclosure of the roundhouse settlement and its subsequent development; this activity dates from the late 1st millennium BC to the early 1st millennium AD (*ibid*.). Phase 7 is a series of Late Iron Age midden deposits dating to the mid 3rd to mid 8th centuries AD. The final occupation phase is a farm mound dated to the Norse or medieval period and this phase is dated to the 12th-15th centuries (*ibid*.). Phase 9 relates purely to modern turf and topsoil.

The Knap of Howar is also located on Papa Westray, just south of St Boniface Church (Ritchie 1983). This is a Neolithic farm site consisting of two stone built, sub-rectangular houses and associated midden deposits dating to the later 4th millennium BC (*ibid*.).

The site of Pool is a multi-period site on the north west coast of the island of Sanday (Hunter *et al*. 2007). The earliest occupation dates to the Neolithic (Phases 1-4) with the majority of evidence coming from a series of midden tips plus some structural features; however, bone preservation in these midden deposits was particularly poor (*ibid*.). These early phases date from the early/mid 4th millennium BC through to the late 3rd millennium BC. Following this there was a period of abandonment, after

which the site was reoccupied during the Iron Age. Evidence for the earlier phase of this occupation (Phase 5) is scant but probably dates to the Later Middle Iron Age. Phase 6 sees an expansion of the settlement with a number of structures being built, modified and demolished; this phase dates to the Late Iron Age or Pictish period and was occupied during the 4th-8th centuries AD. Following is this is Phase 7, denoted as the 'Interface' phase where the first evidence of Scandinavian settlement is seen intermixed with Late Iron Age structures and artefacts (*ibid*.). Despite issues with dating, it is thought that this phase started well before the later 9th century and probably continued into the later 10th century (ibid.). Phase 8, the final phase, relates to the Late Norse settlement and dates from the 10th to the late 12th or early 13th century (*ibid*.).

The last site from Orkney is another multi-period site from the Island of Sanday. The site of Tofts Ness (Dockrill *et al*. 2007), was occupied from the Neolithic through to the Early Iron Age, with Phases 1 and 2 belonging to the Neolithic and containing structural and midden remains. Phase 3 is an Early Bronze Age structure dating to the mid 2nd millennium BC. Phase 4 is an early roundhouse dating to the Late Bronze Age which was followed by a period of abandonment and a sand-blow event (Phase 5). The final occupation phase saw the building and occupation of a large roundhouse, which is thought to date to the Early Iron Age, around the mid 1st millennium BC (*ibid*.).

Northern Isles – Shetland

Due to some of the issues outlined in Section 5.2.1 and the frequent poor preservation of animal bone from sites in Shetland (Bond pers. comm.) only two sites were examined from this region, Old Scatness and Scord of Brouster, the locations of which are shown on figure 5.3. The site of Old Scatness, located in the south mainland of Shetland, is a multi-period settlement, principally focused on a broch and surrounding Iron Age occupation, although there is cultural material present dating from the Neolithic right through to the Post Medieval period (Dockrill *et al*. 2010). The site stratigraphy is divided into a total of eleven phases; the first three date from the Neolithic through to the Late Bronze Age and include arable soils and some cultural material (*ibid*.). No animal bone measurement data was available for these deposits. Phase 4 relates to the construction of the broch and a large stone revetted ditch surrounding the settlement; a small quantity of bone was available from this phase. Phase 5 represents the post-broch period or Middle Iron Age. Dating to the 1st and 2nd centuries BC; this phase includes an extensive settlement dominated by two aisled round houses located west of the broch (*ibid*.). Phase 6, the Later Middle Iron Age, was characterised by significant growth and modification of this village and dates to the 1st-4th centuries AD (*ibid*.). Phase 7 - the Late Iron Age or Pictish phase - again saw modification of the village, with the construction of a series of multi-cellular structures of typical Pictish architectural style; this phase dates from the 5th century AD to the arrival of Scandinavian settlers in the 9th or 10th century (*ibid*.). Phase 8 relates to a variety of activities on site indicative of Viking and Norse settlement, including the infilling and reuse of the Pictish buildings, the presence of many diagnostic Norse artefacts and the scant remains of a Norse building. Phase 9

was mostly composed of Late Norse midden deposits dating to the 11th to 13th centuries and later. Phase 10 was comprised of Post Medieval settlement dating to the 17th century with a possible hiatus in settlement in the 18th century, and finally, Phase 11 was a 19th century crofting settlement (*ibid*.). Bone measurement data was available in varying quantities for all phases from Phase 4 onwards; however, the majority of that used in this study came from Phases 5-8.

The second site examined from Shetland was the Scord of Brouster, located near Walls in the west mainland. The site contains three early prehistoric sub-oval houses and a number of clearance cairns and field dykes (Whittle *et al*. 1986). Occupation dates from roughly the middle of the 3rd millennium BC to the middle of the 2nd millennium BC.

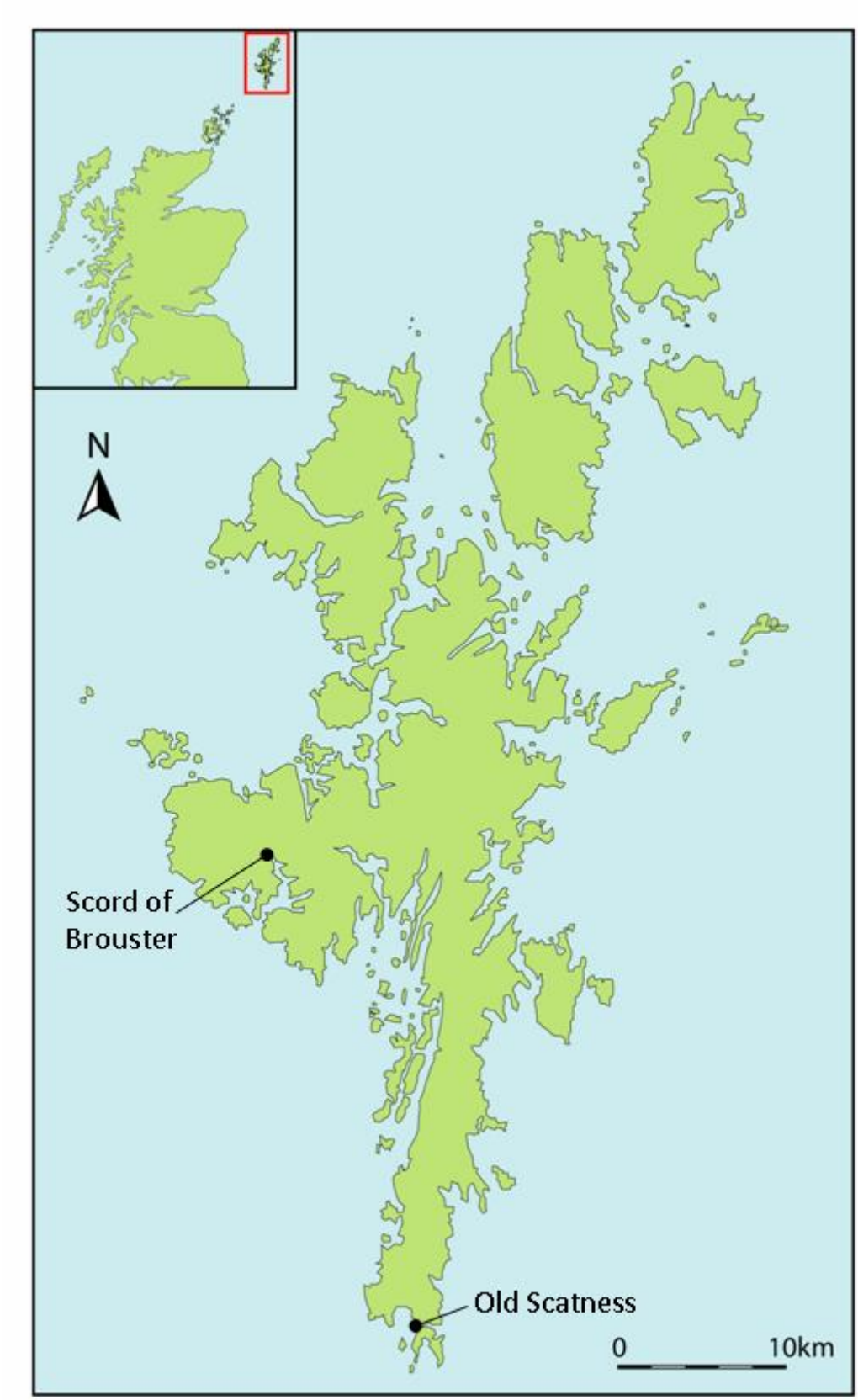

Figure 5.3 Map of Shetland showing sites included in this study. (Illustration by D. Bashford).

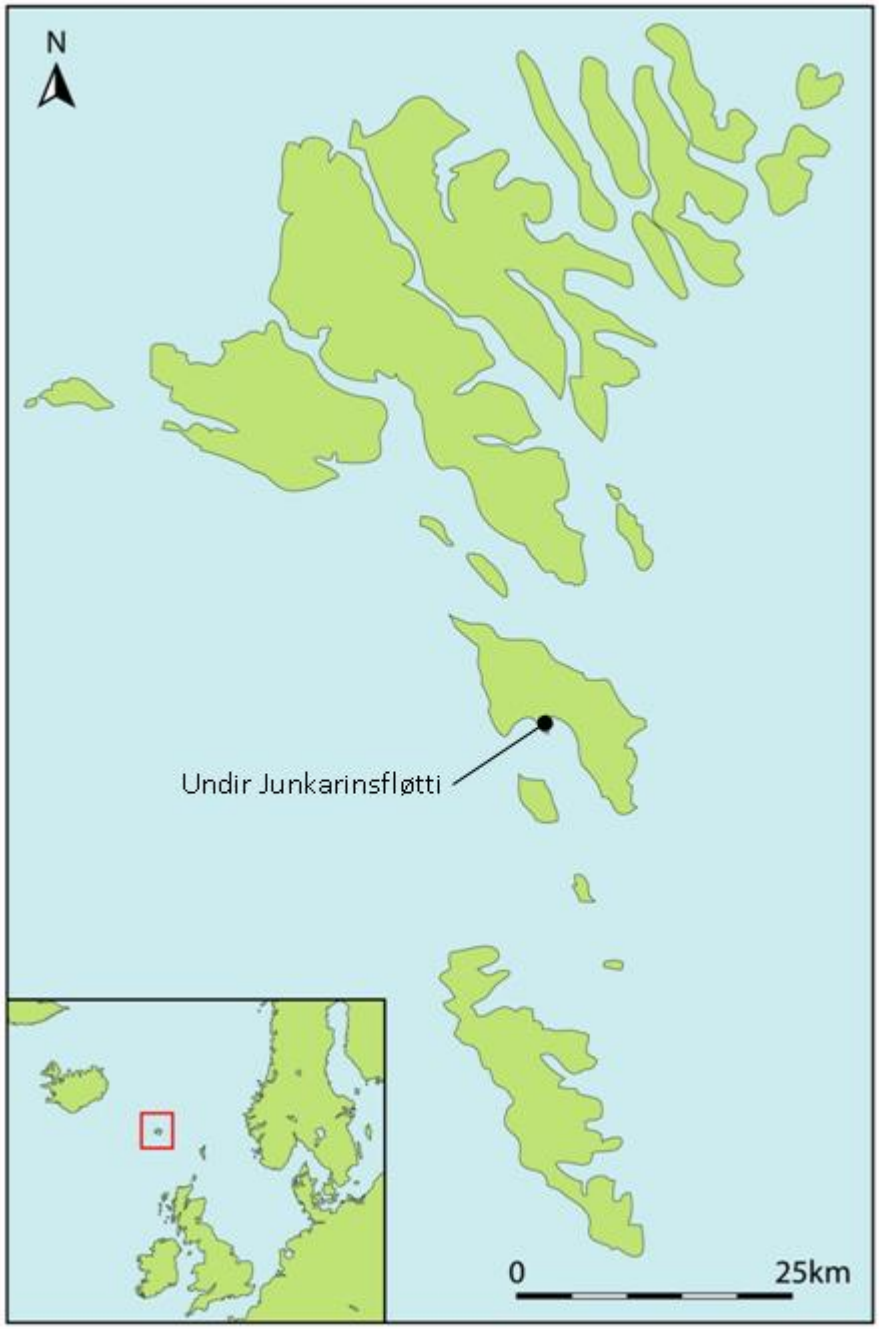

Figure 5.4 Map of the Faroe Islands showing the location of Undir Junkarinsfløtti. (Illustration by D. Bashford).

Faroe Islands

Only a single site was available for analysis from the Faroe Islands - that of Undir Junkarinsfløtti in Sandur on Sandoy (see figure 5.4). This site consisted of a series of

Viking and Norse period middens exposed by coastal erosion, with a Late Norse structure also associated with the upper midden deposits (Church *et al*. 2005). All of the dates for the site were very similar (due to a plateau in the radiocarbon calibration curve), placing the site within the 10th-13th centuries AD. However, the site could be separated into three phases based on the stratigraphy, radiocarbon dating and cultural material. The first phase dated to the 9th-12th centuries AD, the second phase to the 11th-12th centuries AD and the final phase to the 11th-13th centuries AD.

Iceland

A total of six sites were examined from Iceland (shown on figure 5.5). The first two are located in the Eyjafjord region in the north of the island. The site of Gásir was a Medieval trading centre and dates from the mid 13th to early 15th century AD (Harrison 2008 & 2009). It is likely that many of the animal bones found at the site came from elsewhere and isotopic signatures indicate differences in grazing patterns (Harrison 2009), although it is thought that much of the stock would have come from the nearby farm of Möðruvellir (Harrison & Roberts 2010).

The second site from Eyjafjord is that of Möðruvellir. This was a high status church farm site occupied from the 1150s onwards (Harrison & Roberts 2010). The bone material from Möðruvellir used in this study dates from the 16th to 18th centuries AD. Excavations at the site have concentrated on midden deposits from a large farm mound (Harrison 2007).

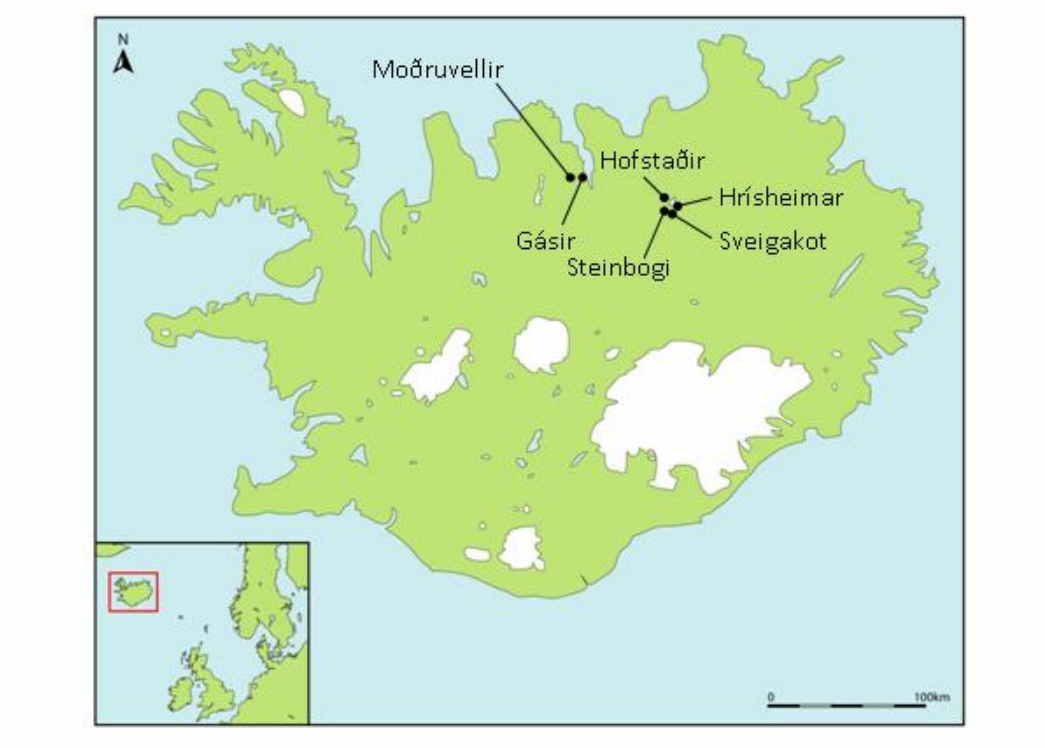

Figure 5.5 Map of Iceland showing sites included in this study. (Illustration by D. Bashford).

The other four Icelandic sites are located in the Mývatn region. Hofstaðir was a high status, Viking Age hall with associated buildings and midden deposits from designated midden heaps and the infill of buildings; the site was occupied from AD 940-1050 (McGovern *et al.* 2009).

Sveigakot was an early settlement site, with midden deposits directly in contact with the late 9th century *landnám* tephra layer (McGovern *et al*. 2007); the bones examined in this study date from this early (c. AD 1000) settlement date. The early settlement was characterized by a series of sunken-featured buildings, which were later replaced by a small hall in the late 10th century (*ibid*.). The site was abandoned and then reoccupied in the late 11th century (*ibid*.).

The site of Hrísheimar consisted of a pit house, latrine and the remains of a possible early hut or tent structure, all of which were overlain by midden deposits dating from AD 875-1050 (Edvardsson & McGovern 2007). Iron production activity was also identified at the site as well as the main farm ruin, which is currently unexcavated (*ibid*.).

The final site is that of Steinbogi, where excavations focused on midden deposits associated with a small farm. Artefactual material suggested a medieval date of around AD 1200 (McGovern 2002).

Greenland

A total of 17 sites were examined from the Norse Greenland settlements, ten from the Western Settlement (figure 5.6) and seven from the Eastern Settlement (figure 5.7). The majority of these are ordinary farm sites (see table 5.1) with associated middens. The farms usually have a series of often interconnecting buildings constructed of stone and turf, comprising a dwelling and a variety of ancillary structures for storage and the housing of animals etcetera (e.g. Vebæk 1992). Excavation of many of these sites took place in the late 19th and early 20th century and hence little in the way of stratigraphic recording took place. However it is thought that these excavations mainly focused on later phases of occupation (McGovern 1985) and so bones from these sites are likely to date to the 14th and 15th centuries - therefore, a lack of stratigraphic phasing is not necessarily a significant

problem. Sites that do not come under this basic description are discussed in more detail below.

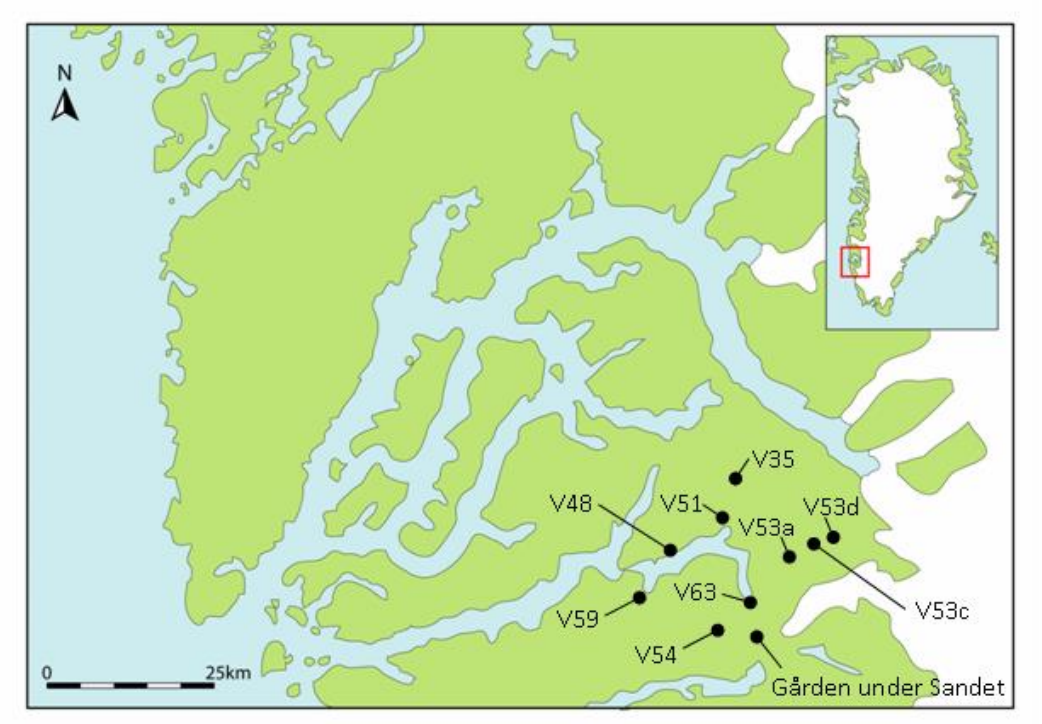

Figure 5.6 Map of the Western Settlement in Norse Greenland showing sites included in this study. (Illustration by D. Bashford).

The site of Gården under Sandet (GUS) in the Western Settlement is a typical farm settlement made up of a complex series of buildings forming a single farm, with many phases of modification and construction (Arneborg 2003a). Eight phases of construction were identified, with dates ranging from c. AD 1000 to AD 1350. The animal bone finds from the site were split into three main phases for analysis, based on the construction phases. Phase 1 was dated to c. AD 1000-1150 (construction phases 1-3), Phase 2 dates were AD 1150-1300 (construction phases 4-6) and Phase 3 dated from AD 1300 to AD 1400, approximately the time of site abandonment (*ibid*.).

Site V48, although broadly falling into the category described above, does have excavated deposits dating back to the time of settlement. McGovern (1985) mentions that these deposits can be divided into three phases; however, this data was not available when collecting bone measurement data and so the measurements have to be treated as a single group dating from the late 10th to the early 15th century AD.

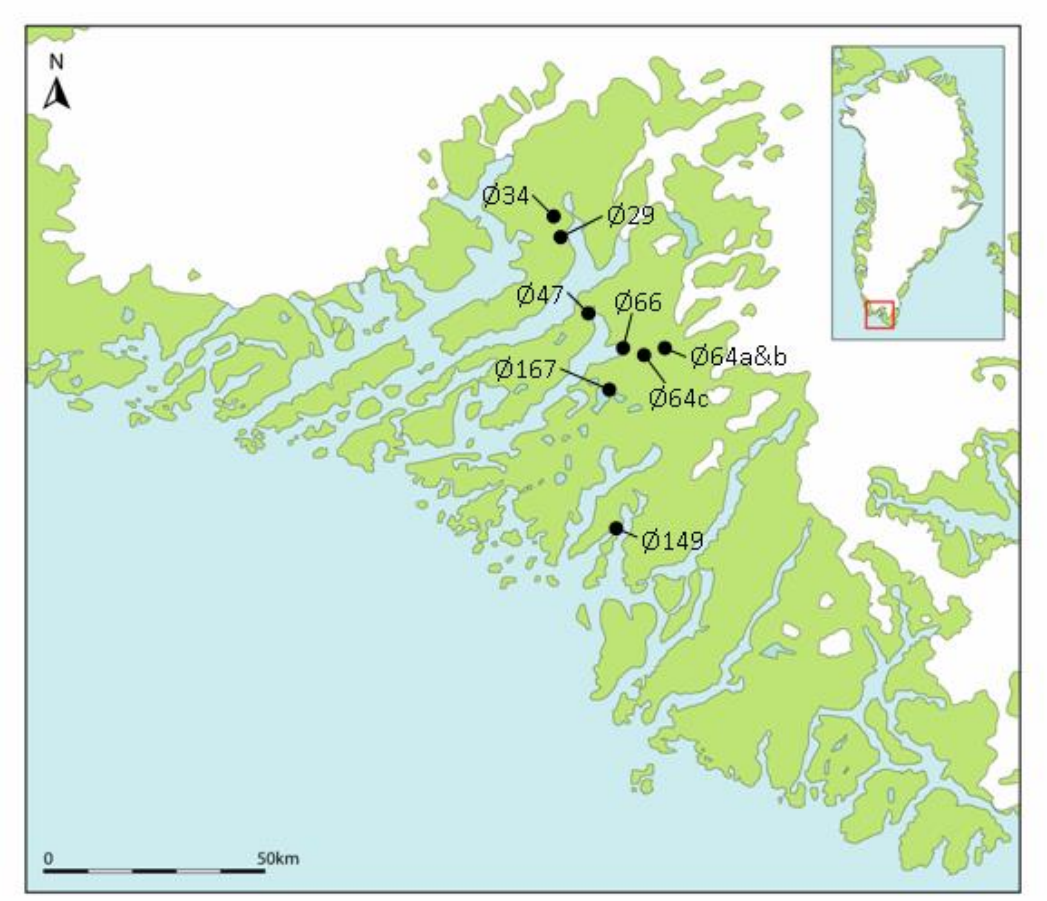

Figure 5.7 Map of the Eastern Settlement in Norse Greenland showing sites included in this study. (Illustration by D. Bashford).

V51 (Sandnes) is another settlement where only deposits from the later phases have been excavated. However this is not an ordinary farm site but a church farm – in fact the highest status farm in the Western Settlement (McGovern 1985).

The site of Brattahlid in the Eastern Settlement is made up of at least two farmhouses and a church (Degerböl 1934), and was reputedly the farm of Erik the Red, the founder of Norse Greenland. Whether this is true or not, the farm is of a relatively high status. The excavated deposits again relate to the later period of settlement (McGovern 1985).

The highest status site in the Eastern Settlement, for that matter in the whole of Norse Greenland, is Gardar or Ø47, which was the Episcopal Seat for Norse Greenland. Skeletons excavated from the graveyard date to the 12th-14th centuries (Arneborg *et al*. 1999).

The site of Ø34 is a fairly modest farm, located near to Brattahlid, which consists of a group of 17 ruins including a small dwelling and a byre (Guldager *et al*. 2002: 53f). Excavations have focused on a midden deposit located next to the dwelling house (Nyegaard 1996). However most of the dating evidence has come from palaeoenvironmental investigations (Schofield *et al*. 2008). These showed evidence for peat cutting activity some time previous to AD 1020-1190, thought to be associated with the building of the farm, and evidence for site abandonment at around AD 1420-1630 (*ibid*.).

The site of Ø149 is another relatively high status farm, as in its later incarnation it was the place of a Benedictine convent (Vebæk 1991). All of the excavated bones come from this later phase of activity, dated to the 12th-15th centuries (*ibid.*; Arneborg *et al*. 1999).

The final site from the Eastern Settlement, Ø167, is intriguing as its date of abandonment is much earlier than expected. This abandonment is dated to the mid to late 13th century, from the skeleton of a man found in the passageway of one of the houses. As he was not buried, he is believed to have been the last man present in the whole neighbourhood (Vebæk 1992).

5.3 DATA COLLECTION

As noted above, data were collected from a variety of sources. The following sections describe how each different type of data was treated in order to produce a coherent, standardised project dataset.

5.3.1 Measurements taken by the author

Measurements from 11 of the sites studied (see table 5.1) were taken by the author. All of these measurements were taken according to the guidelines described in von den Driesch (1976); brief descriptions of measurements mentioned in the text are given in table 5.2. A wide variety of measurement were collected from limb bones, foot bones and teeth (lower third molars) to give a good spread of measurements being affected by different genetic and environmental factors and also allowing appropriate measurements to be used for the different hypothesis. Although tooth

measurements were collected and may have been useful for some of the hypotheses examined, due to their lower reactivity to environmental variation than bones; they were only available from a small number of sites and therefore were not able to be used in the current study. They are however available for future study.

The majority of measurements were taken using digital callipers accurate to 0.01mm; however, all measurements were recorded at a precision of 0.1mm, as it was considered that this represented the upper limit of reproducible precision. Each measurement was taken at least three times and very rarely were these three measurements in agreement at the 0.01mm level, however good agreement was usually found at the 0.1mm level. Additionally, the majority of measurements taken by other authors and colleagues were taken at 0.1mm precision.

Dimension	**Bones**	**Description**
GL	All long bones	Greatest length
Bp	All long bones Phalanx 1	Breadth of the proximal end
SD	All long bones Phalanx 1	Smallest breadth of the diaphysis
Bd	All long bones Phalanx 1 Astragalus	Breadth of the distal end
GLl	Astragalus	Greatest length of the lateral side
GLpe	Phalanx 1	Greatest length of the peripheral side
BT	Humerus	Breadth of the trochlea

Table 5.2 Brief description of measurement abbreviations used in text. For detailed descriptions for individual bones see von den Driesch (1976).

On occasion, bone dimensions were too large to be measured using the digital callipers available. Depending on where the measurement data was being collected, alternative measurement apparatus was employed accordingly. Whilst working at the Zoological Museum in Copenhagen (bone measurements from Greenland sites) alternative, larger vernier scale callipers were available for taking measurements of greater than 250mm, again accurate to 0.01mm. For a very few measurements of bones from the site of Howe, Orkney, taken at the Tankerness House museum stores in Kirkwall, measurement equipment was more limited and here a thirty centimetre rule was used, being accurate only to the nearest millimetre. Finally, measurements of larger bones taken at the University of Bradford (sites of Tofts Ness and Old Scatness) were made with the aid of an osteometric box accurate to the nearest 0.5mm. Where measurements were taken using any instrument other than digital callipers accurate to 0.01mm a note was made of this fact, so that this could be taken into account during data analysis. All measurement data were recorded on paper recoding sheets and later transferred into electronic form, initially in an MS Excel spreadsheet.

During measurement recording, notes were also made where taphonomic or pathological factors may have had an effect on the bone dimension in question. In cases of severe damage no measurement was taken; however, if damage was slight the measurement was taken but a note was made of the nature and extent of the damage. These data were later excluded from any data analysis carried out, but are available for later study if deemed necessary.

In order to minimise size variation related to animal age no unfused epiphyses or ends of diaphysis were measured. Bones where epiphyses were firmly attached but the fusion line was still visible were measured but noted as having the fusion line visible; these data are available for study but were excluded from analysis in the current project. Therefore only ends of bones with fully fused epiphyses were used for analysis here. Likewise for bones without fusing epiphyses, the astragalus being of particular relevance, only bones that had a smoothed, mature appearance were measured. Those that appeared porous were discarded from analysis.

5.3.2 Measurements taken by others

Measurements not taken by the author fall into two categories: unpublished measurements donated by a variety of colleagues working on archaeozoological assemblages in the North Atlantic, and those from published sources. All sources are listed in table 5.1; those from published sources are given with an author and date reference and those donated by colleagues are cited with an initial and surname.

Measurements used from unpublished, donated data were all taken following von den Driesch (1976). Occasionally measurement data were presented in centimetres and all of these were converted to millimetres for consistency. Additionally, although the majority of donated measurement data were taken to a precision of 0.1mm this was not always the case. Measurements from some of the Western Isles sites (Á Cheardach Mhor, Sollas, Northton, Udal) were only taken to a 0.5mm level of precision, evidently no improvement could be made to this situation, but it should be noted when examining the results. On some occasions (for example a small number

of the Pool data) measurements were recorded to the nearest 0.01mm, as discussed above this was thought to be an unrealistic level of precision and all of these measurements were rounded to the nearest 0.1mm to bring them into line with the majority of other data.

Published data were used for a variety of the sites examined and varied greatly in quality. Many of these measurements were taken before the publication of von den Driesch's guide to measuring animal bones (1976) and therefore care had to be taken when selecting data for study. Only measurements that could be directly compared to those listed in von den Driesch (*ibid*.) were used. Again, many of the measurements had to be converted from centimetres to millimetres and some measurements were only taken to the nearest 0.5 or 1mm. Older publications were more prone to these issues. As with measurements taken by the author, all measurements were initially entered into MS Excel spreadsheets.

5.3.3 Limitations and problems encountered during data collection

As with the compilation of any dataset, particularly one collected from a wide variety of sources such as the one being studied here, a number of problems were encountered which should be noted at this point.

One issue already discussed is that of measurement equipment. Although for the vast majority of cases the authors own callipers were perfectly adequate to undertake all required measurements, on a small number of occasions bone dimensions were too

large to be measured in this way and alternative methods had to be used. These alternative methods varied with location as described above.

Another major problem was the fragmentary nature of the bones being studied. All of the regions under study may be classed as marginal and therefore practices such as marrow cracking and processing of bones for fats, etcetera were commonplace (Outram 1999) rendering many of the bones small un-measurable fragments. In some cases, where data were collected from other workers or published reports, measurements of complete bones only had been taken, vastly reducing potential sample sizes for some measurements (e.g. Smith 1994). Another problem arising from fragmentation is that where measurements were taken from the earlier fusing end of a bone, for example distal tibia or proximal metacarpal, it was often not known if the other end of the bone had reached full fusion or not. Where measurements were taken by the author and it could be seen that the other end of a bone was unfused, a note was made so that it may be possible in the future to make comparisons between fully fused bones and those with an unfused epiphysis at one end. At the time of measuring it was not thought likely that this would be a problem, as measurements were only taken from fused epiphyses, however recent work by English Heritage on 'The Sheep Project' suggested that for certain epiphyses some post fusion growth, or in some cases shrinkage, may occur (P. Popkin pers. comm.).

It was found by the author that certain measurements were more difficult to take accurately than others – i.e., when taking the measurement three times there was less agreement between the three measurements. In particular, humerus Bd was

found to vary considerably with only small adjustments to bone position within the callipers; humerus BT was found to be an easier, more consistent measurement to take, although not very clearly defined by von den Driech (1976). The majority of other measurements gave reasonably consistent results on being measured three times; where any variation was found the mean of the three measurements was recorded.

Other problems were those inherent in collecting data from a variety of sources. It was not often possible to know what equipment had been used in taking measurements or if the measurements from a particular site had all been taken by one person or a number of different researchers. In some cases, where hand written archive records were consulted it is clear that a variety of different workers did take measurements. Popkin (2007) made a survey of how experienced archaeozoologists take certain measurements and found that although all researchers were essentially following the guidelines of von den Driesch (1976) slightly different approaches were taken which in some cases could affect the resulting measurement. It is however not known if the difference between methods would result in statistically significant datasets.

5.4 Data Processing

Upon collection, as mentioned above, all data were entered into MS Excel spreadsheets. Each workbook contained data from one site and species and was divided into worksheets by element. Whilst this was a convenient and straightforward method of collecting and recording data it was not convenient for

later retrieval of groups of data under a variety of different criteria such as region, date or skeletal element. For this reason all data were imported into a single MS Access database where they could be sorted, filtered or queried as necessary. For example all astragalus GLl measurements from sites in Iceland could be retrieved using a simple query and could then be extracted for further analysis. This Access database contains measurements of over 7000 bones from sheep, goat, sheep/goat and cattle and is included in electronic form as appendix 1. This database was used as a storage and selection device only; all data analyses were carried out in MS Excel or PASW Statistics 18 as appropriate.

In order to examine the dataset to enlighten on the hypotheses proposed in chapter four a variety of statistical methods were employed. As an initial step in data analysis and in order to give a broad overview of the nature of the dataset a set of summary statistics were calculated. The calculation of summary statistics for every taxon, bone dimension, site and period available was felt to be totally impractical in terms of time available and the information that would be offered through such an overly detailed analysis. For this reason a set of dimensions were selected based on those which were most numerous and represented the most sites. This allowed the largest sample sizes possible and the most representative picture of the region under study to be gained.

For sheep the bone dimensions selected were astragalus GLl and Bd, metacarpal and metatarsal GL and SD, phalanx 1 GLpe and Bp, radius GL and Bp, and humerus BT and tibia Bd. It was felt important to include both length and breadth measurements,

particularly where they were paired on the same element, to give some impression of bone shape as well as bone size. While every attempt was also made to examine measurements from different areas of the body, a large part of this study was reliant upon published and archive bone measurement data taken by a wide variety of researchers. As such, these groups of data were extremely varied in both size and the selection of measurements taken, with some areas of the body less well represented than others. The numbers of measurements of cranial and vertebral elements and the pelvis were too few to be included in this statistical summary analysis, however small numbers of measurements of such elements are available for a selection of the sites examined. As well as being the most numerous, the bones selected above have qualities that make them useful in biometrical studies. The metapodials are sensitive to sexual polymorphism (Howard, 1963) and therefore should be good indicators of sex variation. The astragalus is much less sexually dimorphic and gives a good impression of overall body size (Noddle 1979; Davis 2000). The distal tibia may also be a good indicator of adult size as it ceases to increase in breath before or at fusion (Davis 2000). Finally Noddle (1979) believed that the first phalanx may give some indication of 'primitiveness' as the Mouflon, the presumed ancestor to the domestic sheep, was long toed.

Summary statistics were calculated using PASW Statistics 18 and included the number of cases, the mean, the minimum and maximum values, standard deviation and variance. These data are listed in appendix 2 and provide the starting point for all other analyses. Although only a selection of the bone measurements available are presented in the summary statistics, this does not mean that all other measurements

were excluded from further analysis; these were included as and when necessary or appropriate.

Depending on the particular question or hypothesis, the sites involved and the data available, a variety of data presentation methods were used in addition to the summary statistics detailed above. Where single bone dimensions were being examined, histograms and sometimes box plots were created in PASW Statistics 18. These were used to look at varying distributions of bone measurements between sites or periods. Where it was necessary to examine two bone dimensions at once or bone shape was under consideration scatterplots of dimensions were created either in PASW Statistics 18 or in MS Excel. In some cases where it was necessary to further examine bone shape, breadth versus length indices were calculated such as those detailed in Howard (1963). An example of such a calculation would be:

$$(SD/GL)x100$$

which provides a measure of the breadth of the bones in terms of a percentage of the bone length or, put more simply, an indication of bone robustness - the higher the index value the more robust the bone.

In many cases the sample sizes for measurements of a particular element from a site were extremely small with potentially only one or two examples. In these cases measures were taken to improve sample size. This was achieved through the calculation of log ratio values (Meadow 1999) allowing measurements from different bones to be compared against a standard and hence be pooled in order to increase sample size.

Log-ratio values were calculated using the following formula:

Log-ratio = Log (archaeological measurement/standard measurement)

Where the log-ratio value is zero this indicates that the archaeological measurement was the same as the standard, where the log-ratio value is positive it indicates that the archaeological measurement was larger than the standard and negative values indicate that the archaeological specimen was smaller than the standard.

The standard used for the comparison of sheep and sheep/goat measurements was a hypothetical standard created from published data in Clutton-Brock *et al*.'s (1990) study of the osteology of the Soay sheep. The standard measurements are listed in table 5.3 and come from a group of Soay males. Although within this paper notation given by von den Driesch (1976) was not used, the diagrams provided allowed measurements to be selected that matched von den Driesch's (*ibid*.) criteria for specific bone dimensions.

The standard for cattle log-ratio measurements was a hypothetical standard created from Dobney *et al.*'s (no date) work on the animal bones from the city of Lincoln. Here mean measurements from the 4th century deposits were used as they formed the largest and probably most homogenous dataset of all the different phases. The values used are displayed in table 5.4.

Bone	Dimension (von den Driesch 1976)	Value (mm)
Atlas (12)	GL	49.74
Scapula (10)	SLC	18.26
	GLP	30.54
	LG	22.95
	BG	19.66
Humerus (7)	Bd	28.62
Radius (7)	Bp	29.71
	Bd	27.64
	SD	16.03
Femur (7)	Bp	44.09
	DC	19.36
	Bd	36.88
Tibia (5)	Bp	39.42
	Bd	24.75
	SD	13.84
Astragalus (9)	GLl	26.60
	Bd	17.21
Calcaneum (7)	GL	52.22
Metacarpal (8)	GL	119.93
	Bp	21.74
	Bd	23.70
	SD	14.10
Metatarsal (8)	GL	128.66
	Bp	19.01
	Bd	22.63
	SD	11.87
Phalanx 1 (16)	GLpe	34.52
	Bp	11.85
	Bd	10.48
	SD	9.23

Table 5.3 Standard measurements used for the calculation of log-ratio values for sheep and sheep/goat measurements. Values are from a group of Soay males (Clutton-Brock *et al*. 1990) and represent mean measurements; figures in brackets after bone name show number in sample. Values for phalanx 1 are a mean of equal numbers of fore and hind limb bones.

Bone	Dimension (von den Driesch 1976)	Value (mm)
Scapula	GLP (36)	62.5
	SLC (31)	46.7
Humerus	BT (9)	68.1
Metacarpal	Bd (101)	53.6
	Bp (247)	52.6
	GL (21)	184.4
	SD (35)	29.4
Tibia	Bd (105)	56.1
Astragalus	Bd (167)	38.7
	Dl (152)	34.6
	GLl (157)	61.5
Metatarsal	Bd (133)	49.8
	GL (21)	211.3
	SD (33)	24.0

Table 5.4 Standard measurements used for the calculation of log-ratio values for cattle measurements. Values are from cattle from 4th century Lincoln (Dobney *et al*. no date) and represent mean measurements; figures in brackets after dimension show number in sample.

5.5 Limitations of the Data

One of the major limitations of the collected dataset is that although as a whole it is large, when examining individual sites or bone measurements the sample sizes are often very small. Many of these data subsets are too small to be robust enough to undergo statistical testing, particularly more complex methods such as multivariate analyses. In some cases this can be compensated for through the use of methods such as log-ratio conversions (see above). However, in many other cases this is not possible or the resulting datasets are still small, and in these cases the small sample size must be borne in mind during data interpretation.

Due to these restrictions on sample size only very basic analyses of size and shape (proportion) changes can be made. Complex analyses of shape differences that may be achieved through multivariate methods, such as discriminant analysis or principal components analysis, are not felt to be necessary here due to the nature of the questions being asked. However it should be noted that bone shape, in terms of robustness, is thought to be important in the following analyses.

5.6 SUMMARY

Although the datasets described above do have a number of limitations, not least in the sample sizes for individual sites or phases, the collated dataset does present an excellent opportunity to analyse sites covering a wide range of dates, regions, site types and economic situations. Date wise, the sites cover approximately six millennia of occupation in the North Atlantic. The east-west distance covered by the sites is over 2500km and latitudes range from c. 57°N to c. 65°N. The majority of sites are costal but inland sites are also included and a variety of climatic situations are also encompassed. All in all this dataset provides an excellent opportunity to examine changes in domestic mammal bone size and shape across a wide variety of situations. Conversely, in the case of some of the hypotheses a wide range of variables need to be accounted for or where possible limited.