CHAPTER 6:

RESULTS AND DISCUSSION

‘In the old household, the farming community knew exactly how to make the best use of each particular organ of the sheep. It has sometimes been said that they utilized every part of the sheep except the gall bladder and hooves’ (Adalsteinsson 1990: 288)

6.1 INTRODUCTION

The quote above is placed here as a timely reminder that when we are talking about size changes in the bones of domestic livestock there is a knock on effect on the size of other body parts and that, in turn, changes in the size of these will have a direct effect on the humans that consume them. This point will be returned to towards the end of this chapter (Section 6.6).

Examination of the summary statistics for sheep (appendix 2) shows that, in general, sheep from the Neolithic and Bronze Age phases of the Northern and Western Isles sites, tend to be slightly larger on average than those from the later periods in these regions; although most of their measurements fall within the upper ends of the ranges for the Iron Age and Norse data. This would tend to indicate a decrease in size over time, from the Neolithic period through to the Iron Age, and is in general agreement with Noddle’s (1979) findings for cattle and sheep in the Northern Isles. Whether these changes can be attributed to human selection for smaller, possibly easier to manage, livestock or a natural size diminution brought about by the
limitations of island living, is difficult to say; although whatever the reason there
would be certain advantages to supporting a larger number of smaller stock over
smaller numbers of larger bodied animals.

Following the Iron Age it is difficult to discern any other overall changes in size
(through examination of summary statistics alone), until the Post Medieval period. In
the Post Medieval and Crofting periods at Old Scatness there appears to be a rather
dramatic increase in bone size, so much so that this was apparent to the naked eye,
without the aid of measuring equipment (Bond & Nicholson 1998). What is also
apparent at this time is the greatly increased variability in size of these bones,
illustrated through elevated standard deviation and variance values (appendix 2).
Historical documentation records the import of new breeds of sheep into the
Northern Isles at this time. For example Fenton notes ‘Already by 1814, however, Mr.
Gifford of Busta had a mixture of Northumberland muggs and the Black-
Face, with a
dash of the Cheviot breed, all crossing with native Shetland ewes and these crosses
mingling with each other again’ (Fenton 1997: 447). This can be seen as a clear
attempt at improving the conformation of the Shetland flock.

The remainder of this chapter will address each of the four hypotheses laid out in
Section 4.8 in turn. The results will be presented for each hypothesis, followed by a
discussion of their interpretation. The chapter ends with a summary discussion of all
the data presented and some thoughts on what this might mean for the human
populations living in the North Atlantic through the periods examined.
6.2 Latitude Hypothesis

The latitude hypothesis predicts that with increasing latitude there will be a decrease in vegetation productivity, due to increasingly poor growing conditions and hence a corresponding decrease in domestic mammal body size due to lower levels of available quality nutrition. The following section compares mean sheep (only bones positively identified as sheep were used in this analysis, bones designated as sheep/goat were not used) bone measurements from sites at varying latitudes during the broader Norse settlement period covering a date range from the 9th to 15th centuries AD. Although this specification meant that not all sites could be included in the analysis it was felt that some restriction in the date range was necessary to narrow down the potential variables affecting body size. It may be that this date range is still too broad; this will be discussed further below.

6.2.1 Results for latitude hypothesis

The first part of this analysis involved the plotting of mean sheep bone dimensions against site latitude and superimposing trend lines onto the resulting scatterplots to examine any correlation between the two variables. If the hypothesis was to be accepted a negative correlation between latitude and bone size needed to be present.

The first dimension to be examined was the astragalus G1 (figure 6.1). The trend line plotted indicates a positive correlation between latitude and astragalus length; however, this correlation is only slight and appears to be strongly influenced by the plot for Gásir. This is interesting, as the site at Gásir is a trading settlement and it
seems unlikely that bones found at the site were from animals actually raised at the site itself. If they were brought in from elsewhere, could this plot be anomalous? If the data point for Gásir is removed (figure 6.2) the trend line is then reversed and indicates a negative correlation, which would be in agreement with the hypothesis, this will be discussed further below (Section 6.2.2). Examination of data for astragalus Bd shows a very similar pattern (figures 6.3 & 6.4) to that for GLI in that the apparent positive correlation is strongly influenced by one site: Gásir. Again removal of this site from the plot produces a slight negative correlation although this is not as marked as for GLI.

The data for metacarpal GL and SD shows only the slightest indication of a positive correlation between latitude and bone size (figures 6.5 & 6.6); whereas that for tibia Bd (figure 6.7) appears to indicate a reasonably strong positive correlation. Examination of a final dimension, radius Bp (figure 6.8), also shows a very slight positive correlation indicated by the trend line, but a great deal of variation is present for any given region. The spread of data for tibia Bd and radius Bp were examined more closely through box and whisker plots (figures 6.9 & 6.10). For radius, no specific trend relating to bone size and latitude could be determined for either dispersion of data or in central tendency. There was no discernable pattern with all measurements falling within a similar broad range. The data for tibia Bd appears fairly consistent, with similar dispersion and central tendency for the majority of sites with an increase in size for the Icelandic (highest latitude) sites. A Pearson correlation test for tibia Bd indicated a correlation of 0.325 between bone size and latitude,
significant at the 0.01 level. No significant correlation was found between radius Bp and latitude.

Therefore it seems that overall for the sites examined the relationship between latitude and bone size is the opposite of that predicted, i.e. that bone size becomes larger with increased latitude. This will be discussed further in Section 6.2.2.

One final examination of the relationship between bone size and latitude was made. This compared just the Eastern and Western Settlements in Greenland. Here one of the main variables between the two settlements is their latitude. Eastern Settlement sites fall around 61°N and those in the Western Settlement around 64°N. Here mean values were examined for a number of sheep and cattle bone dimensions and bar charts were constructed (figures 6.11 & 6.12) showing the location (Eastern or Western Settlement) of the highest and lowest mean values for each dimension for both sheep and cattle bone measurements. The bar charts show that a larger number of lowest mean measurements belong to sites from the Western Settlement and conversely highest mean measurements more often belong to sites from the more southerly Eastern Settlement, seen most clearly in the sheep measurements. It should be noted however that Eastern Settlement sites did not always have the highest means, nor Western Settlement sites always the lowest. These data would appear to broadly concur with the hypothesis that bone size will decrease with increasing latitude.
Figure 6.1 Mean sheep astragalus length in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.

Figure 6.2 Mean sheep astragalus length in millimetres plotted against latitude for sites dating to the Norse period, with the site of Gásir removed. Data points are labelled according to settlement region.
Figure 6.3 Mean sheep astragalus breadth in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.

Figure 6.4 Mean sheep astragalus breadth in millimetres plotted against latitude for sites dating to the Norse period, with the site of Gásir removed. Data points are labelled according to settlement region.
Figure 6.5 Mean sheep metacarpal length in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.

Figure 6.6 Mean sheep metacarpal shaft breadth in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.
Figure 6.7 Mean sheep tibia distal breadth in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.

Figure 6.8 Mean sheep radius proximal breadth in millimetres plotted against latitude for sites dating to the Norse period. Data points are labelled according to settlement region.
Figure 6.9 Box and whisker plot of sheep tibia distal breadth in millimetres plotted against latitude for sites dating to the Norse period.

Figure 6.10 Box and whisker plot of sheep radius proximal breadth in millimetres plotted against latitude for sites dating to the Norse period.
Figure 6.11 Bar chart showing location of sites in the Greenland Norse settlements with lowest and highest mean values for a series of sheep bone dimensions.

Figure 6.12 Bar chart showing location of sites in the Greenland Norse settlements with lowest and highest mean values for a series of cattle bone dimensions.
6.2.2 Discussion of latitude hypothesis

The results for the latitude hypothesis are extremely variable and no clear pattern of an overall relationship between latitude and bone size has become evident.

When mean sheep bone size for a variety of dimensions was plotted against latitude, the overall trend was towards slight positive correlation. This however varied between different bones and dimensions, appearing most marked for tibia Bd and least so for metacarpal SD. Although for radius Bp the trend line indicated that there was a slight positive correlation, this was not apparent to the naked eye, examination of the dispersal of data showed no obvious pattern relating to latitude and a Pearson correlation test found no significant correlation. Data for astragali were perhaps even more intriguing. These included data from the Icelandic trading centre of Gásir. The animals from Gásir were much larger than had been expected, and when removed from the plots the trend lines indicated a slight negative correlation rather than the positive one seen when Gásir was included. This large size was thought likely to be due to the animals not originating from the site itself but from another location, with potentially better conditions for growth. However, the excavators (Harrison & Roberts 2010) suggest that the most likely supply site for Gásir is the nearby site of Möðruvellir, which is located at the same latitude and therefore does not necessarily offer superior conditions for growth. The site is however a high-status church farm (ibid.). It should also be noted from the other latitude plots that, in general, sites from Iceland also tend to show bones from the larger end of the scale. Therefore it is felt that the plots for Gásir should be retained, and probably reasonably represent sheep from that latitude in Iceland.
It seems then that overall there is a slight increase or no change in bone size with increasing latitude, which contradicts the proposed hypothesis. There are several reasons why this may be the case. Within the region of study, latitude is not by any means the only determinant of climate or environment, with two other particularly important environmental factors being worthy of note. Firstly, the Gulf Stream, which as mentioned in Chapter 4 has an ameliorating affect on the climates of Orkney, Shetland and the Faroe islands, rendering them milder in climate than their latitudes suggest and effectively providing them with the climate of more southerly locations, at which bone size tends to increase with increasing latitude (Geist 1987).

The second important environmental factor is that of island size and land availability. Iceland is a much larger land mass than Orkney, Shetland or the Faroe Islands and therefore has a much larger potential for land available for grazing, even though problems of land degradation do appear to have been severe (e.g. Simpson et al. 2004). It is likely that some level of island dwarfism is playing a part in the size difference between bones from the smaller island groups and those from the larger land mass of Iceland (and probably Greenland).

Another important factor in why the proposed hypothesis was not supported is the particular latitudes being examined. Geist (1987) noted that the changeover point at which increasing latitude switched from showing a positive correlation with bone size to a negative correlation was around 60-65°N. This means that for the latitudes being examined in this study the correlation could go either way or not be present at all.
Another factor for consideration is the date ranges for the sites under consideration. Although a relatively narrow date range (compared to the dataset as a whole) was selected, the period covered does encompass the significant climatic shift of the beginning of the Little Ice Age, and not all of the sites cover the entirety of the time period selected. As such, some of the variation noted may be due to temporal differences as much as spatial ones. Additionally it should be noted that this hypothesis is based on research examining wild and not domestic species as mentioned in Section 3.4.5.

When looking at sites solely in Greenland, where latitude is likely the primary control on climatic differences between the two settlements, the hypothesis of decreasing bone size with increasing latitude does appear to be supported, with bones in the more northerly Western Settlement being on average smaller than those in the Eastern Settlement. Therefore the latitude hypothesis can be partially supported but not applied to the entire study region.

6.3 Status Hypothesis

The status hypothesis predicts that within a particular geographical area and period of time sites of a higher status would have animals of a larger stature than those of a lower status within that area and time period. It postulates that higher status settlements would have access to greater resources, particularly tracts of land for grazing and therefore domestic livestock would be better nourished and able to grow larger. To test this hypothesis three different areas are investigated: firstly the
Western Isles of Scotland, where the difference between sheep at broch sites and wheelhouse settlements is examined; secondly, sheep from two settlements from the Mývatn area of Iceland are investigated; Hofstaðir, based around a large feasting hall, and Sveigakot, an ordinary farm site. Finally, high and low status sites in the Western Settlement of Greenland are considered through the examination of sheep/goat bones and cattle bones. Here the distinction should be made between the use of sheep and sheep/goat bones. In the Western Isles goats are not positively identified until the Norse period (see Section 4.2.2) and therefore it is felt reasonably safe to assume that the vast majority of ovicaprine bones identified from deposits dating to earlier than this period belong to sheep. In Iceland both sheep and goats were present and here only bones positively identified as sheep have been used, those designated as sheep/goat or goat are not used here. For the particular sites examined here for Greenland, none of the measured bones were positively identified as sheep or goat and as both species are known to have been present in Norse Greenland these bones are designated as sheep/goat.

6.3.1 Results for status hypothesis

Western Isles

For the Western Isles four sites were examined: Dun Vulan, a broch site on South Uist; and three wheelhouse sites (Cnìp on Lewis, and Sollas and Udal both on North Uist (see figure 5.1). A single phase was chosen for each site, focusing around the 1st century AD to allow fair comparability between the sites. However the time breadths covered by phases from different sites did vary. For Dun Vulan the group of bones from the area adjacent to the broch were used, dating to 1st-4th centuries AD. The
bones from Sollas were from Wheelhouse B, dated to the 1st or 2nd centuries AD and those from Cnip and Udal both came from deposits dated to the 1st century AD. Therefore the Dun Vulan assemblage has the greatest variability in date; however, pottery evidence from the site suggest that these deposits were laid down towards the earlier part of the suggested time frame (Parker Pearson & Sharples 1999), making them a reasonably good comparison for the other sites. With the exception of the Udal the sample sizes are very small and this must be taken into account when examining the following figures and data. However it does also appear that the mean sheep bone measurements for Dun Vulan are consistently low and that those for Cnip are consistently high; measurements from Sollas appear to generally fall between those for Cnip and Dun Vulan and the dataset from Udal appears broadly similar to that from Dun Vulan.

The first bone to be examined is the astragalus and for this bone only GLI had enough data for comparison across all of the sites. These data are presented in figure 6.13 below and generally follow the broad pattern described above. Measurements from the Udal have the widest range: this is not surprising given that this is by far the largest dataset. All other measurements fall within the range of the Udal data. The two measurements from Cnip and single measurement from Sollas fall within the upper part of the range and those from Dun Vulan are fairly evenly spread across the range.

Metacarpal greatest lengths (Figure 6.14) again follow a similar pattern, Udal and Sollas have the largest sample sizes and widest ranges. The ranges overlap a great
deal, but Sollas has the larger animals and Udal the smaller ones. The two measurements from Cnip broadly correspond to the extremes of the range for Sollas. The single measurement for Dun Vulan falls below the ranges from both Sollas and Cnip and corresponds to the lower end of the range for Udal.

Metacarpal SD measurements (figure 6.15) show a slightly different pattern with the single Dun Vulan measurement falling well within the ranges for Sollas and Cnip and towards the higher end of the range for Udal. There is much less difference between the two Cnip SD measurements than was seen in the GL measurements, possibly suggesting the presence of animals of two different sexes, one of which is particularly long compared to its breadth, suggesting the likely presence of a castrate.

Examination of the scatterplot of metacarpal GL versus SD (figure 6.16) shows that generally, bones from Cnip and Sollas tend to be larger, whereas those from Dun Vulan and Udal appear smaller. It is also apparent that within the sites there are variations in sheep bone shape, some bones being relatively tall and slender and others being short and robust. These differences are most likely due to the presence of a mix of males, females and castrates at the sites.

The proximal breadth of the radius (figure 6.17) again shows a similar pattern. Measurements from Cnip fall towards the top of the range, those from Dun Vulan towards the bottom of the range and Sollas and Udal fall in the middle. All four sites have similar range breadths, all of which overlap.
The final bone dimension examined was the breadth of the trochlea in the humerus (figure 6.18). This appears to show a slightly different pattern to the other dimensions described above. The mean measurements are all very similar, with Dun Vulan having the largest mean (albeit by a narrow margin); in contrast to the other dimensions the smallest values belong to Sollas and Cnip. As for all the other measurements the sample size here is small; however, a slightly different pattern does seem to be represented.

Due to the apparent and unexpected larger size of animals from Cnip compared to those from Dun Vulan, it was felt necessary to investigate further. To do so a log-ratio analysis was used to increase sample sizes and allow an overall comparison between the two sites. The log-ratio diagrams are shown in figure 6.19, with mean log values indicated, and further confirm what is hinted at by the histograms of individual bone dimensions: that on average the sheep bones from Cnip are larger than those from Dun Vulan. An independent samples, two-tailed t-test found the difference between Dun Vulan and Cnip to be significant at the 99.9% confidence interval (t=-3.508, df=76, p=0.001).

In summary, there does not appear to be any evidence for the sheep from the broch site of Dun Vulan being any larger than those from the wheelhouse sites of Sollas, Cnip and Udal. Conversely those from Dun Vulan are, on average, smaller than those from Cnip, the possible reasons for this will be discussed further below (Section 6.3.2).
Iceland

To examine status differences in Iceland two sites located in the Mývatn region were selected. These were the high status site of Hofstaðir and the lower status site of Sveigakot (see figure 5.5 for location). In comparison to the data from most of the Western Isles sites the sample sizes for these two sites are relatively large, however, they are still not as large as is desired for many statistical analyses.

A number of sheep bone dimensions were examined through the use of means and histograms (figures 6.20 – 6.26). There appears to be no notable difference in bone size between the two sites. Of the seven dimensions examined Hofstaðir has the highest mean in only four cases indicating no overall larger size at this site over Sveigakot. The distributions displayed on the histograms are very similar for both sites.

Further examination of sheep bone dimensions were made through scatterplots for the metacarpal, metatarsal and radius where corresponding length and breadth measurements were available in sufficient quantities to be of use. The plots of metatarsal GL v SD (figure 6.27) and radius GL v Bp (figure 6.28) do not appear to show any notable differences between Hofstaðir and Sveigakot, except possibly the presence of a few smaller individuals at Hofstaðir shown in the metatarsal plot. The plot of metacarpal GL versus SD (figure 6.29) shows a different pattern, in that many of the Sveigakot animals appear to be relatively shorter than those from Hofstaðir. To explore this further a shape index \((\text{SD/GL}) \times 100\) was calculated and plotted against bone length. The shape index gives a measure of robustness: the higher the value,
the wider the bone is relative to its length. The plot of metacarpal robustness versus length (figure 6.30) shows an interesting pattern and essentially represents an exaggeration of the pattern seen in the GL v SD plot. It can be seen here that a large proportion of the Sveigakot sheep fall into a more robust category than the majority of those from Hofstaðir. An arbitrary line can be placed on the plot that separates almost all of the Hofstaðir animals and just over half of the Sveigakot animals from the remainder of those from Sveigakot. This higher bone robustness seen at Sveigakot would appear to be in contradiction to the hypothesis that animals at lower status sites would be relatively poorly nourished compared to those at higher status sites, nutritional differences tending to have a greater effect on bone breadth than bone length according to Pálsson and Vergés (1952a). This will be discussed further below.

**Greenland**

Useable data for the Greenland sites was extremely scant and for this reason the log-ratio method described in Chapter 5 was employed in order to increase sample size and allow easier comparison between sites. The first dataset examined is that for bones identified as sheep/goat. Here data from three sites in the Western Settlement are presented (figure 6.31), V51, (Sandnes) the highest status farm identified in the Western Settlement (McGovern 1985), V35, and V48, both lower status farms (see figure 5.6 for locations).

The largest range of log ratio values is from V51 and the smallest range from V48. In spite of grouping the measurements via the log-ratio method the sample sizes,
particularly for V35, are still small. The ranges for all three sites overlap considerably and at first inspection appear to show very little difference. Examination of the mean log values does however seem to show some differences between the datasets. V35 (low status) has the lowest mean log value, V51 (the high status site) only has a slightly higher mean, whereas the second low status site (V48) has the highest mean log value. An independent samples, two-tailed t-test showed there to be a significant difference between the log values for V48 and V51 (t=2.620, df=92, p=0.010). As for Iceland and the Western Isles, this again shows that the animals from the higher status site V51 are certainly not larger than those from the lower status sites and in fact were, on average, smaller than those from V48 and broadly comparable to those from V35.

Cattle bone measurement data was even scarcer than that for sheep/goat and again the only realistic way of comparing between sites was the use of the log-ratio method. Here the standard used was a group of measurements from 4th century Lincoln (Dobney et al. no date), see table 5.4. Figure 6.32 shows log-ratio values for V51 (Sandnes), the highest status site in the Western Settlement, in comparison with four other lower status sites, V48, V53c, V53d and V54. As for the sheep/goat measurements the cattle from V51 do not appear to be any larger than those from the lower status sites. The majority of the measurements fall on or below zero on the log value scale indicating that they are, in the main, smaller than or the same size as the standard measurement. Only sites V53d and V54 have measurements larger than the standard and in both cases all of these plots are attributable to single metacarpals with the largest log values deriving from the breadth measurements.
This would tend to indicate the possible presence of a bull at each of these sites and these larger size animals cannot reliably be attributed to any increase in nutrition.

What is clear from the plots is that more measurable cattle bones were available from V51 than any of the other sites. This could indicate that either more cattle were kept at this higher status farm, which is in agreement with McGovern’s cattle to caprine ratio data (1985: table 7) which shows a value of 1.41 for V51 compared to 0.55 for V53c for example (ibid.). Another possibility is that cattle numbers were fairly even across the sites but those from the lower status sites were more thoroughly processed for marrow and fats etcetera, providing fewer identifiable and measurable pieces. However the first scenario appears more likely, i.e. that there were more cattle present at V51 in the first place, given their greater resource requirements over sheep and goats.

Therefore it appears that barring the possible presence of a bull at V53d and V54 there is no apparent size difference between the cattle at V51 and those at the lower status sites. Log values for V48 and V53c do have slightly lower means and fall within the lower part of the range for V51 and if the mean log values for V53d and V54 are recalculated, in each case excluding the single large metacarpal, the means are dramatically reduced. That for V53d moves down to -0.04 (equal to V48 & V53c) and the mean for V54 becomes -0.03 (equal to V51). V53d and V54 also have log values present that fall below the range of V51. Overall the data suggest that the cattle from the lower status sites may have been very slightly smaller on average than those from V51. However, the samples are very small and the differences only slight.
Figure 6.13 Histogram of greatest lateral length of the astragalus for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.

Figure 6.14 Histogram of greatest length of the metacarpal for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.
Figure 6.15 Histogram of shaft breadth of the metacarpal for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.

Figure 6.16 Scatterplot of greatest length versus shaft breadth of the metacarpal for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.
Figure 6.17 Histogram of proximal breadth of the radius for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.

Figure 6.18 Histogram of the breadth of the trochlea of the humerus for sheep from Dun Vulan, Cnip, Sollas and the Udal, Western Isles.
Figure 6.19 Log-ratio values of sheep bones from Dun Vulan and Cnip, Western Isles. Red arrows indicate mean values.
Figure 6.20 Histogram of greatest length of the metacarpal for sheep from Hofstaðir and Sveigakot, Iceland.

Figure 6.21 Histogram of shaft breadth of the metacarpal for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.22 Histogram of greatest length of the metatarsal for sheep from Hofstaðir and Sveigakot, Iceland.

Figure 6.23 Histogram of shaft breadth of the metatarsal for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.24 Histogram of greatest length of the radius for sheep from Hofstaðir and Sveigakot, Iceland.

Figure 6.25 Histogram of proximal breadth of the radius for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.26 Histogram of distal breadth of the tibia for sheep from Hofstaðir and Sveigakot, Iceland.

Figure 6.27 Scatterplot of greatest length versus shaft breadth of the metatarsal for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.28 Scatterplot of greatest length versus proximal breadth of the radius for sheep from Hofstaðir and Sveigakot, Iceland.

Figure 6.29 Scatterplot of greatest length versus shaft breadth of the metacarpal for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.30 Scatterplot of greatest length versus robustness index of the metacarpal for sheep from Hofstaðir and Sveigakot, Iceland.
Figure 6.31 Log ratio values for sheep/goat bones from the Western Settlement.

Mean values $V35 = 0$, $V48 = 0.03$, $V51 = 0.01$. 
Figure 6.32 Log ratio values for cattle bones from the Western Settlement. Mean values $V51 = -0.03$, $V48 = -0.04$, $V53c = -0.04$, $V53d = -0.01$, $V54 = -0.01$. 
6.3.2 Discussion of status hypothesis

In the Western Isles no evidence was found to support the status hypothesis, which predicted that the sheep from the broch site of Dun Vulan would be larger, on average, than those from the wheelhouse sites examined. On the contrary, the Dun Vulan sheep were seen to be significantly smaller on average than those from the wheelhouse site of Cnip. This was particularly surprising as McCormick (2006) noted, in his archaeozoological analysis of the Cnip assemblage, the small size of cattle at Cnip compared to those at Dun Vulan (and Howe in Orkney). He attributes this to the poor availability of grazing near to Cnip, which he describes as a ‘very limited area of machair and Lewisian black earth, a fertile mixture of peat and shell sand, which is suitable for the production of grass, but it seems likely that much of this land would have been reserved for tillage’ (ibid.: 166). Dun Vulan on the other hand is located along the main part of the machair belt that runs along the west coast of a large part of the Western Isles (see Section 4.2.1) and therefore should have had access to reasonable quantities of good quality grazing. Therefore McCormick’s (ibid.) assumption about the small size of the Cnip cattle seems to make sense. However the data for sheep presented above appear to contradict McCormick’s findings for cattle.

The supposition that the Cnip cattle were smaller than those found at Dun Vulan was based on four metatarsal GL measurements, two from each site. There is c. 15-20mm difference between these metatarsal lengths from the two sites, which may easily be accounted for by those from Dun Vulan being from castrates and those from Cnip being from cows or possibly bulls. It is also difficult to determine what phases these
bones came from and if they are indeed from directly comparable time-frames. The majority of the cattle bone measurement data for Dun Vulan came from the ‘platform’ which dates to the 2\textsuperscript{nd}-6\textsuperscript{th} centuries AD (see table 5.1); later than the time period being examined here for sheep. A brief examination of the small quantity of metatarsal breadth measurements available for the two sites shows them to be broadly comparable. Therefore from the available data there appears to be little compelling evidence for larger cattle size at Dun Vulan over Cnip and therefore there is not necessarily a contradiction between the cattle and sheep data.

This does not however answer the question as to why the sheep from Cnip are, on average, larger than those from Dun Vulan. One possible reason is a difference in the balance of males and females at the sites, with potentially more males present at the site of Cnip. If this were the case, the greatest differences between the two sites should be visible in the metapodial measurements, as these are the most sexually dimorphic bones present in this analysis. However this is not the case, in fact there is less apparent difference in metapodial measurements than observed for some other measurements.

Another possible explanation is that local environmental conditions, for example the amount of shelter for vegetation from wind and salt water, were such that better quality grazing was available at Cnip than at Dun Vulan, although it appears overall that Dun Vulan should have had access to the greater quantity of pasture. Other research has shown that changes in vegetation type - not necessarily quantity - can affect bone size in grazing mammals (Lewis et al. 2010). Detailed study of the
vegetation, soils and topography of the site hinterlands would be required to examine this proposal more thoroughly. Somewhat related to this and possibly a more likely explanation is a return to the subject of latitude (see Sections 3.4.3 & 6.2). At the relatively southerly latitudes of the Western Isles animals should increase in size with increasing latitude (Geist 1987). The question is whether the c. 1° increase in latitude between Dun Vulan and Cnip would be sufficient to produce the increase in size observed or whether there are further factors such as variations in husbandry methods at play.

For the two sites examined in Iceland, Hofstaðir and Sveigakot, very little difference was seen between the two sites in the majority of sheep bone measurements, with the exception of the shape of the metacarpals. Those from Sveigakot were on the whole found to be more robust than those from Hofstaðir and it was thought that these more robust animals were potentially better nourished that those of a more slight conformation, which if true would contradict the proposed hypothesis.

One possible explanation for the presence of these potentially better nourished animals at the lower status site of Sveigakot is the difference in date ranges covered by the two sites. Sveigakot was occupied from the beginning of the settlement period, from c. 875AD, with settlement continuing through to c. 1000AD. At Hofstaðir, occupation began somewhat later at c. 940AD and continued until 1050AD for the particular deposits examined here, although there is still a farm present in this area today (McGovern et al. 2007.) It may be that the more robust sheep metacarpals present at Sveigakot belong to the earlier period of occupation when
land degradation was much less pronounced than subsequently (Simpson et al. 2004). One other possible explanation is variation in the sexes represented at the two sites. It is possible that there was a greater representation of more robust males at Sveigokot and a preponderance of more slender females at Hofstaðir. However, further examination of the scatterplot shows other groupings that may represent males, females and castrates at both sites (see annotations on figure 6.30). Castrates are potentially represented by a few particularly tall individuals, with GL values over 130mm. The remaining measurements then appear to fall into two groups, which are particularly distinct for Hofstaðir and slightly less so for Sveigakot. These represent short slight animals, likely females and taller more robust animals, likely males. The latter group may include a mix of rams and wethers. Whatever the reason for the difference in shape of sheep metacarpals between Hofstaðir and Sveigakot, it does not appear that in this case the hypothesis regarding status can be upheld.

In the case of Greenland there was also very little to suggest that the animals from the higher status site of V51 were any larger than those from the lower status sites, and in some cases they were found to be smaller. It would seem that even if the inhabitants of V51 did have access to greater quantities of land and subsequently more high quality pasture, they were likely to keep a greater number of animals on this land, thus preventing them from growing significantly larger than those at lower status sites. Examination of cattle to caprine ratios and estimated pasture area data given by McGovern (1985: tables 7 & 14) shows the cattle to caprine ratio at V51 to be 2.56 times higher than at V53c; whereas the estimated pasture available is only 2.33 times higher. This would appear to indicate that the stocking density of cattle
was greater at the higher status site of V51 than at the lower status site of V53c, hence preventing the cattle growing notably larger than at the lower status site. In terms of risk management this would appear to make sense as having a greater number of smaller cattle is a lower risk strategy than maintaining just a few large cattle.

Analysis of the sheep/goat data showed that animals from the high status site of V51 had a significantly smaller mean log value than those from V48; additionally, there were a few particularly small bone dimensions present for V51 (see figure 6.31). One possible explanation for the presence of these surprisingly small animals at this high status site may be the payment of tithes or taxes. If payment of such dues were to be made to the church at V51 of, for example, one sheep per annum then it seems plausible that the farmers at the low status sites would be likely to send their poorest animal in payment and keep the better conformed animals for themselves, thus resulting in a selection of smaller animals being present at the high status farm.

Overall the status hypothesis cannot be upheld: there is no evidence to suggest that animals at high status farms were of a larger build than those at lower status farms, and in some cases it appears the opposite is true. A variety of reasons for the observed differences have been offered, the majority of which are environmentally based, however other more human, social factors have also been considered, notably the gifting of animals as tithes or taxes from the lower status farms to those of higher status, resulting in the presence of smaller animals at higher status farms. Additionally, the likelihood of higher stocking densities at sites where a greater
quantity of land is available has been postulated for Greenland; however, this may equally be applied to the sites from other regions.

### 6.4 Agricultural Intensification Hypothesis

The intensification hypothesis states that during the Iron Age, particularly the Later Middle Iron Age (LMIA) and the Late Iron Age (Pictish period), intensification of agricultural practices, such as increased dairying and the introduction of new crops, will be apparent in bone measurement data. That is to say there will be an increase in bone size at this time due to increased levels of nutrition brought about by improvements in animal husbandry such as the increased production of fodder. Therefore it is predicted that in the Northern and Western Isles, during the later part of the Iron Age, domestic mammal bone size will increase.

To examine this hypothesis sheep bone measurements from five sites were analysed. As mentioned above for the Status Hypothesis during the Iron Age in the Western and Northern Isles no goat bones are positively identified and therefore it is assumed that all ovicaprine bones belong to sheep. From the Western Isles the sites of Sollas, Dun Vulan and Udal were examined, for locations see figure 5.1. The two periods covered for Sollas are deposits from Wheelhouse A dated to the 1\textsuperscript{st} century AD or possibly earlier (MIA) and deposits from the later Wheelhouse B, dated to the 1\textsuperscript{st} or 2\textsuperscript{nd} century AD (LMIA). Two assemblages are analysed for Dun Vulan, the midden adjacent to the Broch dated to the 1\textsuperscript{st}-4\textsuperscript{th} centuries AD and the ‘platform’ dated to the 2\textsuperscript{nd}-6\textsuperscript{th} centuries AD. For Udal the time period covered is slightly earlier, looking at the later 1\textsuperscript{st} millennium BC and the 1\textsuperscript{st} century AD. In Orkney the site of Howe is
examined and again two time periods are compared; bones from Phase 7 dating to the 1st-4th centuries AD (LMIA) and those from Phase 8 dating to the 4th-7th centuries AD (LIA). Finally from Shetland bone measurements from Old Scatness were examined from three phases: bones from Phase 5 dating to the 2nd-1st centuries BC (MIA); those from Phase 6 dating to the 1st-4th centuries AD (LMIA); and those from Phase 7 dating to the 5th-9th/10th centuries AD (Pictish or LIA).

6.4.1 Results for agricultural intensification hypothesis

Sollas

For the astragalus (figures 6.33 & 6.34) only one bone was available from the later deposits, and this plotted at the top end of the range for those from the Middle Iron Age. More data were available for the metacarpals: the histograms of length and shaft breadth (figures 6.35 & 6.36) show that those from the later period cover the larger end of the range. However, the sample for the earlier deposits is small and overlaps with the later bones at the lower end of the range. Examination of a scatterplot of these data (figure 6.37) however shows total separation of the two assemblages; those from the later Wheelhouse B being larger than those from Wheelhouse A. Examination of the metatarsal data, where again the sample sizes are small, does not show the same pattern of size increase (figures 6.38-6.40); here no real discernable difference is detected between the two assemblages. Examination of histograms for tibia Bd (figure 6.41) and humerus BT (figure 6.42) also give no indication of a size increase between the two assemblages. Overall, these data suggest a possible size increase visible in the metacarpals and maybe the astragalus; however the datasets are extremely small.
Figure 6.33 Histogram of greatest length of the astragalus for sheep from Sollas, Western Isles.

Figure 6.34 Histogram of distal breadth of the astragalus for sheep from Sollas, Western Isles.
Figure 6.35 Histogram of greatest length of the metacarpal for sheep from Sollas, Western Isles.

Figure 6.36 Histogram of shaft breadth of the metacarpal for sheep from Sollas, Western Isles.
Figure 6.37 Scatterplot of greatest length versus shaft breadth of the metacarpal for sheep from Sollas, Western Isles.

Figure 6.38 Histogram of greatest length of the metatarsal for sheep from Sollas, Western Isles.
Figure 6.39 Histogram of shaft breadth of the metatarsal for sheep from Sollas, Western Isles.

Figure 6.40 Scatterplot of greatest length versus shaft breadth of the metatarsal for sheep from Sollas, Western Isles.
Figure 6.41 Histogram of distal breadth of the tibia for sheep from Sollas, Western Isles.

Figure 6.42 Histogram of breadth of the trochlea of the humerus for sheep from Sollas, Western Isles.
Dun Vulan

As for Sollas, samples from Dun Vulan, particularly for the earlier assemblage (1\textsuperscript{st}-4\textsuperscript{th} century AD), are small. Additionally only four bone dimensions were available in quantities of a size to make analysis worthwhile. The histogram for sheep astragalus GL1 (figure 6.43) shows that the bones from the later deposits (2\textsuperscript{nd}-6\textsuperscript{th} C. AD) fall at a slightly higher range than those from the earlier deposits; however there is total overlap between the two assemblages and an independent samples, two-tailed t-test found there to be no significant difference between the two assemblages (t=-1.831, df=37, p=0.075). For tibia Bd (figure 6.44), although again there is overlap between the two assemblages, the upper end of the range is dominated by the later assemblage and the lower end by the earlier assemblage and here a t-test showed there to be a significant difference between the two assemblages (t=-2.827, df=20, p=0.010). The picture for humerus BT (figure 6.45) is more difficult to comment upon as there are only two measurements for the earlier deposits and these fall fairly centrally to the range for the later deposits. A similar picture is presented by the radius Bp data (figure 6.46).

The samples from Dun Vulan are small and the ranges of measurements overlap considerably, which is not surprising given the potential overlap in dates for the two assemblages. However there does appear to be a slight tendency towards larger bones in the later deposits and small bones in the earlier deposits, particularly notable in the tibia, which would lend support to the agricultural intensification hypothesis.
Figure 6.43 Histogram of greatest length of the astragalus for sheep from Dun Vulan, Western Isles.

Figure 6.44 Histogram of distal breadth of the tibia for sheep from Dun Vulan, Western Isles.
Figure 6.45 Histogram of breadth of the trochlea of the humerus for sheep from Dun Vulan, Western Isles.

Figure 6.46 Histogram of proximal breadth of the radius for sheep from Dun Vulan, Western Isles.
Samples from Udal cover a slightly earlier time frame than the other Western Isles sites and essentially examine any changes that may have occurred over the BC-AD boundary. The samples from Udal are considerably larger than those from the other Western Isles sites and make for a more robust data set.

The first element examined, the astragalus (figures 6.47 & 6.48) shows no apparent difference between the assemblage from the Later 1st millennium BC and that from the 1st century AD in either GLl or Bd measurements, the means are also almost identical for the two samples. Phalanx 1 data (figures 6.49 & 6.50) show the same picture as for the astragalus, with no discernable difference between the two assemblages in either the dispersion of data or mean values; the same story is repeated for radius Bp (figure 6.51). From these measurements it seems that there was no change in sheep bone size between the end of the 1st millennium BC and the 1st century AD. However a slightly different picture is seen when looking at data for the metapodials.

Data for metacarpal GL and SD is shown in figure 6.52-6.54. For the 1st century AD deposits, metacarpals are on average slightly longer than those from the earlier deposits; however, the ranges are very similar. SD measurements are conversely smaller on average in the 1st century AD deposits than in the earlier deposits, with the two samples having overlapping but slightly different ranges. When these data are plotted in a scatterplot a clear shape difference is seen. The majority of the 1st century AD bones are relatively long and slender whereas those from the earlier
deposits are shorter and more robust. Examination of the metatarsal data (figures 6.55-6.57) shows an even more exaggerated version of this pattern, with the increase in lengths being even greater. T-tests of metapodial measurements shows there to be a significant difference between metacarpal SD measurements from the two time periods (t=-5.137, df=16, p=0.00), but not for GL measurements (t=0.594, df=15, p=0.561). For metatarsal measurements the difference in GL was found to be significant (t=3.152, df=19, p=0.005) and that of SD not (t=-1.687, df=22, p=0.106).

Given that there is no apparent change in size of astragali, phalanges or radii, yet there was a lengthening and narrowing of the metapodials, it is suggested that at this time there was no increase in nutrition, but instead a possible change in husbandry practices with an increased emphasis on castrates in the 1st century AD, compared to the later 1st millennium BC. It is not surprising that no evidence of an overall increase in bone size was found for Udal, as the time period examined was earlier than the period of proposed increased fodder production evidenced by the introduction of new crop plants.
Figure 6.47 Histogram of greatest length of the astragalus for sheep from Udal, Western Isles.

Figure 6.48 Histogram of distal breadth of the astragalus for sheep from Udal, Western Isles.
Figure 6.49 Histogram of greatest length of the phalanx 1 for sheep from Udal, Western Isles.

Figure 6.50 Histogram of proximal breadth of the phalanx 1 for sheep from Udal, Western Isles.
Figure 6.51 Histogram of proximal breadth of the radius for sheep from Udal, Western Isles.

Figure 6.52 Histogram of greatest length of the metacarpal for sheep from Udal, Western Isles.
Figure 6.53 Histogram of shaft breadth of the metacarpal for sheep from Udal, Western Isles.

Figure 6.54 Scatterplot of greatest length versus shaft breadth of the metacarpal for sheep from Udal, Western Isles.
Figure 6.55 Histogram of greatest length of the metatarsal for sheep from Udal, Western Isles.

Figure 6.56 Histogram of shaft breadth of the metatarsal for sheep from Udal, Western Isles.
Figure 6.57 Scatterplot of greatest length versus shaft breadth of the metatarsal for sheep from Udal, Western Isles.

**Howe**

Samples from Howe are mostly of a reasonable size and are comparable to those from Udal. The time periods examined are the Later Middle Iron Age and the Late Iron Age (Pictish period). Sheep astragalus data, shown in figures 6.58-6.60, indicate a slight size increase between the two periods. There is a great deal of overlap between the two, but the top ends of the ranges are exclusively occupied by bones from the Late Iron Age and the bottom end of the range by those from the Later Middle Iron Age. The scatterplot indicates that there may be a very slight change in shape towards a more robust form. Independent samples, two tailed t-tests indicate a significant difference in astragalus Bd (t=2.132, df=120, p=0.035), but not in astragalus GLl (t=0.962, df=120, p=0.338).
Tibia Bd measurements (figure 6.61) also indicate a very slight size increase between the two periods being examined with a very similar picture to the astragali measurements being presented. However, a t-test did not find a significant difference between the two groups (t=-0.356, df=33, p=0.724). Phalanx 1 measurement data (figure 6.62-6.64) for both length and breadth also show a very similar pattern with large overlap in distribution of measurements but the largest bones all belonging to the later deposits. T-tests confirmed significant differences between both GLpe (t=3.161, df=163, p=0.002) and Bp (t=2.710, df=176, p=0.007) datasets. The scatterplot of length versus breadth measurements does not show the slight increase in robustness indicated for the astragalus, however the case for phalanges is complicated by differences between the fore and hind limbs that cannot be accounted for here.

Measurements of humerus BT (figure 6.65) do not show as clear cut a pattern as the bones described above. The mean for the Late Iron Age is very slightly larger, but other than this there is no obvious difference between the two data sets. Radius length and breadth measurements (figure 6.66 & 6.67) also show no discernable difference between the two assemblages. Likewise metacarpal SD measurements (figure 6.68) show very little difference; the mean is very slightly larger for the Late Iron Age but the largest bone comes from the earlier deposits and the smallest from the later deposits. Alternatively, metatarsal data (6.69) indicate that shaft breadth became reduced over the time period in question: the difference in metatarsal SD between the two phases was shown to be significant (t=-3.868, df=19, p=0.001).
Overall for the site of Howe there does appear to be some indication of a slight size increase in sheep between the Later Middle Iron Age and the Late Iron Age, although this is restricted to certain bones: the astragalus, tibia and phalanx 1 from those examined here. These changes are not reflected in the humerus, radius or metacarpal dimensions examined and the metatarsal shaft width appears to decrease.

If there was a slight improvement, and given the possible changes observed the changes would only have been slight, it is possible that not all bones were affected equally and that some would experience an increase in size with an increase in nutrition whilst others would not. This will be discussed further below.
Figure 6.58 Histogram of greatest length of the astragalus for sheep from Howe, Orkney.

Figure 6.59 Histogram of distal breadth of the astragalus for sheep from Howe, Orkney.
Figure 6.60 Scatterplot of greatest length versus distal breadth of the astragalus for sheep from Howe, Orkney.

Figure 6.61 Histogram of distal breadth of the tibia for sheep from Howe, Orkney.
Figure 6.62 Histogram of greatest length of the phalanx 1 for sheep from Howe, Orkney.

Figure 6.63 Histogram of proximal breadth of the phalanx 1 for sheep from Howe, Orkney.
Figure 6.64 Scatterplot of greatest length versus proximal breadth of the phalanx 1 for sheep from Howe, Orkney.

Figure 6.65 Histogram of breadth of the trochlea of the humerus for sheep from Howe, Orkney.
Figure 6.66 Histogram of greatest length of the radius for sheep from Howe, Orkney.

Figure 6.67 Histogram of proximal breadth of the radius for sheep from Howe, Orkney.
Figure 6.68 Histogram of shaft breadth of the metacarpal for sheep from Howe, Orkney.

Figure 6.69 Histogram of shaft breadth of the metatarsal for sheep from Howe, Orkney.
Old Scatness

Three time periods were examined for Old Scatness: Middle Iron Age, Later Middle Iron Age and Pictish (Late Iron Age) and, as for many of the other sites, the sample sizes were small. It has been previously postulated (Cussans 2006) that there was an increase in sheep bone size between the Middle Iron Age and the Later Middle Iron Age at Old Scatness and, as the hypothesis states, it was thought likely that this was due to intensification in agricultural practices at this time. This proposal was based almost entirely on changes observed in tibia Bd measurements (figure 6.70) which do appear to show the presence of larger bones in the Later Middle Iron Age than in the Middle Iron Age, as ever the sample sizes are small. Analysis of data for the astragalus (figure 6.71 & 6.72), which is more numerous, does not appear to show any difference between the Middle Iron Age and Later Middle Iron Age. The scatterplot of sheep astragalus length versus breadth (figure 6.73) does seem to show distinct groupings relating to phase, with the majority of Later Middle Iron Age astragali being larger than the majority of Middle Iron Age astragali, although the ranges do almost entirely overlap. It is also of note that two of the three bones plotted for the Pictish period are at the largest end of the point scatter; the third however plots in the smallest part of the graph.

Examination of sheep phalanx 1 data (figures 6.74 & 6.75) shows the means for length and breadth to be slightly larger for the Later Middle Iron Age than the Middle Iron Age; however the ranges entirely overlap for Bp and almost entirely overlap for GLpe. Once again a single Pictish bone is found at the large end of the range. The sample for radii (figure 6.76) is again very small and has a slight indication of larger
size in the Later Middle Iron Age with a larger mean: but as ever, considerable overlap between the ranges. The single Pictish measurement is located in the middle of the range. The sample for humerus BT (figure 6.77) is also very small and the single specimen for the Later Middle Iron Age falls below all of those for the Middle Iron Age.

Overall for Old Scatness there is little compelling evidence for a size increase in sheep during the later part of the Iron Age, however there are occasional hints that this may be the case. Without a larger dataset no firm conclusions can be made.
Figure 6.70 Histogram of distal breadth of the tibia for sheep from Old Scatness, Shetland.

Figure 6.71 Histogram of greatest length of the astragalus for sheep from Old Scatness, Shetland.
Figure 6.72 Histogram of distal breadth of the astragalus for sheep from Old Scatness, Shetland.

Figure 6.73 Scatterplot of greatest length versus distal breadth of the astragalus for sheep from Old Scatness, Shetland.
Figure 6.74 Histogram of greatest length of the phalanx 1 for sheep from Old Scatness, Shetland.

Figure 6.75 Histogram of distal breadth of the phalanx 1 for sheep from Old Scatness, Shetland.
Figure 6.76 Histogram of proximal breadth of the radius for sheep from Old Scatness, Shetland.

Figure 6.77 Histogram of breadth of the trochlea of the humerus for sheep from Old Scatness, Shetland.
6.4.2 Discussion of agricultural intensification hypothesis

In the Northern and Western Isles there is evidence for an increase in sheep bone size for some dimensions at some sites. These increases appear to happen some time after the 1st century AD and possibly continue into the Late Iron Age or Pictish period. It is felt that the most likely explanation for these size increases would be an increase in available nutrition, either through improvements in the quality of pasture land or through the introduction of new crops and the greater availability of fodder. Improvements in the quality of pasture land are a possibility as there is evidence for climatic amelioration during the early centuries AD (Butler 1998), but this did not continue into the Late Iron Age, when there are apparent continued size increases in sheep bones. It is possible however that climatic amelioration was one of a number of factors that prompted or allowed the introduction of new crops. Once introduced, crops such as oats would have improved the availability of winter fodder and helped keep more stock in better condition over the winter months, thus allowing them to grow larger.

A particularly intriguing question is why not all of the bones examined appeared to be affected, i.e. size increases were evident in some dimensions and less so or not at all in others. The dimensions that appear to show the greatest changes in size over time seem to be those of the lower limb, astragalus, metapodials, phalanges and tibia Bd, whereas little difference was observed in radius Bp or Humerus BT. Referring back to Section 3.5.2 this may indicate that the timing of any improvement in nutrition may have been early on in the life of the sheep as this is when the bones the feet and lower limbs accomplish a larger part of their growth, while other bones
higher up the limbs mature later on. Earlier this was referred to as a wave of maturation. This may indicate that any extra nutrition gained was during the time of foetal and neonatal growth, i.e. through nutrition provided via the ewe mother. This would fit particularly well with the hypothesis for the provision of extra fodder which may be given preferentially to pregnant livestock over the winter months to ensure higher survivorship of lambs in the spring. If this were true, size increases should also be evident in elements of the skull which is also one of the first body parts to develop as discussed in Section 3.5.2. Unfortunately no measurement data from skull elements is available in the current dataset.

The sheep from Udal are an interesting case in that they show no evidence of a slight size increase, unlike the other sites. As already mentioned this is thought likely to be due to the earlier dates of these deposits and essentially further attests to these changes in size only occurring after the 1st century AD. Other changes in animal husbandry do appear to have taken place at this site however, with the likely increased appearance of castrates in the 1st century AD.

Other possible reasons for the slight size increases noted at the majority of sites examined should also be considered. A change in emphasis from female to male animals is one possibility. A change from ewes to castrates appears to be present at Udal, but this pattern is not repeated at the other sites and a change from ewes to rams seems highly unlikely and most likely to manifest itself in an increase in metapodial robustness rather than in astragalus dimensions or tibia Bd which demonstrate low levels of sexual dimorphism in sheep (Davis 2000). It is also possible
that larger animals were being consciously selected for through control of ewe-ram pairings. In this case, one may expect to find a more dramatic increase in size, possibly affecting all bones examined. If sheep were being selected for larger size it is likely that the reason for this would be to increase meat yield. In this case, it would be expected that increases in the size of upper limb bones would also be present and may be greater than those of the lower limb. Alternatively the provision of extra fodder may have simply been a means to ensure greater survivorship through the winter, with an unintentional side effect of slightly increased bone size.

6.5 LAND DEGRADATION HYPOTHESIS

This hypothesis is split into two parts. The overall hypothesis states that as environmental conditions become poorer, for example, through a shortened growing season or a reduction of land available for grazing, livestock animals will become smaller. This should be particularly manifested in breadth measurements which are preferentially diminished over length measurements through poor nutrition. The test of this first part of the hypothesis looks at the deteriorating climatic conditions in the Norse Greenland settlement, which occurred with the onset of the Little Ice Age, and appear partly responsible for the abandonment of the settlement at some point in the 15th century. According to the hypothesis, livestock bone size should diminish over the time of the settlement, particularly towards the very end of the occupation when climatic conditions were at their poorest. Two sites were examined for this part of the hypothesis, Gården under Sandet (GUS) in the Western Settlement and Ø34 in the Eastern Settlement; which were the only sites that provided sufficient time
depth. The majority of other Norse Greenland sites included in this study only had bones available from later deposits.

The second half of the hypothesis looks at landscape degradation in Iceland. The sequence of landscape degradation and soil erosion in Iceland, largely brought about by the impact of human activity, in particular the introduction of grazing mammals, is discussed in Section 4.6.4. The amount of available grazing land would appear to have been dramatically reduced over time, with Edvardsson et al. (2004) noting that the 18th century was a time of particular hardship in Iceland with poor climate and landscape degradation making farming conditions particularly difficult. Therefore this part of the hypothesis it is predicted that bones from the 18th century will be smaller than those from earlier deposits.

As no one site with sufficiently fine phasing of bone measurement data was available, it was decided to examine two closely located sites with bone material relating to different time periods. For this reason the sites of Gásir and Móðruvellir, located in Eyjafjord at 65°51’N, were selected. Both sites are high status, Gásir being a trading site and Móðruvellir a church farm (Harrison & Roberts 2010). The deposits from Gásir date to the mid 13th to early 15th century and although as a trading site it is likely that animals were brought into the site and not necessarily raised there (as mentioned in Section 6.2) the excavators believe it most likely that many of these animals came from the nearby site of Móðruvellir which was a church farm from the 1150s onwards (ibid.). The bone material being examined from Móðruvellir itself dates from the 16th to 18th centuries AD. It is felt that given their close proximity and
the likelihood of many of the Gásir bones having originated from Möðruvellir that these two assemblages should be comparable and that the main determining factor in bone size will be environmental degradation.

6.5.1 Results for land degradation hypothesis

Greenland

The first site examined in Greenland is the Western Settlement site of Gården under Sandet (GUS). From here sheep and goat bone measurements were examined across the three phases of the site (see table 5.1); bones designated sheep/goat were not included for reasons that will become clear. Great effort was made during the original archaeozoological analysis to distinguish sheep from goat where possible (Enghoff 2003) and therefore it is felt that the identifications are fairly reliable.

The first analysis made was an examination of mean measurements of dimensions of the astragalus (GLl, GLm, DL, Bd), shown in figure 6.78. The figure illustrates both sheep and goat measurements and highlights a distinct difference between the two assemblages. Sheep astragalus measurements increase in size between Phase 1 and 2 and then decrease again between Phases 2 and 3. This appears to fit reasonably well with the hypothesis. An increase in size following settlement may well be due to the mild climate and expansion of grassland with the removal of wood and shrub land, bone size being reduced again as climate deteriorates in the later part of the settlement.
The measurements for goats however give a very different picture. These show a decrease in bone size between the first two phases and then very little change in the last phase. There are a number of possible reasons why the size changes observed differ between sheep and goat and these will be discussed more fully below. However, it seems that the most likely reason for this difference is the change in vegetation occurring after settlement. As mentioned above, the main change that took place was the clearance of wood and shrub land (possibly greatly assisted by the presence of goats) and the expansion of grasslands. This would result in an increase in food availability for grazing sheep and a concurrent decrease in food availability for browsing goats.

Following the analysis of the astragalus means, a broader view of changes in sheep bone size was required. To achieve this, given the small sample sizes of the other bone dimensions available, a log-ratio analysis of all available measurements was employed. This served to increase sample size and allow better comparability between phases. Due to the differential effects of poor nutrition on bone breadth and length two figures were constructed to allow length and breadth dimensions to be examined separately. Log ratio values for bone lengths are shown in figure 6.79 and mean log values for each phase are indicated. The data here appear to agree well with those presented for sheep astragalus alone, showing an overall increase in length and then a mean decrease in the final phase, although some larger animals are still present. Figure 6.80 shows the log values for the breadth measurements and presents some rather surprising data. Once again the mean log values for each phase are marked, but here, unlike for the length data, the means are all the same. The
spread of log values for breadth measurements are also almost identical. The log-ratio values therefore indicate that overall there are changes in bone length but no apparent changes in bone breadth. However it must be borne in mind that the log-ratios derive from a variety of different bone elements that show differing reactions to environmental changes. As there is a change in bone length and not apparently in bone breadth it would seem that the GUS sheep bones were being affected by a more complex set of factors (not surprisingly) than a change in nutritional level alone.

This is examined more closely in a more detailed investigation of sheep astragalus dimensions. Figure 6.81 is a scatterplot of astragalus length versus breadth and shows distinct differences between the three phases; annotations have been added with proposed theories for the changes in size and shape observed. There appears to be an overall size increase between Phase 1 and Phase 2, as noted above, which is postulated to be the result of improved nutrition. The astragali for Phase 3 have a much more dispersed distribution and it is proposed that the cause of this may be twofold. Overall the Phase 3 astragali are shorter than the majority of those from the previous two phases. It is proposed that the reduction in bone length seen here and in the log-ratio diagram (figure 6.79) is not necessarily related to a reduction in nutritional intake but rather more directly a result of a drop in temperature. Allen’s rule, discussed in Section 3.4.1, states that animals raised at lower temperatures will be shorter limbed than those of the same taxa or species raised at higher temperatures. This is a heat saving mechanism designed to reduce body surface area over which heat can be lost.
Further examination of the astragalus scatterplot shows that three of the data points have breadths within the range of Phase 2 measurements and the other three have much lower values, similar to Phase 1 and smaller. It is proposed that these particularly small specimens come from the very latest period of occupation when decreasing nutrition starts to take effect on bone size. However, the fine stratigraphic detail needed to substantiate this is not currently available. Subsequent to this data analysis the following sequence is proposed for changes in sheep skeletal growth. After settlement, grassland increases and sheep grow larger given the greater quantity of food resources. As the climate deteriorates and temperatures drop, sheep limb length decreases to conserve body heat. Climatic deterioration also leads to a decrease in quality and quantity of pasture land and sheep from the latest period of occupation cannot grow to the same size as their predecessors.

As mentioned above, the size changes observed in goats were quite different to those seen in sheep. To illustrate this further a scatterplot of goat astragalus length and breadth measurements (figure 6.82) was also made. This again shows the decrease in size between Phase 1 and 2 and the similar size of the Phase 2 and 3 animals. One exception is a very small astragalus plotting in the bottom left hand corner of the graph; it seems likely that this maybe a mis-identified sheep astragalus as it would be well placed with the other Phase 3 sheep astragalus plots. This figure does serve to further illustrate that the size changes taking place in goats are quite different to those taking place in sheep.
A second site in Greenland was briefly examined; that of Ø34 in the Eastern Settlement. The only archaeological excavation carried out at this site to date was that of a midden deposit next to the farm buildings. Although no specific site phasing is currently available and the midden itself is yet to be dated it was thought feasible to carry out some preliminary analysis on the bone measurement data. Evidence for, and dating of, peat cutting activity from pollen analyses at the site indicates that the farm was likely occupied for the duration of the Norse settlement of Greenland (Schofield et al. 2008). Additionally, although not phased, the midden was excavated in spits and here these spits were used as analytical units, assuming (it should be noted here that this is the assumption of the present author, confirmation from the excavator is still pending) that the lower spits relate to earlier in the occupation and higher spits relate to later in the occupation. Following these assumptions, tibia distal breadth measurements were examined and a box-and-whisker plot of these data is shown in figure 6.83. This figure does seem to indicate that during the later period of midden formation, the sheep become reduced in size. If the author’s assumptions regarding the phasing and dating of this midden could be substantiated, this data would support the environmental degradation hypothesis.
Figure 6.78 Line graph showing mean sheep and goat astragalus dimensions from GUS, Western Settlement, Greenland. Sheep Phase 1 n=5 (except for GLI n=4), Phase 2 n=4, Phase 3 n=6; Goats Phase 1 n=3, Phase 2 n=4, Phase 3 n=7.

Figure 6.79 Log-ratio values for sheep bone length dimensions from GUS, Western Settlement, Greenland. Mean values are marked with arrows.
Figure 6.80 Log-ratio values for sheep bone breadth dimensions from GUS, Western Settlement, Greenland. Mean values are marked with arrows.

Figure 6.81 Scatterplot of sheep astragalus greatest length versus distal breadth for GUS, Western Settlement, Greenland.
Figure 6.82 Scatterplot of goat astragalus greatest length versus distal breadth for GUS, Western Settlement, Greenland.

Figure 6.83 Boxplot of sheep tibia distal breadth for Ø34, Eastern Settlement, Greenland.
Although sample sizes for Gásir and Möðruvellir were of a reasonable size, at least for bones designated as sheep/goat, instances where measurements of the same bone dimension were present at both sites were rare. For this reason the log-ratio method was again employed. The use of bones identified as sheep/goat is made with some reluctance here, given the clear differences observed between the two species shown at GUS in Greenland. However, the sample sizes for bones identified to species level (sheep, goat or cattle) were extremely small with the exception of sheep metapodials for which a small number of specimens were available and were employed in this part of the study. Very few length measurements were available for the sheep/goat log-ratio analysis and therefore all values were plotted on a single graph for each site; the standard used is the group of Soay males (see table 5.3).

The spread of values (figure 6.84) is quite wide for both sites, particularly when compared to the figures (6.79 & 6.80) for sheep measurements from GUS. This would tend to indicate the presence of both sheep and goats. The majority of values for Gásir sit around or above the zero mark indicating that the majority of the dimensions are larger than those of the standard, although a couple of particularly small dimensions are also present. The data for Möðruvellir are more evenly spread around the zero mark with a larger number of smaller values being present than for Gásir. This would tend to support the hypothesis that during this period animals would be smaller than those from the earlier period found at Gásir. However, a closer look at the data is necessary. The dataset available for log-ratio analysis from
Möðruvellir was made up almost entirely from dimensions of the metapodials plus a few from the tibia. Conversely very few of the log-ratio values from Gásir derive from metapodia, the majority coming from a variety of other elements. Given the use of the log-ratio method this should not necessarily be an issue of concern, however an interesting observation was made for the Möðruvellir data that could mean the lack of metapodial data from Gásir is important here.

When performing the log-ratio analysis it was noted that the majority of the negative log-ratio values for Möðruvellir came from metapodia SD measurements. This was particularly intriguing, as other breadth measurements (Bp & Bd) from the same bones had positive log-ratio values. This would indicate that either these bones were from goats and hence of different proportions to the Soay sheep standard, or that they were sheep bones but of a different overall shape to the Soay standard, i.e. narrower in the shaft and broader in the epiphyses. In order to examine this further, the few positively identified sheep metapodia available were also analysed through the log-ratio method. The results are shown in figure 6.85 and are annotated showing the location of the SD measurements. Three SD measurements were available for Möðruvellir, two of which had negative log-ratio values, demonstrating that some if not all of the metapodial SD measurements from the sheep/goat analysis are likely to have been from sheep. Only one SD measurement was available from Gásir and this falls at the top end of the range of SD measurements for Möðruvellir indicating that there is no evidence for sheep of a larger size being present during the earlier period compared to the later period.
Figure 6.84 Log-ratio values for sheep/goat bones from Gásir and Möðruvellir, Iceland.
6.5.2 Discussion of land degradation hypothesis

Results for the land degradation hypothesis are variable. Evidence from Greenland on the whole supports the hypothesis, whereas that from Iceland does not. Changes in the size and shape of sheep bones observed for GUS in Greenland appear to be attributable to environmental factors, although decreasing nutrition alone cannot explain all of the variation. It seems likely that the direct effects of decreasing...
temperature may have also played a significant role, possibly as a precursor to decreasing levels of nutrition.

The differences seen between sheep and goats were particularly interesting. It is postulated that these were associated with the vegetation changes occurring after settlement that may have been favourable to sheep but not goats. Differences in husbandry of the two species may be an alternative or additional cause for the variation. This may relate to the animals being kept on different parts of the landscape, or being differently provisioned with winter fodder or shelter.

The results from Ø34 appear to support the proposed hypothesis, but as mentioned above, the interpretation of this data is based on a number of assumptions and until these can be affirmed as being correct or otherwise little discussion can be made of the data.

For the Iceland data overall no real difference was seen between the two time periods/sites. There are several possible reasons for this. Firstly, that there was no significant change in available vegetation between the two periods: it may be that there had been significant land degradation prior to the time period covered by the Gásir bones and that this had subsequently stabilised in the particular area under question, hence showing no size change between the two periods examined. This seems unlikely, as the 18th century is noted as a time of great hardship in Iceland (Edvardsson et al. 2004). However, one factor highlighted as particularly contributing to this hardship, in addition to the poor environmental conditions, is widespread
tenantry (ibid.). Both of the sites examined here are high status sites and it is highly unlikely that they would have been subjected to the same levels of hardship due to this as some other sites. Additionally, a high status site such as Möðruvellir is likely to have had access to a variety of resources that may have acted as buffers in times of hardship and careful management of these could have countered the effect of a deteriorating landscape. In relation to this, by this period in Icelandic history it is likely that farmers would have been well aware of the limitations of their landscape and, as mentioned in Section 4.6.4, laws were put into place to protect land from further degradation previous to the 18th century. Simpson et al. (2001) proposed that grazing lands were not overstocked during the historic period and that further land degradation only took place where poor shepherding allowed animals to graze vulnerable areas of land, or animals were not removed from summer pastures early enough at the end of the season. This suggests that land degradation would not have had as great an effect on livestock size as has been postulated in the hypothesis.

6.6 SUMMARY DISCUSSION

The four hypotheses discussed above provide insight into some aspects of Iron Age and Norse life in the lands around the North Atlantic. It is clear from this analysis that livestock bone size and shape is dependant on a variety of interacting variables, and if some of these can be drawn apart they can impart a great deal of information relating to environment and husbandry methods. This study has thus far almost entirely concentrated on the livestock species themselves and very little mention has been made of the human populations that cared for, managed and made a living
from them. It is to the humans we now turn as, after all, domestic livestock would not exist without them and their need for food and other products.

The results of the latitude hypothesis were interesting as it had been assumed, at least by the present author, if not by others, that the more northerly lands of the Faroe Islands, Iceland and Greenland presented a poorer prospect for making a living than those of, for example, the Northern Isles. The results of the latitude hypothesis however contradict this indicating that conditions for raising livestock were apparently more amenable in the north of Iceland and the Faroe Islands than in Shetland or Orkney, despite their higher latitudes. This places these islands in a new, more appealing light as places to settle and practice agriculture.

The status hypothesis also gave some interesting results and was not supported. Some of the suggested reasons for this have their roots in human behaviour. Modern livestock husbandry has a strong focus on the improvement of animal conformation, (see for example the work of Hammond (1932) and Pálsson and Vergés (1952a & b) discussed in Chapter 3) and it is perhaps odd to modern thinking to choose more livestock over ones which were well conformed. However from a dairying point of view and in terms of a low risk strategy (as mentioned above), this make sense, in that a larger number of livestock will produce more milk and the loss of a single animal is less devastating in a larger flock than a smaller one. The other socially pertinent proposal was that of taxes or tithes being paid using the stock in poorest condition. This too seems to make sense, if as a farmer one was obliged to give away a proportion of ones stock each year the most economically sensible way would be to
get rid of the weakest looking animals, thus keeping those that were better conformed or stronger for your own needs.

The economic intensification hypothesis appears to be supported, although the observed changes are small. From the evidence presented it does not seem that this was likely a conscious decision to improve meat yield, but possibly a by-product of the provision of extra fodder for pregnant ewes (and cows?) over winter, resulting in improved growth of the lower limbs of the unborn lambs. In this case it would be particularly interesting to also be able to examine changes in the size of head elements, as these should also respond to the provision of extra nutrition early on in the life cycle. If there were any improvement in meat yield in association with the perceived increase in bone size this may have had a considerable nutritional impact on the human inhabitants at the sites concerned. In situations of poor nutrition, skeletal growth is given precedence over the growth of other later maturing tissues, such as muscle and fat (Dickerson & McCance 1961). This would indicate that with improved nutrition (given at the right time) the percentage increase in the weight of soft, edible, tissues would be higher than the increase in bone weight. Going back to the quote from Adalsteinsson (1990) at the beginning of this chapter one can see that a small increase in bone size may make a considerable difference in the quantity of meat, fat and offal available from a single animal and hence could have a significant impact on the health and nutrition of the human inhabitants of a site.

On the alternative side of this we come to the environmental degradation hypothesis and although for the particular sites examined in Iceland the hypothesis could not be
upheld, the sites examined from Greenland did show evidence of size diminution over time. As mentioned above, in situations of poor nutrition skeletal growth is prioritised over growth of muscle and particularly fat. Therefore where there are noticeable decreases in bone size, an animal is likely to have very little fat reserves and poor muscle mass, resulting in an extremely poor carcass (Pálsson & Vergés 1952a) that has a much decreased nutritional value for the humans that slaughter it, compared to an animal of more robust conformation.

Overall it can be seen that a variety of size and shape changes have occurred over time and space in the North Atlantic region for a variety of reasons and that these would have had a direct effect on the human inhabitants. It is also clear that, especially given the large size of the collected dataset, a great deal more work is possible in this region. The following chapter examines some of these possibilities.