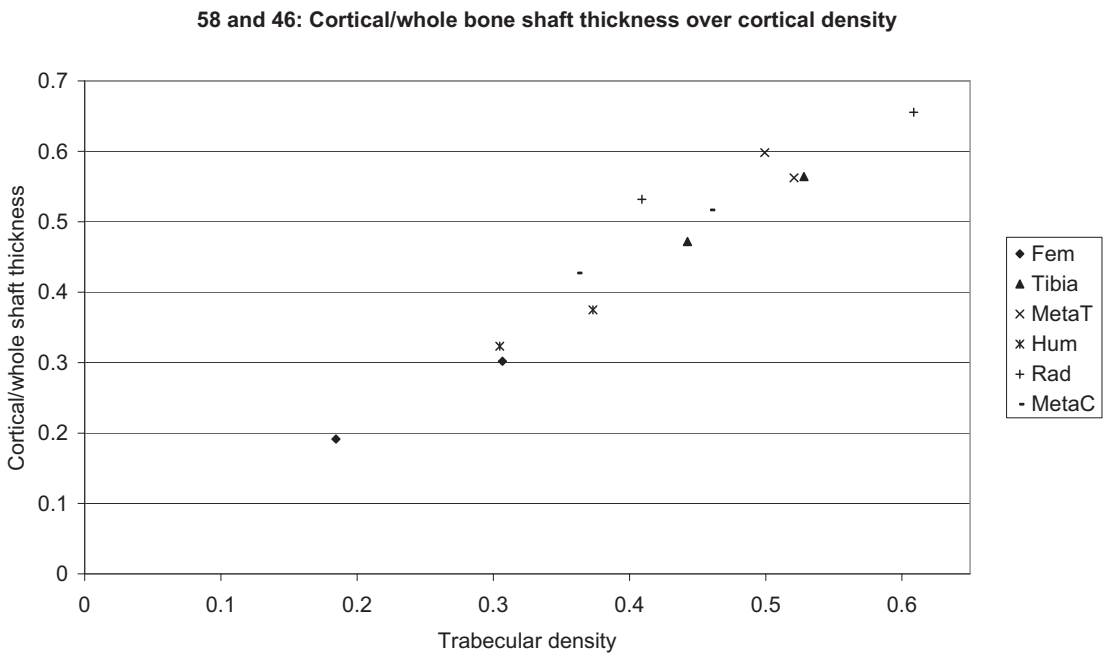

Figure 8.5: Showing the relationship between trabecular bone density and cortical thickness of animals number 58 and 46. The y-axis represents the cortical thickness of the shaft divided by the whole thickness of the shaft in order to overcome the effect of size differences between the animals. Note that the animal with the lower trabecular density also exhibits a lower cortical thickness.

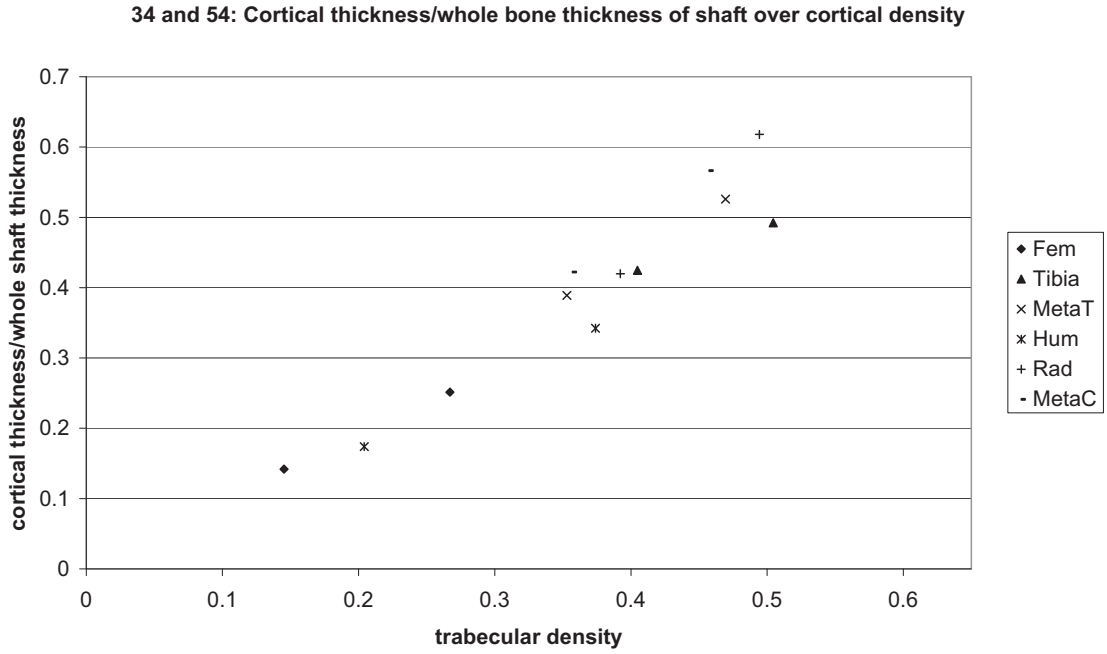

Figure 8.6: Showing the relationship between trabecular bone density and cortical thickness of animals number 34 and 54. The y-axis represents the cortical thickness of the shaft divided by the whole thickness of the shaft in order to overcome the effect of size differences between the animals. Note that the animal with the lower trabecular density also exhibits a lower cortical thickness.

Figures 8.5 and 8.6 clearly demonstrate that, for the majority of the pairs, the animals with the lowest cortical densities also have thinner cortical bone at their shafts. The observed bone densities are therefore the product primarily of bone thickness rather than bone mineral content. This strongly suggests that, unless the preparation processes are capable of reducing the cortical thickness of the bone shafts, they are not responsible for the observed patterns.

Admittedly, this part of the analysis has only examined scan-sites from the shaft of each long bone. More significant differences in absolute bone density exist elsewhere in the skeletons of these animals, but there is no way of assessing whether these are due to variations in bulk density or bone mineral content.

Overall, this analysis shows pairs of animals that display absolute density variation in the shafts of their long bones that can be explained in terms of background variation. It seems reasonable to suggest that the observed differences in the trabecular skeleton are the product of the same background factors affecting the long bone shafts. Alternatively, the observed differences in trabecular bone density might be attributable to preparation method. This presupposes that (at least in the case of pairs 30-22, 70-75, 78-70 and 78-75) the preparation methods only affect trabecular bone and that in each case they have done so in the same direction as the background variation. It is quite possible that the preparation methods employed in each pair preferentially affect the trabecular bone, because this bone type has a proportionally greater surface area than cortical bone. This will promote the efficiency of the chemical reactions responsible for the removal of mineral and other radiodense material from the bone.

An examination of the background information for the animals used in this analysis might clarify the situation. Reference to table 8.4 reveals that animal number 34 was reported by its owner to have been a “poor doer”. Although the meaning of this comment is not elucidated, it is almost certainly indicative that this animal was in a state of lower general health than its counterpart (54). If this lower health was apparent in its skeleton, then it is interesting that animal number 34 (the “poor doer”) exhibits a lower bone density than animal number 54. In this case at least, the background variation is such that it seems to have rendered any variation in density due to preparation method invisible.

In the comparison of animals number 70 and 75 it is relevant than number 70 was collected from Newmarket. Animals from the Newmarket flock were noted at the time of collection as having suffered from poor skeletal health, possibly brought about by nutritional deficiencies (pers comm Elaine Corke, 2001). Furthermore, animal

number 70 was suffering from an oral infection at the time of its death – a circumstance that might have further impinged on its skeletal health and could explain why it has the generally lower bone density of this pair.

The comparison of animals number 78 and 70 presents a similar situation. In this case both animals are from the calcium deficient Newmarket flock. However, in addition to this, animal number 78 is reported to have produced two lambs in every year of its reproductive life (there are no lambing data available for animal number 70). Such a prolific lambing record in circumstances of possible nutritional deficiencies could conceivably lead to the loss of skeletal density in animal number 78 that has been observed. The situation was probably exaggerated by the fact that animal number 78 died slightly later in the year than animal number 70, and so was probably further along the annual cycle of bone loss associated with pregnancy and lactation (described by Hindlang and Maclean 1997 p199 – see section 5.2.6. This would contribute to an understanding of why animal number 70 has a generally higher bone density than animal number 78.

It is only to be expected that animal number 78 also shows a generally lower density than animal number 75. Again, this can be attributed to the possible poor skeletal health of animal number 78, or the difference in methods used to deflesh these two individuals.

8.5.4: Summary

The pattern of absolute density differences within the pairs being examined here is far from self-explanatory. The data show no consistent patterning. Reference to the cortical bone thickness of the long bones suggests that the densities of the long bone shafts at least are the result of background variation rather than the preparation method. It is possible that the preparation method is responsible for the density differences observed in the bone ends. However, the fact that the differences between the trabecular and cortical bone repeatedly follow the same direction suggests that a single process is responsible for both. The previous section reinforces this hypothesis. In four of the six pairs examined, background information supported the interpretation that background variation was responsible for the patterns being observed.

It can be concluded, for these animals, that varying the preparation method has either no effect or a negligible effect on the absolute density of the skeleton, when compared with the impact of background variation. This may be because the preparation methods employed did not affect, or all had a very similar effect on the bone density.

This conclusion is supported by the fact that, while testing the reliability of the methods used in this project, preparation method was shown to have no observable effect on bone density. Alternatively, the background variation may have either mirrored or masked the effects of the preparation method. It is also possible that the measurement method used by this project does not have sufficient resolution to enable the identification of any very small differences in bone density brought about by altering the preparation method within a pair.

8.6: The Impact of Variation in Breed on Bone Density

The potential for the breed of an animal to influence the density of its skeleton has clearly been demonstrated. The genetic contribution to bone density has already been discussed (Johnston and Slemenda 1993 pS54, Peel and Eastell 1995 p990, Smith *et al* 1973 p2802 - see section 5.2.7). In addition to genetic control, different flocks might be subjected to different management regimes. If this is the case, then it is not unlikely that animals from different flocks will experience a variety of levels of nutrition, parity and exercise. All of these factors have already been shown to have some impact on bone density (see chapter 5 and references therein).

The preceding section suggested that the various processes that have been used to deflesh the material do not have any measurable effect on its bone density. Consequently, when selecting matched pairs for further analyses, the preparation method of each skeleton was ignored. This has had the effect of considerably increasing the number of pairs available for this analysis.

8.6.1: Materials

To assess the ways in which the bone density of animals of different breeds compare, groups or pairs of animals that are matched in terms of all of their main variables, with the exception of breed and preparation method, were selected. The available life history information relating to the 16 animals that were suitable for this analysis are displayed in table 8.6. Of these 16 animals, 11 pairs could be formed and analysed.

Skeleton Number	Age (days)	Preparation Method	Breed	Sex	Month of Death	Month of Birth	Locality	Accession Number	Mode of Death	Condition at Death	Comments
48	305	U/K	Soay	F	2	4	Newmarket	3297	Accident	U/K	
26	335	Si	Manx	F	3	4	Royston	2533	Disease	Poor	
25	541	Bo	S X B	C	10	4	Edinburgh	2852	U/K	U/K	
31	556	Bo	Shet	C	10	4	Hoy	2938	U/K	U/K	
42	563	U/K	Shet	C	10	4	Hoy	1557	U/K	U/K	
65	579	Ma	Soay	C	10	4	Newmarket	2775	U/K	U/K	Incomplete
53	954	Ma	Soay	C	12	4	Durham	2773	U/K	U/K	
20	954	Bo	Shet	C	11	4	Hoy	2944	U/K	U/K	
51	1071	U/K	Soay	C	3	4	Durham	2801	U/K	U/K	
38	1076	U/K	Shet	C	4	4	Hoy	1552	U/K	U/K	
81	1322	Si	Hdwk	F	11	3	Hoy	2567	Accident	U/K	
74	1381	U/K	Soay	F	1	4	Newmarket	2788	U/K	U/K	Pregnant
2	3252	Bu	Manx	F	2	3	Norfolk	1019	Disease	Poor	Pregnant
3	3285	Si	Hdwk	F	3	3	Hoy	2568	Accident	U/K	Pregnant
86	3961	U/K	Soay	F	2	4	Bedford	1308	U/K	U/K	
90	3992	Bu	Hbdn	F	3	4	Somerset	1127	U/K	U/K	Pregnant

Table 8.6: Showing all of the 5 main attributes and the background information of the 16 animals that were compared in order to establish the impact of an animal's breed on its bone density. Where more than two matched animals were available, they were split into as many pairs as possible. Si = Simmered; Bo = Boiled; Ma = Macerated; Bu = Buried; Shet = Shetland; S X B = Suffolk-Blackface cross; Manx = Manx Loughtan; Hdwk = Herdwick; Hbdn = Hebridean: M = Male; F = Female; C = Castrate; U/K = Unknown.

The animals described above are not necessarily matched in terms of their preparation method, because preparation method is now known not to affect the bone density of the material significantly. This also means that animals with unknown (U/K) preparation methods can be included in the analysis. These two facts have enabled 11 pairs rather than just one pair (25-31) to be isolated.

The material described above consists of a wide range of sheep breeds. These encompass hill sheep - Shetlands - as well as primitive breeds (Alderson 1984 p5-7). The Suffolk X Blackface represents a downland sheep crossed with a hill sheep (Hall and Clutton-Brock 1989 pp119-187). It should be borne in mind that the nature of the material used in this project is such that animals of a particular breed will tend to come from the same flock. For example, the vast majority of the Shetland sheep used in this project were reared on the Isle of Hoy, in the Orkneys. It may therefore be unwise to conclusively state that any patterns identified in this analysis are solely the result of differences in the breed of the material. It is equally possible that either the habitat of the animals, their diet or the management system under which they were raised are

responsible for any observations that may be made. If this is the case, then any differences observed in this analysis could be caused by factors that are specific to a *flock* rather than a particular breed.

8.6.2: Results

Once again the bone densities for each of the scan-sites of the animals described above were calculated. The material was grouped into matched pairs and the differences between the bone densities of each animal from each pair were calculated. In each case the density of the animal with the overall higher skeletal density was subtracted from that of the animal with the overall lower skeletal density. This generated density differences that tend to be negative. Table 8.7 displays these differences in the same format as previous similar tables. Differences that do not exceed the intra-observer error are greyed-out. Positive differences are shown in red (meaning that the first animal listed in table 8.7 has the higher bone density of the pair). Negative values are shown in black (meaning that the first animal listed in table 8.7 has the lower density of the pair).

Breeds Compared / Scan-site	Manx-Soay (26-48)	Soay-Hdwk (74-81)	Hdwk-Manx (3-2)	Soay-Hbdn (86-90)	SXB-Shet (25-31)	SXB-Shet (25-42)
Pelvis	-0.083	-0.085			0.007	0.045
P Fem	-0.120	-0.177	-0.024	0.025	-0.015	-0.003
D Fem	-0.082	-0.038	-0.002	0.012	0.028	0.035
P Tibia	0.058	-0.071	0.009	-0.007	-0.044	-0.059
D MetaT	0.148		-0.003	-0.002	-0.076	-0.098
Scap		-0.047	-0.023	0.089	0.033	0.024
P Hum	0.010	-0.075	0.059	0.029		0.009
D Hum	-0.029	-0.145	-0.004	-0.039	-0.013	0.036
D Rad	-0.056	-0.087	0.108	-0.014	-0.105	-0.198
D MetaC	0.012	-0.021	0.006	0.026	-0.025	-0.143
Phal1	0.039	-0.014	0.014	-0.013	0.028	-0.030
S Fem	0.109	-0.009	-0.051	-0.139	0.053	0.023
S Tibia	0.002	0.023	-0.026	-0.134	-0.116	-0.147
D Tibia	0.046	-0.075		-0.023	0.005	-0.049
P MetaT	-0.028			-0.041	-0.026	-0.086
S MetaT	-0.035		-0.062	-0.070	-0.117	-0.159
S Hum	0.052	-0.066	-0.105	-0.024	0.015	0.047
P Rad	-0.047	-0.120	-0.106	0.084	-0.074	-0.087
S Rad	0.086	0.026	-0.032	0.001	-0.110	-0.118
P MetaC	-0.127	0.013	0.027	-0.043	0.011	-0.009
S MetaC	-0.003	0.087	-0.024	0.063	-0.071	-0.121

Breeds Compared / Scan-site	SXB-Soay (25-65)	Shet-Soay (31-65)	Shet-Soay (42-65)	Shet-Soay (20-53)	Shet-Soay (38-51)
Pelvis					0.031
P Fem				0.262	0.113
D Fem				-0.022	-0.005
P Tibia				0.003	-0.012
D MetaT	-0.216	-0.140	-0.118	0.017	-0.067
Scap				0.036	-0.005
P Hum				-0.045	0.033
D Hum				0.000	0.249
D Rad				-0.096	-0.090
D MetaC	-0.192	-0.167	-0.049	0.005	-0.097
Phal1	-0.012	-0.040	0.018	-0.002	0.021
S Fem				0.027	0.058
S Tibia				-0.034	-0.075
D Tibia				-0.016	-0.034
P MetaT	-0.120	-0.093	-0.033	-0.035	-0.091
S MetaT	-0.193	-0.076	-0.033	-0.075	-0.102
S Hum				-0.006	0.009
P Rad				0.053	-0.045
S Rad				-0.132	-0.086
P MetaC	-0.138	-0.148	-0.129	-0.005	-0.147
S MetaC	-0.192	-0.121	-0.070	-0.112	-0.141

Table 8.7: Showing the differences in density values between animals from each pair that differ only in their breeds (and preparation methods). All of the greyed-out values are greater than the intra-observer error, and so can be attributed to background variation. Values in red are positive. Values in black are negative.

The absence of data for the entire skeletons of pairs 25-65, 31-65 and 42-65 can be explained by the fact that skeleton number 65 was incomplete. This individual consisted only of the metapodia and phalanges and so data for elements other than these were not available.

The data described above show that variation within the pairs that exceeds the intra-observer error does exist. Whether this variation is the result of the breeds of the animals or of background variation requires some discussion. The data from table 8.7 are not strongly patterned according to skeletal location or bone type. The absolute differences are of the same magnitude as those that have been associated with background variation. Some of the pairs produce strongly uni-directional differences (eg pairs 74-81 or 25-65), while others show multi-directional differences (eg pairs 26-48 or 86-90). A closer examination of these absolute values highlights one area in which the

differences observed here may differ from those attributed to background variation in section 8.4.3. Overall, the data described here exhibit a slightly less marked uni-directionality. On average, 24% of the differences within each of the pairs being examined in this section are positive. This compares with a figure of 17% calculated for the matched pairs described in section 8.4.2 that was attributed to background variation. The animals described here display slightly more multi-directional differences in their densities. Whether this observation is significant, and what might be causing this phenomenon requires some discussion.

8.6.3: Discussion

In previous sections, the differences observed between matched individuals have variously been explained with reference to the background data. In the analysis of breed, the differences within only one pair can be explained in this way. Pair 74-81 shows animal number 81 to have consistently higher bone densities than animal number 74. This can be explained by the fact that animal number 74 belongs to the Newmarket flock that has previously been linked to low bone density, possibly brought about by a calcium-deficient diet (see section 8.5.3). That animal number 74 was pregnant when it died is likely only to have reduced its skeletal density further. In this case, therefore, the background information available can be used to create a plausible suggestion as to the causes of the observed pattern.

With the single exception of the above pair, the background information has proved unable to explain the data described in this section. Indeed, for a number of the patterns described above the background information suggests a pattern that is *contrary* to that which is observed. For example, in pair 3-2 it is animal number 2 that has a relatively higher bone density. This animal died during pregnancy and while in a poor and diseased condition: factors that would normally cause this individual's skeletal density to be considerably reduced. Although previous analyses have included examples where the background life history information has not been able to explain the observed data, these are relatively rare and can often be attributed to the quality or availability of this information. Instances where the background information contradicts the observed data are even more unusual. In these pairs there must be some other factor at work that is responsible for the differences in bone density. Since these animals are known to be of various breeds, it is possible that the variation observed may be attributable to different breeds.

It has already been noted that there is a significant correlation in this analysis between an animal's breed and the flock from which it was culled. It is therefore unwise to conclude that the differences noted in this analysis are solely the result of the breed of the animals. It is quite possible that animal management regimes or habitat are influential in producing the patterns being discussed. It is unfortunate that little or nothing is known about the conditions under which the 95 animals that were examined in this project lived and were raised. It has been reported that the Shetland sheep from the Isle of Hoy, Orkney, lived under harsh conditions and survived on a diet of rough scrub. If this can be taken as an indication that the Shetland sheep used in this project were living under conditions of nutritional or environmental stress, this might explain why they consistently display somewhat lower skeletal densities than the Soay sheep.

Variation in the management regimes within the pairs suggests that differences in factors such as diet, levels of exercise and parity might also exist. In effect this will have the result of increasing the level of background variation that might be expected. The data in table 8.7 suggest that this may in fact be the case. The patterning strongly resembles that which was observed for background variation, with the exception that it is slightly more multi-directional and that it is less explicable with reference to the background information.

8.6.4: Summary

A tentative conclusion at this stage would be that by varying the breed within each pair, additional variation in the background factors has been introduced. This has caused a slight exaggeration of the multi-directionality of the differences within each pair, since in this analysis there is likely to be a more complex interaction of more numerous background factors affecting the density of the skeletons. It has already been suggested (in section 8.4.3) that such interaction will conceivably lead to more complex multi-directional differences between the densities of otherwise matched animals.

It is not unlikely that genetic difference attributable to breed are also capable of affecting the bone density of a group of animals (see section 5.2.7), but the data suggest that any such effects are being masked by the effects of altering the management regime. Reliable conclusions regarding the genetic impact of breed on the bone density of an animal cannot be drawn without access to a considerably larger and more closely controlled collection of experimental material.

8.7: The Impact of Variation in Sex on Bone Density

The body chemistry of an animal is known to contribute to its skeletal density. Since the body chemistry of males, female and castrates is different, then these animals can be expected to have differing bone densities. Sexual differences in bone density are associated specifically with variations in fusion age (Davis 2000 p426), parity and lactation (Hindlang and Maclean 1997 p199) and, in females, ovarian function (Ekenmann *et al* 1995 p356).

Establishing the impact of the sex of an animal on its bone density is central in securing an understanding of differential taphonomic attrition that is likely to occur across a flock or assemblage. If one sex is more or less likely to be affected by destructive taphonomic processes than another, then there exists a danger that sex ratio biases will be created in an assemblage. Such biases must be at least identified and, where possible, rectified. Ascertaining the sex structure of the death assemblage of a particular taxon offers the potential of interpreting whether past flocks were bred primarily for meat, wool, milk or other products (Payne 1973). Unrecognised bias within the sex structure of an assemblage can therefore have ramifications for subsequent interpretations.

8.7.1: Materials

Following the previously used method, this analysis will attempt to ascertain how bone density varies between animals of different sexes by isolating pairs of animals from the experimental material. The animals from these pairs are similar in terms of their main attributes, but are of different sexes. For the purposes of this project, three sexes have been defined. These are males (M), females (F) and castrates (C). Naturally, castrates do not strictly constitute a different sex, but they do exhibit different hormone levels, which may be reflected in their skeletal density. Since the preparation method has been shown not to influence bone density significantly, there was no need for the individuals within each pair to be matched in terms of the methods used to deflesh them. Table 8.8 describes the animals that fit these criteria. A total of 19 animals was suitable for this analysis, from which 29 matched pairs could be derived.

Skeleton Number	Age (days)	Preparation Method	Breed	Sex	Month of Death	Month of Birth	Locality	Accession Number	Mode of Death	Condition at Death
19	331	Si	Shet	M	3	4	Hoy	2572	U/K	U/K
14	340	Ma	Shet	C	4	4	Hoy	2893	U/K	U/K
45	610	U/K	Shet	C	1	5	Hoy	1551	U/K	U/K
59	657	U/K	Shet	M	2	5	Hoy	1594	U/K	U/K
58	668	Ma	Shet	M	2	4	Hoy	1591	U/K	U/K
54	693	Si	Shet	C	3	5	Hoy	2582	U/K	U/K
46	694	Si	Shet	M	3	5	Hoy	2583	U/K	U/K
37	813	U/K	Shet	C	7	5	Hoy	1556	U/K	U/K
57	863	U/K	Shet	M	9	4	Hoy	1593	U/K	U/K
63	920	U/K	Shet	C	11	4	Hoy	1558	U/K	U/K
22	950	Bo	Shet	C	11	4	Hoy	3218	U/K	U/K
55	950	Bo	Shet	M	12	4	Hoy	3281	U/K	U/K
47	950	Bo	Shet	M	11	4	Hoy	3282	U/K	U/K
29	951	U/K	Shet	C	11	4	Hoy	3217	U/K	U/K
52	954	Bo	Shet	M	12	5	Hoy	3289	U/K	U/K
20	954	Bo	Shet	C	11	4	Hoy	2944	U/K	U/K
49	960	Bo	Shet	M	12	4	Hoy	3288	U/K	U/K
40	969	U/K	Shet	C	12	4	Hoy	1550	U/K	U/K
30	970	Ma	Shet	C	12	4	Hoy	2866	U/K	U/K

Table 8.8: Showing all of the five main attributes and the background information of the 19 animals that were compared in order to establish the variation attributable to sex. Where more than two matched animals were available, they were split into as many pairs as possible. Si = Simmered; Ma = Macerated; Bo = Boiled; Shet = Shetland; M = Male; F = Female; C = Castrate; U/K = Unknown.

Table 8.8 raises a number of points that should be stressed. It is clear from this table that the only matched groups of animals available from the experimental material were either males or castrates. Consequently, this analysis will be unable to provide information as to how the bone density of female sheep compares with that of other sexes. This is an unfortunate feature of the experimental material, but cannot be overcome. Also, the animals described in table 8.8 are all Shetland sheep from the Isle of Hoy, in the Orkneys. The mode of death and condition at death of all of these animals is unknown and no comments regarding their life history were provided. No information is therefore available to explain background variation should it become apparent.

8.7.2: Results

The 19 animals available for this analysis enabled 29 pairs to be formed and the animals within them to be compared. As usual, the bone density of each scan-site of one

animal from each pair was subtracted from that of the other. For this analysis, the density of the castrate within the pair was subtracted from the density of the male. The differences obtained are displayed in table 8.9. Again, differences that might be attributed to measurement error (those that are less than the intra-observer error of 0.024) are greyed-out. Positive numbers are shown in red.

Animals Compared / Scan-Site	54-46 (C-M)	54-58 (C-M)	37-57 (C-M)	20-52 (C-M)	20-49 (C-M)	22-47 (C-M)	22-52 (C-M)	22-49 (C-M)
P MetaC	0.025	-0.008	0.014	0.008	-0.034	-0.005	-0.008	-0.051
P MetaT	0.065	0.004	0.031	-0.077	-0.076	-0.008	-0.069	-0.069
Scap	-0.009	-0.043	0.043	-0.086	-0.036	-0.035	-0.053	-0.003
Pelvis	0.085	0.054	0.200			-0.063	-0.140	
D Hum	0.001	-0.006	-0.002	-0.073	-0.044	-0.023	-0.061	-0.032
P Rad	0.064	-0.104	-0.064	-0.008	0.034	-0.166	-0.205	-0.163
Phal1	-0.006	-0.002	0.027	-0.014	-0.062	-0.054	-0.037	-0.085
D Tibia	0.030	0.038	0.056		-0.040	0.169		0.138
D MetaC	0.088	0.002	0.083	0.037	-0.006	0.003	0.022	-0.021
D MetaT	0.085	0.014	0.106	0.013	-0.055	0.028	-0.053	-0.122
P Fem	0.044	-0.003	0.219	0.192	0.237	0.196	0.109	0.154
D Rad	0.113	0.031	0.186	-0.132	-0.055	0.060	-0.085	-0.007
P Hum	-0.030	-0.111	-0.031	-0.026	-0.052	-0.004	-0.035	-0.061
D Fem	0.005	-0.120	0.008		-0.128	-0.025		-0.111
P Tibia	-0.063	0.002	0.040	-0.048	-0.069	0.022	-0.024	-0.045
S Fem	0.083	-0.040	0.017	0.001	-0.039	0.056	0.051	0.012
S Tibia	0.062	-0.024	0.087	-0.065	-0.012	0.005	-0.039	0.013
S MetaT	-0.030	-0.051	0.163	0.050	-0.012	0.072	0.082	0.020
S Hum	0.069	0.001	0.010	-0.048	-0.084	-0.051	-0.051	-0.087
S Rad	0.085	-0.114	0.102	-0.035	-0.159	-0.156	-0.038	-0.163
S MetaC	0.095	-0.002	0.096	0.018	-0.074	-0.023	0.079	-0.012

Animals Compared / Scan-Site	29-52 (C-M)	29-49 (C-M)	63-55 (C-M)	63-47 (C-M)	63-52 (C-M)	63-49 (C-M)	22-55 (C-M)	29-55 (C-M)
P MetaC	-0.074	-0.117	-0.050	-0.040	-0.043	-0.085	-0.015	-0.081
P MetaT	0.000	0.000	-0.113	0.008	-0.053	-0.052	-0.129	-0.060
Scap	-0.111	-0.060	-0.069	-0.077	-0.095	-0.045	-0.027	-0.085
Pelvis			-0.019	0.019	-0.058		-0.101	
D Hum	-0.001	0.028	-0.069	-0.060	-0.098	-0.069	-0.031	0.029
P Rad	0.096	0.138	-0.090	-0.127	-0.166	-0.124	-0.130	0.172
Phal1	0.009	-0.039	-0.057	-0.054	-0.037	-0.085	-0.057	-0.011
D Tibia		-0.057	-0.101	-0.063		-0.094	0.131	-0.065
D MetaC	-0.103	-0.146	-0.025	-0.082	-0.064	-0.106	0.060	-0.065
D MetaT	-0.069	-0.138	-0.019	0.028	-0.053	-0.121	-0.020	-0.036
P Fem	-0.042	0.004	-0.115	-0.006	-0.093	-0.048	0.087	-0.064
D Rad	-0.143	-0.066	-0.211	-0.030	-0.174	-0.097	-0.121	-0.180
P Hum	-0.009	-0.035	-0.091	0.034	0.003	-0.023	-0.129	-0.104
D Fem		-0.143	-0.116	-0.063		-0.150	-0.077	-0.109
P Tibia	-0.056	-0.077	-0.086	-0.023	-0.069	-0.090	-0.040	-0.073
S Fem	-0.045	-0.084	-0.017	-0.028	-0.033	-0.072	0.066	-0.029
S Tibia	0.004	0.057	-0.044	-0.064	-0.108	-0.056	0.025	0.068
S MetaT	0.128	0.066	0.088	0.051	0.061	-0.001	0.109	0.155
S Hum	0.012	-0.025	-0.028	-0.034	-0.034	-0.071	-0.045	0.018
S Rad	-0.018	-0.142	-0.021	-0.166	-0.048	-0.172	-0.011	0.010
S MetaC	0.071	-0.021	-0.022	-0.093	0.010	-0.082	0.048	0.039

Animals Compared / Scan-Site	20-55 (C-M)	40-55 (C-M)	30-55 (C-M)	29-47 (C-M)	20-47 (C-M)	40-47 (C-M)	30-47 (C-M)	40-52 (C-M)
P MetaC	0.001	-0.109	-0.044	-0.071	0.011	-0.099	-0.034	-0.102
P MetaT	-0.137	-0.151	-0.150	0.061	-0.016	-0.030	-0.029	-0.091
Scap	-0.060	-0.123	-0.133	-0.093	-0.068	-0.131	-0.141	-0.149
Pelvis		-0.035	-0.039			0.003	-0.001	-0.074
D Hum	-0.043	-0.112	-0.060	0.037	-0.035	-0.103	-0.051	-0.141
P Rad	0.068	-0.188	-0.133	0.135	0.032	-0.225	-0.170	-0.264
Phal1	-0.035	-0.133	-0.038	-0.008	-0.031	-0.130	-0.035	-0.113
D Tibia	-0.047		-0.120	-0.026	-0.009		-0.081	
D MetaC	0.075	-0.060	-0.047	-0.122	0.018	-0.117	-0.103	-0.099
D MetaT	0.047	-0.032	-0.104	0.012	0.094	0.015	-0.057	-0.066
P Fem	0.170	-0.050	-0.129	0.045	0.279	0.059	-0.020	-0.028
D Rad	-0.169	-0.219	-0.201	0.001	0.012	-0.038	-0.019	-0.183
P Hum	-0.120	-0.162	-0.165	0.021	0.005	-0.037	-0.040	-0.067
D Fem	-0.094	-0.101	-0.120	-0.056	-0.042	-0.049	-0.067	
P Tibia	-0.065	-0.079	-0.005	-0.010	-0.002	-0.017	0.058	-0.063
S Fem	0.016	-0.077	-0.031	-0.040	0.005	0.087	-0.041	-0.092
S Tibia	-0.001	-0.072	0.014	0.048	-0.021	-0.092	-0.006	-0.135
S MetaT	0.077	0.075	0.136	0.118	0.040	0.038	0.098	0.048
S Hum	-0.042	-0.127	-0.039	0.012	-0.048	-0.133	-0.045	-0.133
S Rad	-0.008	-0.042	0.009	-0.135	-0.152	-0.187	-0.136	-0.070
S MetaC	-0.014	-0.013	0.063	-0.032	-0.085	-0.084	-0.008	0.019

Animals Compared / Scan-Site	30-52 (C-M)	40-49 (C-M)	30-49 (C-M)	14-19 (C-M)	45-59 (C-M)
P MetaC	-0.037	-0.145	-0.080	-0.073	-0.037
P MetaT	-0.090	-0.090	-0.089	-0.068	-0.069
Scap	-0.159	-0.098	-0.108	-0.111	-0.010
Pelvis	-0.078				-0.015
D Hum	-0.089	-0.113	-0.060	-0.075	0.022
P Rad	-0.209	-0.222	-0.167	-0.214	0.014
Phal1	-0.018	-0.161	-0.066	-0.088	-0.120
D Tibia			-0.112		
D MetaC	-0.085	-0.141	-0.127	-0.138	0.011
D MetaT	-0.138	-0.134	-0.206	-0.071	-0.045
P Fem	-0.107	0.017	-0.061	0.006	-0.081
D Rad	-0.164	-0.105	-0.087	-0.105	0.058
P Hum	-0.071	-0.093	-0.097	-0.015	-0.079
D Fem		-0.135	-0.154	-0.158	-0.085
P Tibia	0.012	-0.083	-0.009	-0.027	-0.015
S Fem	-0.046	-0.131	-0.085	-0.164	0.057
S Tibia	-0.050	-0.083	0.003	-0.060	0.025
S MetaT	0.109	-0.014	0.046	-0.066	0.069
S Hum	-0.045	-0.170	-0.082	-0.113	-0.023
S Rad	-0.018	-0.194	-0.142	-0.102	0.085
S MetaC	0.095	-0.073	0.003	-0.086	0.015

Table 8.9: Showing the differences in density values for each of the pairs. The individuals from each pair are known to differ only in their sex (and preparation method). The scan-sites are ordered in terms of fusion age – the earliest fusing epiphyses being listed first. All of the greyed-out values are lower than the intra-observer error, and so can be attributed to background variation. Values in red are positive. Values in black are negative.

Table 8.9 shows clear patterning within the data. With the exception of pairs 54-46, 37-57 and 22-47, subtracting the bone densities of the male from those of the castrate has produced an overall negative result. Although positive differences do exist, each comparison, on balance, returns a negative difference. This means that, with the two exceptions already noted, the males have an overall higher bone density than the castrates. The patterning in the data does not relate to the fusion age of the epiphyses. Of note is the fact that the epiphyses of the males have a strong tendency to be denser than those of the castrates, while the bone shafts of both sexes do not conform so rigidly to this trend.

8.7.3: Discussion

The magnitude and directionality of the data described in table 8.9 is comparable to that which has previously been attributed to background variation (up to about 0.28).

It is not unlikely that at least some of the variation apparent in this table is in fact the product of background variation. However, it is unlikely that background variation could coincidentally result in the skeletons of the males almost exclusively having an overall higher density than those of the castrates. In conclusion, even though some background variation is likely to exist, the prevailing pattern seems to result from variations in the sex of the material. In the case of pairs 54-46, 37-57 and 22-47, some other factor must have masked this sex-derived pattern. In the absence of any background information it is impossible to speculate as to the nature of such factors.

The association between castration and bone growth has been the subject of considerable research in the medical literature. Silberg and Silberg (1971 p444) have noted that the bones of castrated animals are more porous than bones of males of the same species. This observation has been variously confirmed. Kapitola *et al* (1995 pp71-2) have recorded a reduction in the bone mineral content of rat tibiae following castration. Similar relationships between bone growth and testosterone levels in the body have been reported by Hope *et al* (1992 p539), Schwartz *et al* (1991 p1169) and references therein. The comparatively low bone density of castrates noted in this analysis is undoubtedly the result of their suffering from reduced testosterone levels.

The observation that trabecular bone is more adversely affected by castration than cortical bone is concurrent with the findings of Soutens *et al* (1984 pS71) and Yeh (2000 p801), although neither of these reports offers an explanation of their findings.

The results of this analysis carry with them a number of archaeological implications. Not least is the potential for misinterpretation of faunal assemblages. The lower bone density of castrates, as compared to males, brings with it the probability that, all other factors being equal, castrates will be more prone to destructive taphonomic processes. This will potentially produce bias in the archaeological record. Since the precise nature of the relationship between bone density and bone survival is unknown, the absolute extent of this bias has not, and cannot, be established at this point. Furthermore, until castrates and males (and females) can reliably be separated in the archaeological record, taphonomic biases between these two sexes will remain effectively invisible.

8.7.4: Summary

It is unfortunate that the nature of the experimental material means that an examination of the bone density of females is impossible. However, in the absence of a larger sample, the inclusion of females in this analysis would be unwise. When more

appropriate material becomes available, this analysis might be completed in order to provide a more complete picture of how bone density varies between animals of different sexes. In the meantime it is possible to suggest that not only do castrated sheep have an overall lower density than complete males, but also that this feature is likely to be the result of hormonal deficiency on the part of the castrates.

8.8: The Impact of Variation in Month of Death on Bone Density

Section 5.2.6 explained that sheep (especially females) are subject to an annual cycle of bone density variation, caused by a combination of nutritional factors, parity and lactation. It seems logical, therefore, that the time of year in which an animal died will have some bearing on the density of its skeleton. It is for this reason that an attempt to assess the nature and degree of seasonal bone density variation would be appropriate. In order to undertake such an assessment it would be necessary to form groups of animals that are similar in four of their five main attributes, but that differ in the month in which they died. Any differences in bone density of the individuals from these groups will be the product of a combination of background factors and the season of the animals' deaths.

Unfortunately, the formation of the necessary groups is problematic. Since all of the animals from the experimental material were born at the same time of year (during the spring lambing season), any animals that died at different times of the year will necessarily have different ages. This means that groups of animals that are matched in all of their main attributes except their month of death cannot be formed, because when month of death differs within a group, so will the age of the animals. Consequently, it will be impossible to be sure that bone density differences observed within a group are the result of variations in the month of death. They could equally easily be due to differences in the ages of the animals.

This lack of control means that this analysis will be unable to provide meaningful results and so little will be gained from pursuing this line of investigation. Since the impact of the month of death of an animal on its bone density will remain unknown, the next (and final) analysis will assume that this impact is significant and will only compare animals that have the same, or very similar, months of death.

8.9: The Impact of Variation in Age on Bone Density

The last of the five main attributes that this project intends to examine is age. It is frequently assumed that the bones from animals of different ages have different densities. Specifically, (unfused) bones from immature animals have been assumed to be less dense than (fused) bones from adult animals. Section 5.2.2 described how the skeletons of humans and other animals have been shown to change throughout life. Developmental bone changes within an individual are often connected or influenced by its sex, diet, levels of exercise or a host of other factors.

According to the considerable body of medical, veterinary and other literature, the bone density of an animal will be relatively high at birth, followed by a marked drop and then a rapid increase in the first few days or months of life (depending on the species involved). This increase continues at a reduced rate until maturity is reached. A gradual decrease in density is possible (especially in female humans) in later life, as osteoporosis takes effect (see section 5.2.2 and references therein).

The ability to identify bias in the age profile of archaeological faunal material is immensely important. Age has been used to interpret the procurement or management strategies that have been used in the past (Payne 1973). If the age data used to reach these conclusions are flawed due to taphonomic bias, then misinterpretation is a distinct possibility. This analysis will attempt to ascertain whether or not bone density varies significantly throughout an animal's life. The reasons for this and the potential impact of any variation on archaeological interpretation will be explored.

8.9.1: Materials

In this section, groups of animals that are similar in their main attributes, with the exception of their ages (and preparation methods), will be formed. The bone density data from these groups will be displayed graphically. The animals that can be appropriately grouped are shown in table 8.10.

Skeleton Number	Age (days)	Preparation Method	Breed	Sex	Month of death	Month of birth	Locality	Accession Number	Mode of Death	Condition at Death	Comments
83	1258	Bu	Soay	F	9	4	Bedford	2229	U/K	U/K	
67	1259	Bu	Soay	F	9	4	Bedford	2228	U/K	U/K	
82	1277	Bu	Soay	F	9	3	Bedford	2224	U/K	U/K	
75	2711	Bu	Soay	F	9	4	Bedford	2225	U/K	U/K	
76	3794	Bu	Soay	F	9	4	Bedford	2227	U/K	U/K	
77	4175	Bu	Soay	F	9	4	Bedford	2226	U/K	U/K	
43	230	U/K	Shet	C	12	4	Hoy	1549	U/K	U/K	
24	238	Ma	Shet	C	12	4	Hoy	2867	U/K	U/K	
42	563	U/K	Shet	C	10	4	Hoy	1557	U/K	U/K	
63	920	U/K	Shet	C	11	4	Hoy	1558	U/K	U/K	
40	969	U/K	Shet	C	12	4	Hoy	1550	U/K	U/K	
30	970	Ma	Shet	C	12	4	Hoy	2866	U/K	U/K	
61	1291	U/K	Shet	C	11	4	Hoy	1559	U/K	U/K	
21	1309	Bo	Shet	C	11	4	Hoy	2943	U/K	U/K	
8	442	Ma	Shet	C	6	4	Hoy	2912	U/K	U/K	
39	447	U/K	Shet	C	7	4	Hoy	1554	U/K	U/K	
16	801	Ma	Shet	C	7	4	Hoy	2913	U/K	U/K	
37	813	U/K	Shet	C	7	5	Hoy	1556	U/K	U/K	
64	1116	U/K	Shet	C	5	4	Hoy	1589	U/K	U/K	
35	1186	Ma	Shet	C	7	4	Hoy	2914	U/K	U/K	
44	1198	U/K	Shet	C	7	4	Hoy	1555	U/K	U/K	

Table 8.10: Showing all of the five main attributes and the background information of the 21 animals that were compared in order to establish the impact of an animal's age on its bone density. These 21 individuals form three sets of animals that can be compared. The animals within each set are listed above in order of increasing age. Bu = Buried; Ma = Macerated; Bo = Boiled; Shet = Shetland; F = Female; C = Castrate; U/K = Unknown.

The matched groups described above include only castrated Shetland and female Soay sheep. Other matched groups could be formed from the available material, but many either contained too few individuals, covered too short an age span or were too discontinuous to be able to produce meaningful results. The youngest animal described above is 230 days old. Consequently, no discussion will be possible regarding the bone density of animals during the first few months of their lives. Conclusions in this area will have to be limited to the discussion already presented in section 8.2.3. Because of the limited range of sex and breed of the animals being examined in this analysis, it will not be possible to draw conclusions that are universally applicable. Instead any conclusions will have to be limited to generalisation. A further feature of the material described above is that none of the matched groups contains animals that span the entire

expected life-span of a sheep. Consequently, none of the matched groups will provide a full picture of how bone density can change throughout an animal's entire life and generalisations will, again, have to be made.

8.9.2: Results

For each matched group, the bone densities of each scan-site of each individual were plotted as a line graph. Since each individual was listed in order of increasing age, the resulting graph represents how the density of each scan-site from a single individual might be expected to change throughout its life. Of course, this relies on the assumption that each individual within a group is similar in all respects other than their age. Since each individual is being compared within a matched group, this assumption is a reasonable one. The fluctuations on each of the graphs (figures 8.7 - 8.12) can be said to be the result of a combination of age and background variation.

The data from each of the matched groups are plotted in figures 8.7 - 8.12. The cortical and trabecular scan-sites for each of the matched groups are plotted on separate graphs. This avoids the need for 21 variables (one for each scan-site) to be plotted on a single graph and is simply for the sake of clarity.