CHAPTER 11: ARCHAEOLOGICAL ASSEMBLAGES: RESULTS (i)

11.0: Introduction

Summary results for each technique performed on the archaeological material are presented below. For mandibular molariform tooth-wear and tooth-development analyses, numerical summary results are given for each of the archaeological sites, in terms of the entire assemblage and also identifiable temporal phases. Indication will be given of the extent of any potential double-counting in each phase. Individual results where the age-diagnosis from tooth-development (based on Brown & Chapman 1991a, b methodology) is at odds with that from tooth-wear are highlighted and discussed. Palaeoeconomic interpretations based on a synthesis of the population results from both techniques, accompanied by graphical expressions of data, including comparisons with Payne's (1973) models of animal exploitation, and comments on any perceived diachronic changes and inter-site coincidental differences, will be presented and discussed in the next chapter (12). These interpretations are not presented in the present chapter since in each case they will be derived from a synthesis of the results detailed below from tooth-wear analysis and tooth-development analysis. Inferences from the results from the two techniques may be contradictory; this will also be explored in chapter 12. In all cases, individual tooth-wear results used to compile the summaries given are recorded in appendix V on the accompanying CD-ROM.

Radiographs from putative foetal mandibles and fragments age-diagnosed using tooth-wear and tooth-development (based on Brown & Chapman 1991a, b) will be examined for tooth-development in terms of Gjesdal's (1969) sequential diagram (figures 3.6a & b); results will then be compared with those tooth-wear analysis. This will form part of a quality check on tooth-wear and tooth-development (based on Brown & Chapman 1991a, b) results, since Gjesdal's (1969) method, though based on modern stock, is independent of the modern control assemblage used in this study. Other aspects of the results used for quality assurance will include a direct comparison of results from individuals where unequivocal age-diagnoses have been made using both tooth-wear and tooth-development (based on Brown & Chapman 1991a, b). Examination of age-diagnosis results from the archaeological controls from The Bedern, York, using tooth-wear and tooth-development techniques will also form part of the quality check. Individual tooth-development results used to compile the summaries given are recorded in appendix VI on the accompanying CD-ROM.

11.1: Metrical analysis of mandibles

Measurements were made of the parameters specified in section 8.6 on mandibles from the 7 archaeological assemblages, using a digital caliper. As discussed in the same section, the parameters chosen for calculations were 'A', the gonion cordale to the most aboral indentation of the mental foramen, and 'C', the length of deciduous premolar row (dP2-dP4). Little of the excavated material was suitable for this examination, however; some of the mandibles, despite bearing the full molar and premolar dentition, were so fragmented, so that one or more of the parameters had to be excluded. Parameter 'A' was very often among these, as the diastema is particularly vulnerable to fracture, and 'A' requires the survival of the diastema as far as the mental foramen, as illustrated in figure 8.4.

Only 7 suitable mandibles were found and measured; these were from Pool and The Bedern (the archaeological control site). Despite containing apparently intact mandibles with full arrays of mandibular teeth the assemblages from Mine Howe, Howe, Earl's Bu, Toft's Ness or Snusgar contained none that was sufficiently complete for this examination. The results for Pool and The Bedern are shown below in tables 11.1 & 11.2. Age-diagnoses were inferred by checking against the A:C ratio on table 9.7. These have been translated in the final column into the age-categories, as in table 9.20, used for the tooth-development (Brown & Chapman 1991a, b) methodology.

Table 11.1: Metrical results: mandibles from the Pool assemblage; measurements in mm (n=6).

Reference	**A**	**C**	**A:C ratio**	**Age diagnosis**	**Age-category**
P60	133.81	55.97	2.39	8-9 months gestation	LFNB
P180	134.93	55.80	2.42	8-9 months gestation	LFNB
P201	132.86	55.00	2.42	8-9 months gestation	LFNB
P209	130.82	54.60	2.40	8-9 months gestation	LFNB
P215	131.74	54.12	2.43	8-9 months gestation	LFNB

Table 11.2: Metrical results: mandibles from the The Bedern, York (control site) assemblage. (NB=new-born; NN=neonate (between birth and 2 weeks))

Reference	**A**	**C**	**A:C ratio**	**Age diagnosis**	**Age-category**
BY06	143.02	54.40	2.63	outside range	post-natal

All of the Pool mandibles suitable for this examination appeared to be from very young animals; as such these are likely candidates for late abortion or stillbirth. These results will be compared later in this chapter in sections 11.5.3 & 11.5.4 with those for the same individuals using the tooth-development methodology.

11.2: Tooth-wear analysis of mandibles

A total of 753 mandibles, mandible fragments, loose dP4s and loose M1s from Orkney archaeological sites were examined for tooth wear (Grant 1982). Analyses were carried out according to the methodology discussed in section 3.4 and described in section 8.5; age-classes (Halstead 1985) were decided for equivocal diagnoses as set out in section 10.3. Results are presented in the form of a numerical population summary based on the entire site assemblage of suitable bovine bone material, followed by similar tables for the identifiable temporal phases shown in table 10.2. Interpretations will be presented in the next chapter. Results for the archaeological control assemblage from the Bedern, York are presented and discussed below in section 11.5.4.

As stated earlier (section 10.3), the unmodified data represent the ‘maximum number of individuals’ in each case. However, as discussed in the same section, there are three factors that might result in ‘double counting’ of individuals:

a) Possible left-hand/right hand mandible mirror replicates from the same jaw.
b) Loose dP4s or M3s that correspond to mandible fragments from the same animal.
c) Loose dP4s that may have been shed from a living animal.

To give an indication of the likelihood and extent of this possibility, for each phase of the study assemblages, together with the tooth-wear summary, data, derived from those presented in appendix V (on accompanying CD-ROM), are presented which suggest the likely numbers of potential replicates from each category above. For factors a) and b), only cases where contexts, handedness and age-diagnoses were both coincident were counted. Animals potentially double counted under factors a) or b) are from no specific age-category. In contrast, for factor c), bovine deciduous 4th premolars are generally shed at around 30-36 months (table 7.1), this translates as age-classes 'D' & 'E' (Halstead 1985), which, from table 10.5, for these assemblages, is covered by dP4 wear-stages 'h' and above (Grant 1982). Hence, loose dP4s from these wear-stages might represent animals falsely categorised as 30-36 months, which could in fact have died at a later age. Table 11.3 summarises the results of the analysis for potential 'double counting' in each category for all the site phases to be discussed.

Table 11.3: Potential cases of 'double-counting'

SITE	**TEMPORAL PHASE**	**a) Possible LH/RH replicates**	**b) Loose teeth which might correspond to mandible fragments**	**c) Potentially shed loose dP4s**	**Total**
Mine Howe	Mid-Later Iron Age	16	7	27	50
	Later Iron Age	9	3	11	23
Howe	Early Iron Age	1	0	3	4
	Middle Iron Age	16	0	7	23
	Later Iron Age	4	0	3	7
	Mid-Later Iron Age	26	1	10	37
Toft's Ness	Neolithic/Bronze Age	0	0	4	4
	Early Iron Age	0	0	1	1
Earl's Bu	Viking Period	0	0	3	3
	Late Norse Period	1	0	3	4
Snusgar	Norse Period	2	0	1	3
Pool	Early Iron Age	1	0	0	1
	Later Iron Age	8	0	1	9
	Scandinavian Interface	7	0	5	12
	Norse Period	2	0	3	5

11.2.1: Mine Howe tooth-wear analysis results

244 tooth-wear analyses of bovine mandibles (n=18) and mandible fragments (n=71) and selected loose teeth (n=155) were carried out on material from the Mine Howe assemblage.

Table 11.4 shows a summary of age-class diagnoses based on the results for the entire Mine Howe assemblage. Two temporal phases were identified within the assemblage for palaeoeconomic analysis: Mid-Later Iron Age, and Later Iron Age (ditch phases D10 & D11). The former is a composite for inter-site comparison purposes, and includes data from the Later Iron Age phase. The full data are presented in appendix V on CD-ROM.

Table 11.4: Summary of tooth-wear analysis of entire Mine Howe assemblage (n=244).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	30	12.3
B	1-8 MONTHS	67	27.5
C	8-18 MONTHS	11	4.5
D	18-30 MONTHS	26	10.6
E	30-36 MONTHS	36	14.7
F	YOUNG ADULT	38	15.6
G	ADULT	21	8.6
H	OLD ADULT	7	2.9
I	SENILE	8	3.3
TOTAL		244	100

Table 11.5 shows a summary of age-class diagnoses based on the results for the Mid-Later Iron Age phase assemblage from Mine Howe (n=224).

Table 11.5: Summary of tooth-wear analysis of the Mid-Later Iron Age phase assemblage from Mine Howe (n=224).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	29	12.9
B	1-8 MONTHS	62	27.7
C	8-18 MONTHS	7	3.1
D	18-30 MONTHS	21	9.4
E	30-36 MONTHS	37	16.5
F	YOUNG ADULT	31	13.8
G	ADULT	18	8.1
H	OLD ADULT	8	3.6
I	SENILE	11	4.9
TOTAL		224	100

As shown in table 11.3, a total of 50 individuals (22.3%) from the Mid-Later Iron Age phase assemblage from Mine Howe were potential candidates for double counting, including 27 loose dP4s which may have been shed from animals after 30-36 months (21.4% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.6 shows a summary of age-class diagnoses based on the results for the Later Iron Age phase (ditch phases D10 & D11) assemblage from Mine Howe (n=100).

Table 11.6: Summary of tooth-wear analysis of the Later Iron Age phase (ditch phases D10 & D11) assemblage from Mine Howe (n=100).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	5	5
B	1-8 MONTHS	28	28
C	8-18 MONTHS	2	2
D	18-30 MONTHS	11	11
E	30-36 MONTHS	14	14
F	YOUNG ADULT	22	22
G	ADULT	11	11
H	OLD ADULT	4	4
I	SENILE	3	3
TOTAL		100	100

As shown in table 11.3, a total of 23 individuals (23%) from the Later Iron Age phase assemblage from Mine Howe were potential candidates for double counting, including 11 loose dP4s which may have been shed from animals after 30-36 months (16.9% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

11.2.2: Howe tooth-wear analysis

Tooth-wear analysis results for the Howe assemblage, interpreted as age-classes, with all phases conflated, are shown in table 11.7. A total of 191 elements, comprising 37 reasonably intact bovine mandibles, 31 mandible fragments and 123 loose M1 and dP4 teeth were examined (Halstead 1985). Four temporal phases were identified within the assemblage for palaeoeconomic analysis: Early Iron Age (site phases 3-6), Middle Iron Age (site phase 7), Later Iron Age, and Mid-Later Iron Age (composite for inter-site comparison). The full data are presented in appendix V on CD-ROM.

Table 11.7: Summary of tooth-wear analysis of entire Howe assemblage (n=191).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	56	29.3
B	1-8 MONTHS	34	17.8
C	8-18 MONTHS	17	8.9
D	18-30 MONTHS	7	3.7
E	30-36 MONTHS	25	13.1
F	YOUNG ADULT	43	22.5
G	ADULT	4	2.1
H	OLD ADULT	5	2.6
I	SENILE	0	0
TOTAL		191	100

Table 11.8 shows a summary of age-class diagnoses based on the results for the Early Iron Age (site phases 3-6) assemblages from Howe (n=11).

Table 11.8: Summary of tooth-wear analysis of the Early Iron Age phase assemblages from Howe (n=11).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	2	18.2
B	1-8 MONTHS	1	9.1
C	8-18 MONTHS	0	0
D	18-30 MONTHS	4	36.35
E	30-36 MONTHS	0	0
F	YOUNG ADULT	4	36.35
G	ADULT	0	0
H	OLD ADULT	0	0
I	SENILE	0	0
TOTAL		11	100

As shown in table 11.3, a total of 4 individuals (36.4%) from the Early Iron Age phase assemblage from Howe were potential candidates for double counting, including 3 loose dP4s which may have been shed from animals after 30-36 months (37.5% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.9 shows a summary of age-class diagnoses based on the results for the Middle Iron Age phase (site phase 7) assemblage from Howe (n=93).

Table 11.9: Summary of tooth-wear analysis of the Middle Iron Age phase assemblage from Howe (n=93).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	25	26.8
B	1-8 MONTHS	13	14
C	8-18 MONTHS	14	15
D	18-30 MONTHS	2	2
E	30-36 MONTHS	8	8.6
F	YOUNG ADULT	27	29.5
G	ADULT	3	3.1
H	OLD ADULT	1	1
I	SENILE	0	0
TOTAL		93	100

As shown in table 11.3, a total of 23 individuals (24.7%) from the Middle Iron Age phase assemblage from Howe were potential candidates for double counting, including 7 loose dP4s which may have been shed from animals after 30-36 months (17.1% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.10 shows a summary of age-class diagnoses based on the results for the Later Iron Age phase assemblages from Howe (n=60).

Table 11.10: Summary of tooth-wear analysis of the Later Iron Age phase assemblages from Howe (n=60).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	16	26.7
B	1-8 MONTHS	14	23.2
C	8-18 MONTHS	1	1.7
D	18-30 MONTHS	0	0
E	30-36 MONTHS	16	26.7
F	YOUNG ADULT	8	13.3
G	ADULT	1	1.7
H	OLD ADULT	4	6.7
I	SENILE	0	0
TOTAL		60	100

As shown in table 11.3, a total of 7 individuals (11.7%) from the Later Iron Age phase assemblage from Howe were potential candidates for double counting, including 3 loose dP4s which may have been shed from animals after 30-36 months (10.3% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.11 shows a summary of age-class diagnoses based on the results for the Middle-Later Iron Age phase assemblages from Howe (n=169).

Table 11.11: Summary of tooth-wear analysis of the Middle-Later Iron Age phase assemblages from Howe (n=169).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	53	31.3
B	1-8 MONTHS	28	16.6
C	8-18 MONTHS	17	10
D	18-30 MONTHS	0	0
E	30-36 MONTHS	27	16
F	YOUNG ADULT	36	21.3
G	ADULT	4	2.4
H	OLD ADULT	4	2.4
I	SENILE	0	0
TOTAL		169	100

As shown in table 11.3, a total of 37 individuals (21.9%) from the Mid-Later Iron Age phase assemblage from Howe were potential candidates for double counting, including 10 loose dP4s which may have been shed from animals after 30-36 months (14.1% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

11.2.3: Tofts Ness tooth-wear analysis

8 bovine mandibles, 16 fragments and 24 loose teeth from Toft’s Ness were examined by wear-stage analysis; table 11.12 summarises the results when allocated into age-classes using the criteria published by Halstead (1985: 219, table 35). Two temporal phases were identified within the assemblage for palaeoeconomic analysis: Neolithic and Bronze Age (site phases 1-4), and Early Iron Age (site phase 6). The full data are presented in appendix V on CD-ROM.

Table 11.12: Summary of tooth-wear analysis of entire Toft's Ness assemblage (n=48).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	4	8.3
B	1-8 MONTHS	16	33.3
C	8-18 MONTHS	2	4.2
D	18-30 MONTHS	4	8.3
E	30-36 MONTHS	4	8.3
F	YOUNG ADULT	8	16.7
G	ADULT	3	6.3
H	OLD ADULT	3	6.3
I	SENILE	4	8.3
TOTAL		48	100

Table 11.13 shows a summary of age-class diagnoses based on the results for the Neolithic and Bronze Age (site phases 1-4) assemblages from Toft's Ness (n=21).

Table 11.13: Summary of tooth-wear analysis of the Neolithic and Bronze Age phase assemblages from Toft's Ness (n=21).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	1	4.8
B	1-8 MONTHS	6	28.6
C	8-18 MONTHS	2	9.5
D	18-30 MONTHS	2	9.5
E	30-36 MONTHS	2	9.5
F	YOUNG ADULT	4	19
G	ADULT	0	0
H	OLD ADULT	1	4.8
I	SENILE	3	14.3
TOTAL		21	100

As shown in table 11.3, a total of 4 individuals (19.0%) from the Neolithic and Bronze Age phase assemblage from Toft's Ness were potential candidates for double counting, all 4 were loose dP4s which may have been shed from animals after 30-36 months (33.3% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.14 shows a summary of age-class diagnoses based on the results for the Early Iron Age (phase 6) assemblage from Toft’s Ness (n=21).

Table 11.14: Summary of tooth-wear analysis of the Early Iron Age phase assemblage from Toft’s Ness (n=21).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	3	14.3
B	1-8 MONTHS	10	47.5
C	8-18 MONTHS	1	4.8
D	18-30 MONTHS	1	4.8
E	30-36 MONTHS	1	4.8
F	YOUNG ADULT	4	19
G	ADULT	1	4.8
H	OLD ADULT	0	0
I	SENILE	0	0
TOTAL		21	100

As shown in table 11.3, a single individual (4.8%) from the Early Iron Age phase assemblage from Toft’s Ness was a potential candidate for double counting, being a loose dP4 which may have been shed from an animal after 30-36 months (14.3% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

11.2.4: Earl’s Bu: tooth-wear analysis

Examination of bone material from the Earl’s Bu excavation revealed a single, reasonably complete, bovine mandible, 8 incomplete mandibles and 25 dP4 and M1 molariform teeth, which were subsequently analysed for tooth-wear and allocated to age-classes, based on

Grant (1975: 438; 1982: 92) and Halstead (1985: 219, table 35). Table 11.15 summarises the results. Two temporal phases were identified within the assemblage for palaeoeconomic analysis: Viking and Late Norse. The full data are presented in appendix V on CD-ROM.

Table 11.15: Summary of tooth-wear analysis of entire Earl's Bu assemblage (n=34).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	1	2.9
B	1-8 MONTHS	3	8.8
C	8-18 MONTHS	0	0
D	18-30 MONTHS	0	0
E	30-36 MONTHS	15	44.1
F	YOUNG ADULT	10	29.5
G	ADULT	2	5.9
H	OLD ADULT	2	5.9
I	SENILE	1	2.9
TOTAL		34	100

Table 11.16 shows a summary of age-class diagnoses based on the results for the Viking phase assemblage from Earl's Bu (n=12).

Table 11.16: Summary of tooth-wear analysis of the Viking phase assemblage from Earl's Bu (n=12).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	0	0
B	1-8 MONTHS	1	8.3
C	8-18 MONTHS	0	0
D	18-30 MONTHS	0	0
E	30-36 MONTHS	6	50
F	YOUNG ADULT	5	41.7
G	ADULT	0	0
H	OLD ADULT	0	0
I	SENILE	0	0
TOTAL		12	100

As shown in table 11.3, a total of 3 individuals (25%) from the Viking phase assemblage from Earl's Bu were potential candidates for double counting, all were loose dP4s which may have been shed from animals after 30-36 months (27.3% of the total from age-classes 'D' to 'I' (Halstead 1985)).

Table 11.17 shows a summary of age-class diagnoses based on the results for the Late Norse phase assemblage from Earl's Bu (n=8).

Table 11.17: Summary of tooth-wear analysis of the Late Norse phase assemblage from Earl's Bu (n=8).

AGE CLASS (Halstead 1985)	**SUGGESTED AGE**	**COUNT**	**PERCENTAGE OF TOTAL**
A	0-1 MONTHS	0	0
B	1-8 MONTHS	1	12.5
C	8-18 MONTHS	0	0
D	18-30 MONTHS	0	0
E	30-36 MONTHS	4	50
F	YOUNG ADULT	1	12.5
G	ADULT	0	0
H	OLD ADULT	2	25
I	SENILE	0	0
TOTAL		8	100

As shown in table 11.3, a total of 4 individuals (50%) from the Late Norse phase assemblage from Earl's Bu were potential candidates for double counting, including 3 were loose dP4s which may have been shed from animals after 30-36 months (42.9% of the total from age-classes 'D' to 'I' (Halstead 1985)).

11.2.5: Snusgar: tooth-wear analysis

Cattle-tooth-wear analyses based on examination of material from the as-yet unpublished excavation at Snusgar gave the age-class distribution shown in table 11.18. A total of 3 mandibles, 8 fragments and 6 loose teeth were examined. The single temporal phase was identified as Norse. The full data are presented in appendix V on CD-ROM.

Table 11.18: Summary of tooth-wear analysis of entire Snusgar assemblage (Norse phase) (n=34).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	0	0
B	1-8 MONTHS	4	23.5
C	8-18 MONTHS	0	0
D	18-30 MONTHS	2	11.8
E	30-36 MONTHS	3	17.6
F	YOUNG ADULT	4	23.5
G	ADULT	2	11.8
H	OLD ADULT	0	0
I	SENILE	2	11.8
TOTAL		17	100

As shown in table 11.3, a total of 3 individuals (17.6%) from the Snusgar assemblage were potential candidates for double counting, including a single loose dP4 which may have been shed from an animal after 30-36 months (7.7% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

11.2.6: Pool: tooth-wear analysis

119 examples of bovine mandible, 65 intact and 54 fragmented, together with 100 M1 and dP4 loose teeth were examined for wear from the Pool assemblage. Table 11.19 summarises the results for the whole assemblage in age-classes using the table published by

Halstead (1985: 219, table 35). Four temporal phases were identified within the assemblage for palaeoeconomic analysis: Early Iron Age, Later Iron Age, Scandinavian Interface and Norse. The full data are presented in appendix V on CD-ROM.

Table 11.19: Summary of tooth-wear analysis of entire Pool assemblage (n=219).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	91	41.6
B	1-8 MONTHS	47	21.5
C	8-18 MONTHS	21	9.6
D	18-30 MONTHS	10	4.6
E	30-36 MONTHS	30	13.7
F	YOUNG ADULT	15	6.8
G	ADULT	1	0.4
H	OLD ADULT	1	0.4
I	SENILE	3	1.4
TOTAL		219	100

Table 11.20 shows a summary of age-class diagnoses based on the results for the Early Iron Age assemblage from Pool (n=5).

Table 11.20: Summary of tooth-wear analysis of the Early Iron Age phase assemblage from Pool (n=5).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	1	20
B	1-8 MONTHS	1	20
C	8-18 MONTHS	0	0
D	18-30 MONTHS	1	20
E	30-36 MONTHS	2	40
F	YOUNG ADULT	0	0
G	ADULT	0	0
H	OLD ADULT	0	0
I	SENILE	0	0
TOTAL		5	100

As shown in table 11.3, a single individual (20%), possibly a LH/RH replicate, from the Early Iron Age phase assemblage from Pool was a potential candidate for double counting,

Table 11.21 shows a summary of age-class diagnoses based on the results for the Later Iron Age phase assemblage from Pool (n=58).

Table 11.21: Summary of tooth-wear analysis of the Later Iron Age phase assemblage from Pool (n=58).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	21	36.3
B	1-8 MONTHS	13	22.4
C	8-18 MONTHS	8	13.8
D	18-30 MONTHS	0	0
E	30-36 MONTHS	6	10.3
F	YOUNG ADULT	8	13.8
G	ADULT	1	1.7
H	OLD ADULT	0	0
I	SENILE	1	1.7
TOTAL		58	100

As shown in table 11.3, a total of 9 individuals (15.5%) from the Later Iron Age phase assemblage from Pool were potential candidates for double counting, including 1 loose dP4 which may have been shed from an animal after 30-36 months (6.3% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.22 shows a summary of age-class diagnoses based on the results for the Scandinavian Interface phase assemblage from Pool (n=81).

Table 11.22: Summary of tooth-wear analysis of the Scandinavian Interface phase assemblage from Pool (n=81).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	37	45.7
B	1-8 MONTHS	21	25.9
C	8-18 MONTHS	6	7.4
D	18-30 MONTHS	11	13.6
E	30-36 MONTHS	5	6.2
F	YOUNG ADULT	0	0
G	ADULT	0	0
H	OLD ADULT	0	0
I	SENILE	1	1.2
TOTAL		81	100

As shown in table 11.3, a total of 12 individuals (14.8%) from the Scandinavian Interface phase assemblage from Pool were potential candidates for double counting, including 5 loose dP4s which may have been shed from animals after 30-36 months (29.4% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

Table 11.23 shows a summary of age-class diagnoses based on the results for the Norse phase assemblage from Pool (n=34).

Table 11.23: Summary of tooth-wear analysis of the Norse phase assemblage from Pool (n=34).

AGE CLASS (Halstead 1985)	SUGGESTED AGE	COUNT	PERCENTAGE OF TOTAL
A	0-1 MONTHS	20	58.9
B	1-8 MONTHS	5	14.7
C	8-18 MONTHS	3	8.8
D	18-30 MONTHS	0	0
E	30-36 MONTHS	4	11.8
F	YOUNG ADULT	1	2.9
G	ADULT	0	0
H	OLD ADULT	0	0
I	SENILE	1	2.9
TOTAL		34	100

As shown in table 11.3, a total of 5 individuals (14.7%) from the Norse phase assemblage from Pool were potential candidates for double counting, including 3 loose dP4s which may have been shed from animals after 30-36 months (50% of the total from age-classes ‘D’ to ‘I’ (Halstead 1985)).

11.3: Examination of radiographs from archaeological material for tooth development, using definitions of Brown & Chapman (1991a, b).

A total of 180 radiographic images of bovine mandibles and fragments of mandibles were examined for tooth development from the archaeological sites. Analyses were carried out according to the methodology discussed in section 3.5.2 and described as adapted for this study and for archaeological assemblages in sections 8.7.3 and 10.4.1 respectively; age-categories were decided for equivocal diagnoses as discussed in the latter section. Discussion of how these results might affect the palaeoeconomic interpretations inferred from conventional tooth wear analyses, including graphical expressions of data, will follow in the next chapter, as mentioned earlier in section 11.0.

It must be emphasised that the results below do not reflect the whole bovine death population of each site or phase, as analysed in the tooth-wear analyses given above. Loose single teeth were excluded, as were mandibles from adult animals. Apart from badly damaged material, the mandibles and fragments chosen for radiography included all those subsequently age-diagnosed using tooth-wear analysis as age-class ‘A’ & ‘B’ (Halstead 1985); in some cases, suitable material from older animals was also examined from age-class ‘C’. Since no loose teeth were examined using the tooth-development methodology, possible candidates for 'double-counting', as discussed in section 10.3 & 11.2, are restricted to cases where both left- and right-hand mandibles may have been examined from the same animal; these will be indicated where appropriate.

Results from each individual animal are tabulated for each site, giving the tooth-development score and age-diagnosis, based on the categories defined in table 9.20, using tables 9.19 & 9.21 to 9.36, depending on the tooth conformation. The latter data are also shown, in codified format, together with the corresponding tooth-wear age-class result (Halstead 1985); in the case of mandibles and fragments bearing a dP4, the dP4 wear-stage result, and, in cases of wear-stage 'b' (Grant 1982), the number of cusp-points worn are indicated (as discussed in section 8.5 & 10.3 using the modification suggested by Mulville *et al*. (2005: 171)). This will be shown to be useful in comparing tooth-wear and tooth-development results.

These results are followed by summary tables representing site phases, as with tooth-wear analysis (section 11.2.1 *et seq.* above), where equivocal age-categories have been resolved using the method discussed earlier (based on Payne (1973: 296) (section 10.4.1)). Summaries are not presented in percentage format, since, as stated above, they do not represent the whole assemblage. Full development score data from each site, including scores for individual teeth, are presented on the accompanying CD-ROM in Appendix VI, as are images of the radiograph films used for scoring.

11.3.1: Mine Howe: tooth development

Radiographs of 38 mandibles and mandible fragments were examined from the site. Table 11.24 shows the results from the whole site assemblage, ordered by diagnosed age.

Table 11.24: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Mine Howe assemblage (n=39).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	**Phase**	**Teeth present**	**Total tooth development score**	**Age-diagnosis (tooth development)**	**Age-class (tooth-wear) (Halstead 1985)**	**dP4 wear (+ cusp wear if 'b')**
MH78	D9	CD	10	F/LFNB	A	broken
MH85	D9	C	6	LF/NB/NN	A	a
MH0.1	D9	D	4	F/LFNB	A-B	
MH06.15	E4.4/5/6	A	6	F/LF/NB/NN	A-D	
MH93	D11	A	6	F/LF/NB/NN	A-D	
MH67	D9	A	6	F/LF/NB/NN	A	
MH94	D9	A	6	F/LF/NB/NN	A-D	
MH06.17	D5	A	6	F/LF/NB/NN	A-D	
MH65	D8	BC	13	LF/NB/NN	A	a
MH71	D9	B	7	LF/NB/NN	A-D	
MH92	D9	AB	13	LF/NB/NN	A-D	
MH98	E9	AB	13	LF/NB/NN	A-C	
MH76	E4.4/5/6	AB	14	LF/NB/NN	B	
MH73	E6	B	7	LF/NB/NN	A-C	
MH79	D11	AB	13	LF/NB/NN	A-B	
MH81	D11	BC	13	LF/NB/NN	B	b 3/6
MH06.08	D5	ABC	21	NBNN	A	a
MH75	D9	C	7	NBNN/INF	B	b 3/6
MH06.05	E3	A	7	NBNN/INF	A-D	
MH91	E4.4/5/6	C	7	NBNN/INF	B	c
MH06.16	D10	A	7	NBNN/INF	A-D	
MH06.07	D10	A	7	NBNN/INF	A-D	
MH70	NK	C	7	NBNN/INF	B	b 2/6
MH86	D10	B	8	NBNN/INF/JUV	A-B	
MH97	E4.4/5/6	ABC	22	INF	B	c
MH66	D10/11	ABC	23	INF	B	b 4/6
MH80	UnStr	ABC	22	INF	B	b 3/6
MH72	D8	ABCD	33	JUV	C-E	g
MH90	D8	ABCD	37	JUV	C	f
MH96	D9	ABC	27	JUV	B-D	c
MH77	E4.4/5/6	AB	18	JUV	A-D	
MH88	E7	ABC	28	JUV	C-E	h
MH89	E7	ABC	27	JUV	C-E	f
MH95	E6	A	9	JUV	A-D	
MH68	D10	ABC	24	JUV	B-D	c
MH69	D10	AB	18	JUV	B-C	
MH74	D10	ABC	27	JUV	C-D	h
MH84	D10	ABCD	38	JUV	C-E	k
MH99	D10	B	10	JUV	B-E	

As can be seen, only 3 mandibles were complete with all four teeth (‘ABCD’) (7.7%); 9 fragments had 3 teeth (23.1%); 9 had combinations of two teeth (23.1%), while in 18 cases only single teeth were present (46.1%). There is one case where double-counting could have occurred: MH88 & MH89 are from the same phase and context, have similar age-diagnoses, and are opposite-handed.

Using Halstead’s (1985) age-class definitions (table 3.3), the dP4 is unworn in age-class ‘A’ (0-1 month); however, as discussed earlier (section 9.11) Mulville *et al*. (2005: 171) suggest that animals showing dentine-exposing wear on 2 cusp-points of the dP4 may still be considered age-class ‘A’. All age-categories derived from tooth-development analysis fall into age-class ‘A’, apart from ‘juvenile’ (JUV) (table 11.43); however, ‘infant’ (INF), at 2-4 weeks, borders the margin of age-class ‘B’ (1- 8 months) (Halstead 1985: 219, table 35).

From table 11.24, some quasi-anomalous results can be seen. Reference MH75, has a dP4 with 3/6 worn cusp-points, and is hence age-classed ‘B’ via Halstead (1985) and Mulville *et al*. (2005); however, it is categorised NB/NN/INF (maximum age 4 weeks) by tooth-development. This has been taken as acceptable, however, as a marginal discrepancy, since the upper limit of INF is consecutive to age class ‘B’ (1-8 months). MH 96, 97, 91, 66 & 80 are similarly marginal when tooth-wear on the dP4 is compared to the tooth-development result; in some of these cases, the dP4 is at wear-stage ‘c’ (Grant 1982). MH81 appears more divergent, however, as it has a dP4 with 3/6 cusp-points worn (hence age-class ‘B’ via Halstead (1985) and Mulville *et al*. (2005)), while being categorised by tooth-development as LF/NB/NN (maximum age 2 weeks post-natal). In this case the degree of cusp-wear is marginal, however, being only 1 cusp-point beyond the cut-off for age-class 'A' (2/6) suggested by Mulville *et al*. (2005). This also mirrors the result of the modern control individual, DS6, discussed in section 9.1, which was age-attested at 19 days.

Table 11.25 summarises the data from table 11.24 covering the Mid-Later Iron Age phases; equivocal results have been resolved using age-category proportionality, as discussed earlier (Payne 1973). The potential case of double-counting mentioned above originated from this phase; if valid, it would reduce the total and number of JUVs by 1. The validity or otherwise of this case is unlikely to affect any subsequent palaeoeconomic interpretations to any significant extent.

Table 11.25: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Mid-Later Iron Age phases of the Mine Howe assemblage (n=37).

Age category	Number
Foetus (F)	2
Late Foetus-Newborn (LFNB)	8
Newborn-Neonate (NBNN)	9
Infant (INF)	5
Juvenile (JUV)	13
TOTAL	37

Table 11.26 summarises age-category results for the Later Iron Age (ditch) phase assemblages only from Mine Howe (n=36).

Table 11.26: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Later Iron Age phase assemblages from Mine Howe (n=12).

Age category	Number
Foetus (F)	0
Late Foetus-Newborn (LFNB)	2
Newborn-Neonate (NN)	2
Infant (INF)	2
Juvenile (JUV)	6
TOTAL	12

11.3.2: Howe: tooth development

Radiographs from a total of 35 mandibles and mandible fragments were examined from the various phases at this site. Table 11.27 shows the individual results from the whole assemblage, arranged by ascending age.

Table 11.27: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Howe assemblage (n=35).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	**Phase**	**Teeth present**	**Total tooth development score**	**Age-diagnosis (tooth development)**	**Age-class (tooth-wear) (Halstead 1985)**	**dP4 wear (+ cusp wear if 'b')**
H148	7	C	6	LF/NB/NN	A	a
H14	8	ABC	19	LFNB	A	a
H16	8	ABCD	24	LFNB	A	a
H26	8	ABCD	23	LFNB	A	½
H47	8	ABC	20	LFNB	A	a
H61	7/8	ABCD	24	LFNB	A	a
H69	7/8	ABC	20	LFNB	A	a
H72	7/8	ABCD	24	LFNB	A	a
H73	7/8	ABC	20	LFNB	A	a
H115	7	ABC	19	LFNB	A	a
H118	7	ABC	20	LFNB	A	a
H147	7	ABC	19	LFNB	A	a
H179	5/6	ABCD	24	LFNB	A	a
H24	8	CD	11	LF/NB/NN	A	a
H48	8	CD	11	LF/NB/NN	A	a
H100	7	AB	13	LF/NB/NN	A-D	
H68	7/8	AB	13	LF/NB/NN	A-D	
H130	7	CD	11	LF/NB/NN	A	a
H82	7	ABC	21	NBNN	A	a
H3	8	BC	14	NBNN/INF	A	a
H55	8	BC	14	NBNN/INF	A	a
H70	7/8	C	7	NBNN/INF	A	a
H132	7	C	7	NBNN/INF	A	a
H129	7	BC	15	NBNN/INF/JUV	B-C	c
H25	8	ABC	22	INF	B	b 5/6
H42	8	ABC	22	INF	B	b 5/6
H149	7	AB	18	JUV	A-D	
H185	9	CD	14	JUV	B-C	c
H190	9	ABCD	32	JUV	B-C	c
H135	7	ABCD	33	JUV	C-D	h
H138	7	ABCD	32	JUV	C	d
H139	7	ABCD	34	JUV	C	d
H117	7	ABC	25	JUV	B-C	c
H7	8	ABC	27	JUV	C	d
H8	8	ABCD	32	JUV	B-C	c

10 mandibles from Howe had four molar and premolar teeth (‘ABCD’) (28.6%); 12 individuals presented with three teeth (34.3%); 10 had combinations of two teeth (28.6%), while in 3 cases only single teeth were present (8.5%). There are 2 cases where double-counting could have occurred: H61 & H69 are from the same phase and context, have similar age-diagnoses, and are opposite-handed. The same criteria apply to H138 & H139.

There are 2 anomalous results: both H25 & H42 were given tooth-wear-stage ‘b’ (Grant 1982), and had dentine-exposing wear in the dP4 in 5/6 cusp-points; they were hence categorised as age-class ‘B’ (age-at-death 1-8 months) (Halstead 1985). In both cases, tooth-development diagnoses were ‘INF’ (died at 2-4 weeks). As with the instances from the Mine Howe assemblage in section 11.2.3.1, since the diagnoses are consecutive, this was an acceptable discrepancy.

Table 11.28 summarises age-category results for the Middle Iron Age (phase 7) assemblages from Howe (n=14); equivocal results have been resolved using age-category proportionality (Payne 1973). One of the potential cases of double-counting mentioned above originated from this phase; if valid, it would reduce the total and number of JUVs by 1. The validity or otherwise of this case is unlikely to affect any subsequent palaeoeconomic interpretations to any significant extent.

Table 11.28: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Middle Iron Age phase assemblages from Howe (n=14).

Age category	**Number**
Foetus (F)	0
Late Foetus-Newborn (LFNB)	5
Newborn-Neonate (NBNN)	2
Infant (INF)	1
Juvenile (JUV)	6
TOTAL	14

Table 11.29 summarises age-category results for Later Iron Age (phase 8) assemblages from Howe (n=12); equivocal results have been resolved using age-category proportionality (Payne 1973).

Table 11.29: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Later Iron Age phase assemblages from Howe (n=12).

Age category	**Number**
Foetus (F)	0
Late Foetus-Newborn (LFNB)	5
Newborn-Neonate (NBNN)	2
Infant (INF)	3
Juvenile (JUV)	2
TOTAL	12

Table 11.30 summarises age-category results for the combined Mid-Later Iron Age phase assemblages from Howe (n=32); equivocal results have been resolved using age-category proportionality (Payne 1973). Both potential cases of double-counting mentioned above originated from this combined phase; if valid, they would reduce the total by 2, the number of LFNBs by 1 and the number of JUVs by 1. The validity or otherwise of these cases is unlikely to affect any subsequent palaeoeconomic interpretations to any significant extent.

Table 11.30: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from combined Mid-Later Iron Age phase assemblages from Howe (n=32).

Age category	**Number**
Foetus (F)	0
Late Foetus-Newborn (LFNB)	15
Newborn-Neonate (NBNN)	5
Infant (INF)	5
Juvenile (JUV)	7
TOTAL	32

11.3.3: Toft's Ness: tooth development

Radiographs from 13 mandibles and mandible fragments from various phases at this site were examined using tooth-development criteria to score each individual tooth. Table 11.31 shows individual results from the whole assemblage, ordered by age.

Table 11.31: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Toft's Ness assemblage (n=13).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	**Phase**	**Teeth present**	**Total tooth development score**	**Age-diagnosis (tooth development)**	**Age-class (tooth-wear) (Halstead 1985)**	**dP4 wear (+ cusp wear if 'b')**
TN45	6	D	4	F/LFNB	A-D	
TN8	1	ABCD	22	LFNB	A	a
TN9	1	ABC	21	NBNN	B	b 4/6
TN17	4	C	7	NBNN/INF	B	b 3/6
TN41	6	CD	12	NBNN/INF	B	b 3/6
TN48	6	AB	16	INF/JUV	A-D	
TN40	6	C	8	INF/JUV	B-C	c
TN21	4	ABC	23	INF	B-C	c
TN32	6	BCD	20	INF	B	b 5/6
TN46	6	ABC	22	INF	B	b 1/6
TN15	3	ABCD	33	JUV	C	d
TN42	6	ABCD	29	JUV	C	d
TN43	6	CD	15	JUV	B-D	e

3 mandibles from Toft's Ness had four teeth (23.1%); 4 mandibles bore three teeth (30.7%); 3 had combinations of two teeth (23.1%), while in 3 cases only single teeth were present (23.1%). No cases of possible double-counting were recognised.

There were 4 borderline anomalies: TN 17, 21, 32 & 41. These were all given a maximum age of 4 weeks by tooth-development ('INF'), but were age-class 'B' (Halstead 1985) by tooth-wear analysis. Of more concern was TN9, whose dp4 scored 'b' by tooth-wear (Grant 1982), and had 4 cusp-points showing wear; hence was awarded age-class 'B' (Halstead 1985). The tooth-development total, at 21 units, was only equivalent to a neonate ('NN', *circa* 2 days-2 weeks). This would have been acceptable if only 2/6 cusps had been worn (Mulville *et al.* (2005)). This result may be contrasted with that of TN46, where a development score of 22 and 1/6 cusp-points worn resolved as 'INF'. The radiographs and photographs of TN9 and TN46 were re-examined, but the same scores were awarded; the former must thus be regarded as a definite anomaly where the two techniques gave contradictory results.

Table 11.32 summarises age-category results for the Neolithic & Bronze Age phase assemblages from Toft's Ness (n=5); equivocal results have been resolved using age-category proportionality (Payne 1973).

Table 11.32: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Neolithic & Bronze Age phase assemblages from Toft's Ness (n=5).

Age category	Number
Foetus (F)	0
Late Foetus-Newborn (LFNB)	1
Newborn-Neonate (NBNN)	1
Infant (INF)	2
Juvenile (JUV)	1
TOTAL	5

Table 11.33 summarises age-category results for the Early Iron Age phase assemblage from Toft's Ness (n=8); equivocal results have been resolved using age-category proportionality (Payne 1973).

Table 11.33: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Early Iron Age phase assemblage from Toft's Ness (n=8).

Age category	Number
Foetus (F)	0
Newborn-Late Foetus (NBLF)	1
Newborn-Neonate (NBNN)	2
Infant (INF)	3
Juvenile (JUV)	2
TOTAL	8

11. 3.4: Earl's Bu: tooth development

Radiographs from 3 mandibles and mandible fragments were examined from excavated material from Earl's Bu. In table 11.34 the individual diagnoses of age category, made using the adapted method of Brown & Chapman (1991a, b), are shown.

Table 11.34: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Earl's Bu assemblage (n=3).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	Phase	Teeth present	Total tooth development score	Age-diagnosis (tooth development)	Age-class (tooth-wear) (Halstead 1985)	dP4 wear (+ cusp wear if 'b')
EB34	X=excl	BC	11	F/LFNB	A	a
EB32	M=V	BC	15	NBNN/INF/JUV	B	b 6/6
EB33	T=LN	C	8	NBNN/INF/JUV	B	b 6/6

2 of the 3 mandible fragments carried two teeth, the other individual had a single tooth. None of the results was anomalous when tooth-wear was compared to tooth development. EB32 was from the Viking phase of the excavation at Earl’s Bu, while EB33 came from the Late Norse phase. EB34, a putative foetus, was unphased. No cases of possible double-counting were recognised.

11.3.5: Snusgar: tooth development

Radiographs from a total of 4 mandibles and mandible fragments were examined from this site. Table 11.35 shows age-category diagnoses from the assemblage, inferred from tooth-development analysis.

Table 11.35: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Snusgar assemblage (n=4).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	**Phase**	**Teeth present**	**Total tooth development score**	**Age-diagnosis (tooth development)**	**Age-class (tooth-wear) (Halstead 1985)**	**dP4 wear (+ cusp wear if ‘b’)**
S14		BC	15	NBNN/INF/JUV	B	b 4/6
S5		ABCD	29	JUV	B	c
S6		ABCD	29	JUV	B	c
S7		ABC	30	JUV	C-E	j

2 of the mandibles had 4 teeth, one had 2, and the other a single tooth. Comparison of the results of tooth-wear and tooth-development was non-controversial; tooth-wear and tooth-development age-diagnoses were in agreement. No cases of possible double-counting were recognised.

11.3.6: Pool: tooth development

Radiographs from a total of 79 mandibles and mandible fragments were examined from the various phases at this site. Table 11.36 shows the individual results from the whole assemblage, arranged by age.

Table 11.36: Tooth-development scores and age-category diagnoses from examination of radiographs of selected mandibles and fragments for tooth development from the Pool assemblage (n=79).
TEETH PRESENT: A=dP2; B=dP3; C=dP4; D=M1.

Study ref.	**Phase**	**Teeth present**	**Total tooth development score**	**Age-diagnosis (tooth development)**	**Age-class (tooth-wear) (Halstead 1985)**	**dP4 wear (+ cusp wear if 'b')**
P21	7.2	C	6	LF/NB/NN	A	b 1/6
P194	NK	C	6	LF/NB/NN	A	a
P199	NK	C	6	LF/NB/NN	A	a
P18	7.2	A	6	F/LF/NB/NN	A-D	
P217	6.7	ABC	20	LFNB	A	a
P210	6.7	ABC	20	LFNB	A	b 1/6
P211	6.7	BCD	17	LFNB	A	a
P173	7.2	ABC	19	LFNB	A	a
P197	7.2	ABC	17	LFNB	A	a
P213	7.2	ABCD	24	LFNB	A	a
P209	8.1	ABCD	23	LFNB	A	a
P175	8.2.2	ABCD	21	LFNB	A	a
P177	8.2.2	ABCD	22	LFNB	A	a
P204	8.2.2	ABC	20	LFNB	A	a
P180	8.1	ABCD	24	LFNB	A	a
P202	8.2.3	ABC	20	LFNB	A	a
P168	NK	ABC	19	LFNB	A	a
P88	NK	ABCD	23	LFNB	A	a
P54	6.7	AB	14	LF/NB/NN	A-D	
P200	6.4	AB	14	LF/NB/NN	A	
P17	7.2	AC	13	LF/NB/NN	A	a
P184	7.2	AC	12	LF/NB/NN	A	a
P218	7.2	AB	13	LF/NB/NN	A-D	
P212	7.2	AB	13	LF/NB/NN	A-D	
P169	8.2.2	BC	13	LF/NB/NN	A	a
P185	8.2.3	AB	14	LF/NB/NN	A-D	
P183	NK	AB	13	LF/NB/NN	A-D	
P89	NK	AB	13	LF/NB/NN	A-D	
P115	6.7	ABC	21	NBNN	A	a
P60	6.4	ABCD	26	NBNN	A	a
P61	6.4	ABC	21	NBNN	A	a
P100	6.4	ABCD	26	NBNN	A	a
P101	6.4	ABC	21	NBNN	A	a
P186	6.1.1	ACD	18	NBNN	A	b 1/6
P196	7.1	ABC	21	NBNN	A	a
P198	7.2	ABCD	25	NBNN	A	a

P215	7.2	ABCD	26	NBNN	A	a
P192	8.2.3	BCD	19	NBNN	A	b 2/6
P119	8.2.3	ABCD	26	NBNN	A	a
P188	8.2.3	ABCD	25	NBNN	A	a
P201	8.2.3	ABCD	26	NBNN	A	a
P116	NK	ABC	21	NBNN	A	a
P51	6.7	CD	12	NBNN/INF	A-B	b 3/6
P193	6.6	C	7	NBNN/INF	B	b 3/6
P8	7.2	C	7	NBNN/INF	A	a
P16	7.2	C	7	NBNN/INF	B	b broken
P20	7.2	BC	14	NBNN/INF	A	a
P110	7.2	A	7	NBNN/INF	A-D	
P189	7.2	C	7	NBNN/INF	B	c
P205	8.2.3	BC	14	NBNN/INF	A	a
P113	NK	BC	14	NBNN/INF	A	
P190	NK	BC	14	NBNN/INF	B	b 1/6
P208	NK	AB	15	NBNN/INF	A-D	
P206	5.1	BC	15	NBNN/INF/JUV	A	a
P195	7.2	BC	15	NBNN/INF/JUV	A	a
P182	8.2.2	BC	15	NBNN/INF/JUV	B	b 4/6
P49	6.7	ABC	23	INF	B	b 6/6
P63	6.4	ABC	23	INF	B	b 6/6
P191	6.3	ABC	22	INF	B	c
P216	6.7	BCD	20	INF	B	b 4/6
P111	7.2	ABC	23	INF	B	b 3/6
P112	7.2	ABCD	27	INF	B	b 3/6
P174	7.1	ABC	23	INF	A	b 1/6
P178	7.2	ABCD	27	INF	B	c
P176	8.1	ABC	22	INF	B	b 4/6
P172	NK	BCD	20	INF	B	b 3/6
P114	NK	ABC	22	INF	A	a
P179	NK	ABCD	27	INF	B	b broken
P171	6.7	ABC	24	JUV	B-C	c
P207	5.2	ABCD	35	JUV	C-D	h
P47	6.7	ABC	24	JUV	B	c
P50	6.7	ABC	30	JUV	B-C	d
P203	6.3	ABC	30	JUV	C-D	h
P181	8.2.2	ABC	27	JUV	B	c
P22	7.2	BC	19	JUV	B-C	d
P38	7.2	ABCD	34	JUV	C	h
P108	7.2	ABCD	29	JUV	B	c
P214	NK	C	10	JUV	C-D	h
P219	NK	ABC	30	JUV	B-C	e

19 mandibles from Pool had four teeth (24.0%); 29 had three teeth (36.7%); 21 had combinations of two teeth (26.6%). There were 10 instances where only single teeth were present in the mandible fragment 12.7%). There are 3 cases where double-counting could

have occurred: P100 & P101 are from the same phase and context, have similar age-diagnoses, and are opposite-handed. The same criteria apply to P210 & P217 and P188 & P201.

There were 13 instances where diagnoses via tooth-development and tooth-wear gave borderline correspondence: P49; 51; 63; 193; 191; 216; 111; 112; 174; 176; 172; 178; 189. All gave tooth-development diagnoses inclusive of age-category ‘INF’ (up to 4 weeks). Apart from the final two instances, in all of these cases, the dP4 was at wear-stage ‘b’ (Grant 1982), with more than 2 cusp-points showing wear (Mulville *et al.* (2005)), giving an age-class ‘B’ (1-8 months) (Halstead 1985). For P178 & P189, the dP4 was wear-stage ‘c’ (Grant 1982), although the age-class was again ‘B’.

Table 11.37 summarises age-category results for Later Iron Age (phase 6) assemblages from Pool (n=21); equivocal results have been resolved using age-category proportionality (Payne 1973). Two of the potential cases of double-counting mentioned above originated from this phase; if valid, they would reduce the total by 2, the number of LFNBs by 1 and the number of NBNNs by 1. The validity or otherwise of these cases is unlikely to affect any subsequent palaeoeconomic interpretations to any great extent.

Table 11.37: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Later Iron Age phase assemblages from Pool (n=21).

Age category	**Number**
Foetus (F)	0
Late Foetus-Newborn (LFNB)	4
Newborn-Neonate (NBNN)	8
Infant (INF)	5
Juvenile (JUV)	4
TOTAL	21

Table 11.38 summarises age-category results for the Scandinavian Interface (phase 7) assemblage from Pool (n=25); equivocal results have been resolved using age-category proportionality (Payne 1973).

Table 11.38: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Scandinavian Interface phase assemblage from Pool (n=25).

Age category	Number
Foetus (F)	1
Late Foetus-Newborn (LFNB)	6
Newborn-Neonate (NBNN)	7
Infant (INF)	8
Juvenile (JUV)	3
TOTAL	25

Table 11.39 summarises age-category results for the Norse (phase 8) assemblage from Pool (n=16); equivocal results have been resolved using age-category proportionality (Payne 1973). One of the potential cases of double-counting mentioned above originated from this phase; if valid, it would reduce the total and number of NBNNs by 1. The validity or otherwise of this case is unlikely to affect any subsequent palaeoeconomic interpretations to any significant extent.

Table 11.39: Age diagnosis summary from examination of radiographs of selected mandibles and fragments for tooth development from Norse phase assemblage from Pool (n=16).

Age category	Number
Foetus (F)	0
Late Foetus-Newborn (LFNB)	7
Newborn-Neonate (NBNN)	6
Infant (INF)	2
Juvenile (JUV)	1
TOTAL	16

11.4: Examination of radiographs from archaeological material using Gjesdal (1969) foetal tooth-development chronology

As discussed in section 9.5.1, this methodology can only be used to diagnose age up to 255 days of gestation, so examinations of radiographs were limited to those previously diagnosed as age-class ‘A’ (Halstead 1985) using tooth-wear analysis. However, so many individuals appeared to be aged beyond the range of the technique, that it was decided to limit further examinations to radiographs from individuals already diagnosed either as foetuses (F), late foetuses (LF), late foetuses/new-born (LF/NB), or foetuses, late foetuses/new-born (F/LF/NB) using the Brown & Chapman (1991a, b) criteria. This amounted to 36 individuals: 28 as ‘LFNB’ and 8 as ‘F/LFNB’. Results of this examination are given in table 11.40.

Table 11.40: Interpretation of radiographs of material categorised as ‘LF, ‘LF/NB’ or ‘F/LF/NB’ by tooth development methodology, using definitions from Brown & Chapman (1991a, b); observations and inferences based on Gjesdal (1969: 210-211, figure 12) (X=tooth missing) (n=36).

Ref	dP2 root	dP2 crown	dP3 root	dP3 crown	dP4 root	dP4 crown	M1 root	M1 crown	Inferred days of gestation (Gjesdal)	Brown &Chap. (mod.) diagnosis
H14	V	formed	½	formed	½	formed	X	X	>255	LFNB
H16	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
H26	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
H47	V	formed	½	formed	½	formed	X	X	>255	LFNB
H61	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
H69	½ ext	formed	½	formed	½	formed	X	X	>255	LFNB
H72	V	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
H73	V	formed	½	formed	½	formed	X	X	>255	LFNB
H115	½ ext	formed	½	formed	½	formed	X	X	>255	LFNB
H118	V	formed	½	formed	½	formed	X	X	>255	LFNB
H147	V	formed	½	formed	½	formed	X	X	>255	LFNB
H179	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
H148	X	X	X	X	½	formed	X	X	>255	F/LFNB
MH78	X	X	X	X	½	formed	0	2 broad goblets	>255	F/LFNB
MH85	X	X	X	X	½	formed	X	X	>255	F/LFNB
MH0.1	X	X	X	X	X	X	0	2 broad goblets	>255	F/LFNB
TN45	X	X	X	X	X	X	0	2 broad goblets	>255	LFNB
TN8	V	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
EB34	X	X	0	formed	0	formed	X	X	<210	F/LFNB
P197	0	formed	½	formed	V	formed	X	X	<243	LFNB
P175	0	formed	½	formed	½	formed	0	2 broad goblets	<243	LFNB
P217	V	formed	½	formed	½	formed	X	X	>255	LFNB
P210	V	formed	½	formed	½	formed	X	X	>255	LFNB
P211	X	X	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P173	V	formed	½	formed	½	formed	X	X	>255	LFNB
P213	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P209	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P177	V	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P204	0	formed	½	formed	½	formed	X	X	<243	LFNB
P180	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P202	½ ext	formed	½	formed	½	formed	X	X	>255	LFNB
P168	0	formed	½	formed	½	formed	X	X	<243	LFNB
P88	½ ext	formed	½	formed	½	formed	0	2 broad goblets	>255	LFNB
P194	X	X	X	X	½	formed	X	X	>255	F/LFNB
P199	X	X	X	X	½	formed	X	X	>255	F/LFNB
P21	X	X	X	X	V	formed	X	X	>255	F/LFNB

Roots description (after Grant, 1982: 95): 0 = none visible; V = just visible; ½ = half-extended; U = almost complete; A = complete (n=22).

5 putative foetuses were diagnosed using this technique: EB34, P175, P197, P204, & P168; these diagnoses were based on the absence of a visible root (‘0’ = ‘none visible’ in table 11.60) in the dP2, dP3 or dP4. However, this may be a conservative estimate, as Gjesdal (1969) does not specify the degree of root development required for age estimation (figures 3.6a & b, table 8.11). If this were to exclude an incipient root (‘V’ = ‘just visible’ in table 11.40), 12 more individuals would be diagnosed as foetal. If ‘root’ equated with a fully developed root in Gjesdal’s figures 3.6a & b (1969) and table 8.6 all the individuals listed in table 11.40 would be foetal, as in no case were roots ‘complete’.

11.5: Results comparisons; quality checks

Four methods were used to quality-check results of age-diagnoses made using the Brown & Chapman (1991a, b) adapted method as utilised in section 11.3 *et seq*. The results for unequivocally aged individuals using this method were first compared to the age-classes derived using tooth-wear analysis for the same animal, providing the age-classes were also unequivocally diagnosed. Secondly radiographs from individuals diagnosed as putative foetuses were examined using the tooth development chronology described by Gjesdal (1969), age-diagnoses from which are independent of the study control assemblage. Thirdly, the age-diagnoses obtained by metrical analysis of the mandible in 5 individuals from Pool (table 11.1 above) were compared to corresponding results by the tooth-development technique. Finally, the results for tooth-wear analysis, mandible metrical analysis and tooth development analysis (Brown & Chapman 1991a, b methodology) of the material from the control site at The Bedern, York were examined and assessed.

11.5.1: Comparison of unequivocal diagnoses by tooth-development analysis with those using tooth-wear analyses.

The results of the tooth development analyses for all the archaeological sites, using the methodology based on the developmental criteria of Brown & Chapman (1991a, b), summarised above in sections 11.3.1-11.3.6, were examined, and the reference number and age-category noted in each case where an unequivocal diagnosis was made. These references were then checked against individual tooth-wear results (shown in appendix V (on CD-ROM)), and in cases where an unequivocal age-class diagnosis was made, the corresponding age-class result noted. The results of this survey are summarised in table 11.41.

Table 11.41: Summary of unequivocal diagnoses of tooth development age-category (rows) (n=81) with corresponding unequivocal tooth-wear age-class results (columns); data collated from all 7 archaeological sites.

Tooth-wear age class (Halstead 1985) → ↓ Tooth Development (Brown & Chapman ↓ 1991a, b) age category	**A: 0-1 months**	**B: 1-8 months**	**C: 8-18 months**
F or LFNB (foetus or late foetus-newborn)	32	0	0
NBNN (newborn-neonate: birth- 2 weeks)	14	1	0
INF (infant: between 2 and 4 weeks)	2	17	
JUV (juvenile: more than 1 month old)	0	8	7

All tooth-development age-categories up to ‘INF’ (2-4 weeks) should, in theory, be in tooth-wear age-class ‘A’ (0-1 month; Halstead 1985). There were no anomalies in category ‘F/LFNB’, but one ‘NBNN’ was in age-class ‘B’; this was TN9, which was discussed above in section 11.2.2.3. Among the ‘INF’ age-category, 17 individuals were from tooth-wear age-class ‘B’ (1-8 months; Halstead 1985). These were from various contexts and were also discussed above; they have been classed as only marginally anomalous, since 'INF' and age-class 'B' are consecutive. All members of the 'JUV' category fell into acceptable age-classes.

There are two main observations that can be made from these data. The tooth-development methodology may be reading low, giving earlier age-categories when compared to tooth-wear; this may be due to a variation in tooth-development timing between ancient stock and the modern control assemblage, where modern tooth-development events more rapidly than with calves in antiquity. Alternatively, the sensitivity of the modification suggested by Mulville *et al*. (2005: 171) may have been set too low; perhaps dP4 teeth with more than 2 cusp-points showing wear might be given wear-stage 'a/b'. As mentioned earlier, this is reinforced by the 3/6 cusp-point-wear seen in the dP4 of the modern control DS6, age-attested at 19 days (table 8.1). Table 11.42 is a breakdown of the cusp-wear of the 17 individuals from table 11.41 above diagnosed 'infant' (INF: 2-4 weeks) at age-class 'B' (1-8 months (Halstead 1985)):

Table 11.42: Tooth-wear stages (Grant 1982) of dP4 where tooth-development age diagnosis was 'INF', and tooth-wear age-class (Halstead 1985) was 'B' (n=17).

dP4 wear stage and cusp wear (Grant 1982; Mulville *et al.* 2005)	**'b' 1/6**	**'b' 2/6**	**'b' 3/6**	**'b' 4/6**	**'b' 5/6**	**'b' 6/6**	**'c'**	**dP4 broken**
Number of individuals	2	0	4	2	3	2	3	1

Individuals had a spectrum of wear from a single cusp-point to wear-stage ‘c’ (Grant 1982). If the ‘INF’ diagnosis is valid, this appears to indicate that mastication, culminating in wear, must have been initiated at an early age after birth. Mulville *et al*. (2005: 171), quote Serjeantson, who reported observing slight wear on teeth *in utero*. Ruminants have been seen to ‘proto-chew’ before birth (Fraser & Broom 2002: 200-201), which might reinforce this view, although none of the foetal, stillborn or new-born individuals in the modern control assemblage of this study showed any signs of wear in the mandibular molariform teeth (tables 9.2 & 9.3). However, one individual, P21, from the archaeological assemblage, had 1/6 cusp-wear, was diagnosed as Halstead (1985) age-class ‘A’ by tooth-wear, ‘LFNB’ by tooth-development, and a foetus of less than 240 days using Gjesdal’s tooth-development sequence (1969); if valid, this may have been a case of tooth-wear *in utero*.

As mentioned in section 9.1, these data generally corroborate the modification suggested by Mulville *et al.* (2005) to age-class ‘A’ (Halstead 1985), that individuals with up to 2/6 cusp-points in wear on the dP4 be included, although the result for DS6 suggests that 2/6 may be a conservative estimate. These animals probably reflect the modern practice of weaning onto solid food (calf starter ration and hay) at around 2 weeks; recommended for home-reared, bucket-fed calves (Webster 1984: 49), which could initiate tooth-wear. This practice may also have been initiated at a similar age in ancient cattle.

11.5.2: Examination of radiographs from archaeological material using Gjesdal (1969) foetal tooth-development chronology

Table 11.43 shows the collated tooth-wear and tooth-development (Gjesdal 1969 and Brown & Chapman 1991a, b) results for the 5 individuals diagnosed as putative foetuses using the latter technique.

Table 11.43: collated results for individuals diagnosed as foetuses using the Gjesdal (1969) tooth development sequence (all<255 days gestation).

Ref	Teeth present	Foetal age (days of gestation) using Gjesdal (1969) sequence	Age-category based on Brown & Chapman (1991a, b) method	Age-class using tooth-wear analysis (Grant 1982; Halstead 1985)
P175	ABCD	<243	LFNB	**A**
P197	ABC	<243	LFNB	**A**
EB34	BC	<210	F/LFNB	**A**
P204	ABC	<243	LFNB	**A**
P168	ABC	<243	LFNB	**A**

These results correlate satisfactorily; all were diagnosed as foetuses using the tooth-development radiographic techniques. Tooth-wear based age-diagnoses were all in the youngest age-class ‘A’ (0-1 month post-natal; Halstead 1985); this demonstrates the inadequacy of this method for the age-diagnosis of very young or foetal animals.

11.5.3: Comparison of results from metrical examination of mandible with those from tooth-development

5 mandibles from Pool were sufficiently intact to allow measurement of parameters ‘A’ and ‘C’ (sections 8.7.2 & 11.2.1). All were subsequently diagnosed as aged 8-9m gestation using the study criteria (table 11.7). Tooth-wear analysis resulted in all 5 being assigned to

age-class ‘A’ (less than 1 month) (Halstead 1985). Tooth-development analysis produced results varying around new-born (NB). These results are summarised in table 11.44.

Table 11.44: collated results for individuals age-diagnosed using metrical analysis of mandibles.

Reference	**Age diagnosis using metrical analysis of mandible**	**Age-class using tooth-wear analysis (Grant 1982; Halstead 1985)**	**Age-category using tooth-development analysis based on Brown & Chapman (1991a, b)**
P60	LFNB	A	NBNN
P180	LFNB	A	LFNB
P201	LFNB	A	NBNN
P215	LFNB	A	NBNN
P209	LFNB	A	LFNB

These metrical age-category results correlate well with those from tooth-development and tooth-wear analyses. All are diagnosed age-class ‘A’ (Halstead 1985) by tooth-wear analysis, which covers animals from 0-1 month, while the two ‘LFNB’ (7 months gestation to birth) diagnoses by tooth-development are similar to the metrical results, and the 3 ‘NN’ (birth to 2 weeks) results correspond with an age-diagnosis around the point of birth.

11.5.4: Examination of material from the archaeological control site at The Bedern, York.

The 8 mandibles from York were collected to act as archaeological controls to the Orkney site material. The Bedern, as an urban English mediaeval ecclesiastical context, is in complete contrast to the marginal maritime Orkney sites, where the majority of phases were Iron Age or early Norse. It has been suggested that the infant deaths from The Bedern were the result of slaughter for calfskin to produce parchment (Hamshaw-Thomas 2001: 623). Age-diagnosis of these mandibles by tooth-wear and tooth-development is summarised in table 11.45. This table also shows the patterns of cusp wear in the dP4 where the wear-stage result for that tooth was ‘b’. Individual tooth-scores are shown in Appendix VI on the accompanying CD-ROM.

Table 11.45: Tooth development scores and diagnoses for material selected from The Bedern, York (archaeological control site) assemblage; age-classes diagnosed by tooth-wear analysis and dP4 cusp-wear patterns are shown in the final columns (n=8).

Ref.	**Tooth dev. score**	**Code**	**Age category (tooth dev.)**	**Age-class (tooth wear)**	**dP4 wear-stage; cusp-points worn if ‘b’**
BY01	24	ABC	JUV	B	b 6/6
BY02	22	ABC	INF	B	b 5/6
BY03	13	CD	INF/JUV	B	c
BY04	24	ABC	JUV	B	b 3/6
BY05	24	ABC	JUV	B	b 6/6
BY06	13	CD	INF/JUV	B	b 4/6
BY07	22	ABC	INF	B	b 6/6
BY08	13	CD	INF/JUV	B	b 6/6

These results tend to reinforce the earlier discussion in section 11.3.1 concerning age-class ‘B’ (Halstead 1985). All of these individuals were consigned to that class, despite the unequivocal diagnosis of 2 animals, BY02 & BY07 as ‘infants’ (INF: 2-4 weeks) using the tooth-development methodology; cusp-wear on the dP4 for these was 5/6 and 6/6 respectively. These are again only marginally anomalous, since ‘INF’ and ‘JUV’ are consecutive categories. The remaining animals were variously ‘juveniles’ (JUV: >4 weeks), or INF/JUV, both of which categorisations correlate with age-class ‘B’.

As mentioned above in section 11.1, one of these mandibles, BY06, was sufficiently intact for metrical examination; no age-diagnosis could be inferred (table 11.2) since the ratio value was beyond the range of interpretation curve, whose end-point was at 9 months gestation/birth; however, since the result value was greater than the end-point, the individual can be assumed to have been post-natal, which corresponds with the other age-diagnoses derived by tooth-wear and tooth-development.

11.6: Archaeological results: summary.

This synthesis of results appears to justify the use of the tooth-development technique (developed from Brown & Chapman 2001a, b) as an adjunct to tooth-wear analysis (Grant 1982; Halstead 1985, incorporating Mulville *et al.* 2005), in order to sub-categorise results diagnosed as less than one month by the latter technique. A number of marginal anomalies, where individuals have been placed into a temporally adjacent category using tooth-development compared to the diagnosis for tooth-wear, could be partially reconciled by adjusting the cut-off for dP4 cusp-wear suggested by Mulville *et al.* (2005), perhaps from 2/6 cusp-points to 3/6 or 4/6. This is reinforced by data from the modern control assemblage. Results from the archaeological control site (The Bedern, York) correspond with these findings.

There remains a single more anomalous result where the age-category diagnosed by tooth-development appears to be adrift from that of tooth wear by a matter of 2 weeks (TN9). Despite a review of the data for both methods, these diagnoses stand; however, adjusting the cut-off for dP4 cusp-wear from 2/6 to 4/6 cusps (Mulville *et al.* 2005), as discussed, in effect, extending from the first to the first and second double-cusp of the dP4, would entirely reconcile this result. The examination of more modern age-attested mandibles aged between birth and 2 months would be necessary, however, before consideration could be given to validating this modification.

Of the other methods attempted, metrical examination of the mandible appears of only marginal value, since few archaeological examples of the element were sufficiently intact, and the method appeared to be valid only for later foetal material, using the available modern controls. The tooth-development sequence published by Gjesdal (1969) was also of only limited use since data were limited to foetuses of less than 255 days gestation, and some of the verbal descriptions of development stages were somewhat vague, imprecise, and difficult to reconcile with what was seen on the radiograph. However, it was herein used as an adjunct to tooth-wear and tooth-development (Brown & Chapman 1991a, b) in order to confirm a foetal diagnosis.

CHAPTER 12: ARCHAEOLOGICAL ASSEMBLAGES: RESULTS (ii) & INTERPRETATIONS

12.0: Introduction

This chapter contains interpretations of animal-exploitation inferred from the results of tooth-wear analyses of the bovine bone material recovered from various phases of the archaeological study sites, as presented in the previous chapter. In addition, the corresponding mortality implications of the age-diagnoses made on neonate material from each phase are given, based on examinations of radiographs for tooth-development (using the modified method of Brown & Chapman (1991a, b)), and also presented in the last chapter. Where possible, a composite inference of palaeoeconomic strategy made from a synthesis of the two sets of results will then be made.

In general, two models of interpretation of bovine neonatal mortality will be tested: abortion or neonate mortality versus culling for dairying. The former would be indicated by age diagnosis, using tooth-development analysis, of foetuses (F or LFNB) or neonates up to around 2 weeks (NBNN), while culling might be indicated by calves aged greater than 2 weeks (INF or JUV). This is based on the premise discussed earlier (section 8.0), that in unimproved cattle, the minimum age at which the calf can be disposed of without threatening the lactation of the dam is around 10 days at the earliest (Halstead 1998: 6).

After a brief description of the phasing sequence at each site, bar-charts, representing age-at-death population profiles, based on the results of tooth-wear analysis, are shown for each of the archaeological study sites. In all cases results are given in terms of individual temporal site phases. Interpretations are inferred, in terms of possible animal exploitation strategies, for each site temporal phase, following conventional lines loosely based on Payne's ovine models, and by consideration of the alternative model of bovine age-at-death for an economy based on milking, postulated by Vigne & Helmer (2007: 29) (as discussed in section 2.2.1). Where appropriate, comment is made concerning the effect, if any, cases of potential double-counting (as discussed in sections 10.3 & 11.2) would have had on interpretation.

In addition, bar-charts are presented representing the age distribution of neonate mandibles and mandible fragments selected from the assemblage for radiography and subsequent analysis for tooth development patterns, using the modified version of the methodology of Brown & Chapman (1991a, b) (discussed in section 3.5.2 and described as adapted for this study in sections 8.8.3, 9.6 *et seq.* and 10.4.1). In subsequent discussions, these bar-charts are taken to represent the age distribution pattern for neonates in the entire population, although they only represent a proportion of the material submitted for wear analysis, since loose teeth from archaeological assemblages, as discussed earlier, are unsuitable for radiography, due to possible taphonomic damage. Comment is made in each case, where appropriate, upon how the age-distribution pattern for neonates might modify any inferences about cattle exploitation using conventional means by tooth-wear analysis, particularly in the light of ethnographic observations made of milk let-down in recent Greek herding with 'unimproved' cattle (Halstead 1998: 6).

Results are given for the temporal site phases summarised in table 10.2, and reproduced in table 12.1. Inter-phase comparisons of interpretation may be used to demonstrate diachronic palaeoeconomic changes. In some cases phasings from different sites are contemporary, so that inter-site comparisons can be made.

Table 12.1: summary of site phases (from table 10.2).

SITE	**PHASE**
Mine Howe	Mid-Later Iron Age
	Later Iron Age
Howe	Early Iron Age
	Middle Iron Age
	Later Iron Age
	Mid-Later Iron Age
Toft’s Ness	Neolithic/Bronze Age
	Early Iron Age
Earl’s Bu	Viking Period
	Late Norse Period
Snusgar	Norse Period
Pool	Early Iron Age
	Later Iron Age
	Scandinavian Interface
	Norse Period

Where published reports of excavations are available, for Howe, Toft’s Ness and Pool, inferences drawn from this study on possible bovine exploitation strategies are compared with those published in the animal bone reports. In most cases, speculative aetiologies for foetal neonate mortality will be given where appropriate, in the light of age-diagnoses derived from tooth-development studies and any specific factors relevant to the site. These will be based on tables 5.5 & 5.6, which showed the most likely potential disease aetiologies at specific calf ages and gestation stage, and are reproduced below (tables 12.2 & 12.3).

Table 12.2: some common infectious causes of bovine abortion (after Canant 1984: 931).

Age	**Cause of sporadic abortion**	**Cause of epizootic abortion**
1st trimester (0-3 months gestation)	BVD Trichomoniasis	BVD Trichomoniasis
2nd trimester (4-6 months gestation)	Campylobacter	IBR
3rd trimester (7-9 months gestation)	Listeriosis Mycotic abortion *Arcanobacterium pyogenes* Salmonellosis	Brucellosis Leptospirosis

Table 12.3: Common causes of early calf mortality showing age of peak incidence.

Calf Age	**Condition**
Birth	Dystocia (calving difficulty)
0-1 week	Diarrhoea due to *E. coli*
	Navel-ill
1-2 weeks	Diarrhoea due to Rotavirus
	Diarrhoea due to *Cryptosporidia* species
2-6 weeks	Diarrhoea due to Salmonellosis
5-10 weeks	Calf pneumonia; due to BVD, IBR, RSV, PI3, Adenoviruses, *Mycoplasma* species, *Pasteurella* species, etc.

12.1: Mine Howe

This Iron Age site and its excavation, commencing in 2000, were described in section 4.2. Radiocarbon dating produced various date ranges for a number of phases, listed in table 12.4. Phases with prefix ‘E’ were from the ‘workshop’ area of the site, while those with prefix ‘D’ were from the ditch surrounding the mound and its terminals. Phases E8 and D12 were excluded from the population summaries below, as they may have included some modern material (date ranges c. 7th century AD to modern). Roughly 25% of the Mine

Howe assemblage examined for tooth wear came from 'E' phases, and 75% from 'D' phases. Of the material examined for tooth development by radiography, 25 were 'D' phase and 11 'E' phase.

Table 12.4: Date ranges from phases at Mine Howe. Prefix E = workshop; prefix D = ditch (Mainland 2007).

Phase	Date range
E3	c. 170BC-80AD
E4	c. 150BC-150/220AD
E4.1	c. 170/120BC-70AD
E4.2	c. 180/120BC-70AD
E4.3	c. 170BC-110/220AD
E4.4	c. 60BC-130/230AD
E6	c. 1^{st} and 2^{nd} centuries AD
E7	60/130AD-540AD
E8	c. 7^{th} century AD to modern

Phase	Date range
D4	c. 1^{st} century BC – 1^{st} century AD
D5	c. 10AD-220AD
D6	20AD – 240AD
D7	20AD – 240AD
D8	a little later than 40BC – a little later than 210AD
D9	c. 50AD – c. 260/320AD
D10	c. 120AD – c. 380/420AD
D11	c. 250AD – c. 420AD
D12	c. 7^{th} century AD to modern

For the purposes of this study, two temporal phases were identified for analysis: Mid to Later Iron Age, and Later Iron Age only. The latter was represented by Ditch phases D10 and D11 (n=102), while the earlier phase was the conflated total of all phases (n=224), including D10 & D11, but excluding the modern phases E8 & D12. This enables intra site comparison with the Later Iron Age phases from Pool and Howe, and with a Mid to Later Iron Age conflation from Howe.

12.1.1: Mine Howe: Mid-Later Iron Age phases

Figure 12.1 shows a combined population profile, prepared from the age-at-death diagnoses (Halstead 1985) derived from tooth-wear-stage analyses (after Grant 1982: Mulville *et al*. 2005) of the assemblages from phases specified in section 12.1 above.

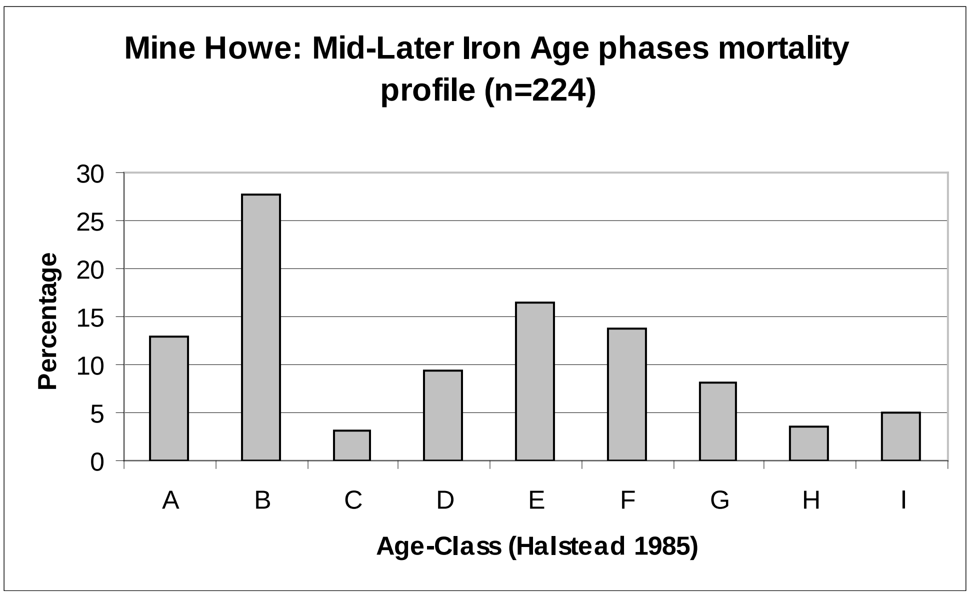


Figure 12.1: Mine Howe: bar-chart showing bovine mortality profile of Mid-Later Iron Age phases based on tooth wear analysis (n=224).

This profile appears to demonstrate a heavy death toll among the neonates of age-classes 'A' & particularly 'B' (0 to 1 month; 1 to 8 months), with further smaller peaks around 'E' and 'F' (2 to 3 years; 3 to 4 years), followed by a diminishing attrition rate to 'I' (senile) (Halstead 1985: 219, table 35) (table 8.4). In the neonate age-classes this appears to follow Payne's 'milk' model, where, once lactation was established, there appears to have been deliberate slaughter of unwanted neonates, probably males; a proportion of the remaining females being kept as the kernel of the milking herd.

Here, however, the peaks in ‘A’ and ‘B’ are reversed: Payne’s ovine model shows more deaths in class ‘A’ than ‘B’. This could indicate that at Mine Howe there may have been a delay in maintaining let-down without the presence of the calf, hence delaying early slaughter, or that some calves were selectively fattened for veal, with slaughter at around 6 months. In Payne’s ‘milk’ model, however, beyond ‘B’ there is a gradual diminution of the population, as older animals, predominantly milking cows, die off through old age or sickness or are slaughtered when seen to be barren (Payne 1973: 203). Here, there appears to have been selective slaughter between the ages of 2 and 4 years; at around the optimum period in terms of weight gain for cattle to be slaughtered for meat (Hambleton 1999: 78). Hence this mortality pattern might be loosely interpreted as ‘combined milk and meat’ in terms of Payne’s paradigms.

Alternately, these animals from age-classes ‘E’ and ‘F’ might represent barren heifers in a ‘milk’ economy which had failed to conceive and calve and hence been culled for meat; in current Western dairy husbandry, the target for delivery of the first calf is 2 years of age (Leaver 1999: 27). However, this may be delayed for a further 2 or 3 years in marginal conditions such as the Northern Isles (Serjeantson & Bond 2007b: 204).

The Mine Howe Mid – Later Iron Age phases mortality pattern closely follow that suggested by Vigne & Helmer for Neolithic dairying, mentioned in section 2.2.1. Here, calves were retained during the maternal lactation, on the assumption that their presence was necessary for milk-let down, and slaughtered at 5-9 months (i.e. age-classes ‘B’ to ‘C’ (Halstead 1985)), while worn-out cattle were slaughtered at 4-8 years (‘F/G’ to ‘H’) (Vigne

& Helmer 2007: 29). Some additional slaughter for meat might account for the earlier peaks at ‘E’ and ‘F’.

The potential number of individuals in this combined phase that may have been double-counted (50) is considerable; in particular, 27 possible cases of shed teeth. However, the total phase assemblage comprises 224 individuals. The possible shed teeth are restricted to age-classes ‘D’ to ‘I’ (Halstead 1985), they represent 21% of the total in those classes. If all cases of double-counting were valid, the percentage distribution as represented in figure 12.1 would probably be only slightly affected, with the earlier age-classes gaining slightly at the expense of those from ‘D’ to ‘I’. Palaeoeconomic interpretations as discussed above would be generally unaffected.

37 mandibles from the Mid – Later Iron Age phases at Mine Howe (excluding E8 & E9) were suitable for radiography and subsequent tooth-development analysis. The age-category cohorts predicted from the analysis are shown in figure 12.2.

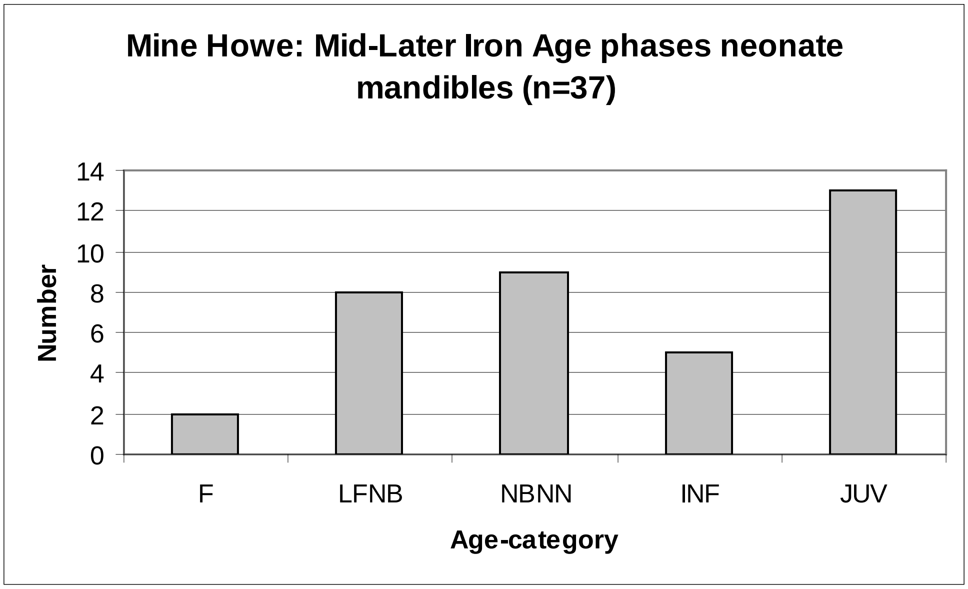


Figure 12.2: Mine Howe: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from Mid-Later Iron Age phases (n=37).

10 individuals were foetal or late-foetal/newborn individuals (‘F’+‘LFNB’). Since 36.5% of the study assemblage consisted of mandibles and mandible fragments rather than loose teeth (table 10.1), assuming the loose teeth were aged in similar proportions to the mandibles and fragments, this represents roughly 12.1% of the whole assemblage. The two putative foetuses (‘F’) recovered were likely to have been second-trimester abortions; from table 12.2, possible abortifacients might have been IBR or *Campylobacter* species; the late foetuses/new-born (LFNB) animals may have aborted or been born dead through Listeriosis, Mycotic abortion, *Arcanobacterium pyogenes* infection, Salmonellosis, Brucellosis or Leptospirosis (table 12.2). However, maternal nutritional insufficiency may have been a contributory factor towards abortion or stillbirth. Alternatively, calving difficulties or infection of the unhealed navel may have lead to the death of the infant, or it may have succumbed to scour caused by *Escherichia coli* (table 12.3).

As mentioned previously, it has been suggested that anthropogenic slaughter of neonates to maximise milk for human consumption may not proceed till the lactation has been securely initiated by suckling of the offspring, which occurs around the 10th day after birth at the earliest (Payne 1973: 302, Halstead 1998: 6); this would probably preclude the 9 new-born/neonate animals ('NBNN'; birth-2 weeks). These represent around 11% of the entire assemblage; possible infectious causes of death would have been diarrhoea due to Rotavirus, *Cryptosporidia* species or *Escherichia coli* infections (table 12.3). Together with the putative abortions and stillbirths mentioned above, these represent around 23% of the whole assemblage.

This does not appear to indicate that there was a particularly heavy anthropogenic slaughter of neonates that might have been expected in a dairying palaeoeconomy by some authorities (for example, Legge 1981a: 86-87, 1981b: 172, 1989: 226-227, 2005: 12). Perhaps some males may have been slaughtered at a later stage to maximise milk for human consumption (Payne 1973: 281), represented by the 'infants' or 'juveniles' in the same figure; their ages coincide with those suggested to reflect security of lactation in first- and subsequent calvers, as mentioned above (Halstead 1998: 6). As mentioned in section 11.3.1, a single juvenile (JUV) may have been double counted, as left- and right-mandibles were recovered from the same site context and similarly age-diagnosed. Given the numbers of juveniles identified, the validity or otherwise of this case does not affect interpretation.

12.1.2: Mine Howe: Later Iron Age phases

Figure 12.3 shows the mortality profile for the Later Iron Age phases from Mine Howe (ditch phases D10 & D11).

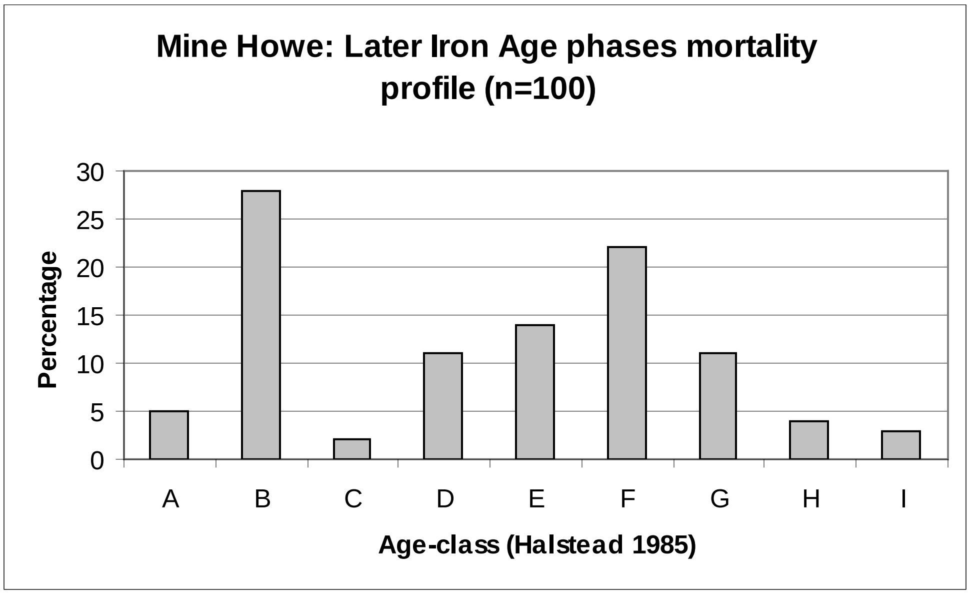


Figure 12.3: Mine Howe: bar-chart showing bovine mortality profile of Later Iron Age phases based on tooth wear analysis (n=100).

There are two clear peaks of mortality in this profile: age-class ‘B’ (1-8 months; 28% of the death population) and age-class ‘F’ (3-4 years; 22% of the death population). There is a rising progression through ‘C’, ‘D’ & ‘E’, and a declining progression through ‘G’, ‘H’ & ‘I’. This again appears to correlate closely with the pattern for Neolithic milking suggested by Vigne & Helmer (2007), discussed above in section 12.1.1. Following Payne (1973), however, this would again be a combined milk/meat exploitation pattern as discussed for the Mid-Later Iron Age phase grouping.

Validity of the 11 potential cases where shed teeth may have been counted would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 16.9%. The overall total of potential double counting through all age-classes is 23 (23%). If all these cases were valid, this would only marginally alter the distribution pattern in figure 12.4; hence the interpretation given above would remain largely intact.

12 mandibles and fragments of mandible from the Later Iron Age phases were diagnosed by tooth-wear analysis to be from individuals in age-classes ‘A’ & ‘B’, and hence radiographed for age-diagnosis by tooth-development analysis, using the adapted methodology of Brown & Chapman (1991a, b), described in sections 8.8.3, 9.6 *et seq.* and 10.4.1. The percentage distribution of the various age-categories is shown in figure 12.4.

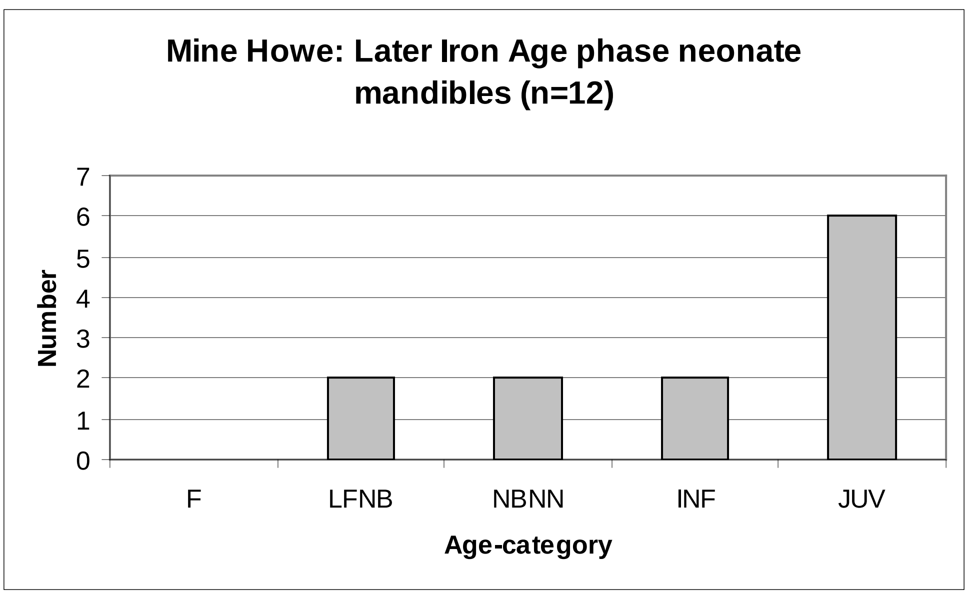


Figure 12.4: Mine Howe: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from Later Iron Age phases (n=12).

The majority of these neonate mandibles appear to have been ‘juvenile’ (>1 month). These animals could also have been reared for early slaughter and perhaps consumed on site in feasting in the autumn; alternatively, they may represent animals slaughtered post-lactation, following the pattern for Neolithic milking suggested by Vigne & Helmer (2007), discussed above in section 12.1.1. This is reinforced by the peak (28%) of age-class ‘B’ in figure 12.4. ‘LFNB’ and ‘NBNN’ individuals, which, as discussed above, were possibly attritional deaths, represented 11% of the phase population; ‘LFNB’ individuals, almost certainly abortions, stillbirths, or died at or around birth, were 5.5% of the population.

12.1.3: Mine Howe: summary

In general terms, the findings from Mid-Later and Later Iron Age phases at Mine Howe suggest that both meat and milk may have been exploitation strategies in cattle-keeping; however, there appears to be little to suggest that there was deliberate slaughter of infants to facilitate the latter strategy, in the pattern suggested by some authorities (for example, Legge 1981a, b, 1989, 2005) using Payne’s ovine paradigms (1973). This might suggest that calves were retained during lactation, as necessary to stimulate milk let-down. In both phase-groupings, there was some suggestion that calves may have been fattened for autumn slaughter, this may be reinforced by the putative ‘ritual’ nature of the site. In discussing the palaeoeconomics of cattle domestication at Mine Howe, it is important to consider possible human social activity at the site, as inferred from initial reports of the excavations from 2000 to 2005, and discussed in section 4.2. The principal structures revealed consisted of an underground chamber within a mound, with a circumferential ditch perforated by a causeway; adjacent to this, a roundhouse, used for metalworking activity. Apart from this, no evidence of domestic structures was found; activity on the site within and around the underground chamber can probably be inferred as ‘ritual’, with the structure being used, perhaps, as an oracle. The transformation of ore or bog-iron to metal implements within the round house may also have been seen at some stage as a ‘ritual’ activity. The three human interments found around the site may reinforce this interpretation (Harrison 2005).

This ‘ritual’ context of Mine Howe must be taken into account when interpreting these findings, as this may skew the analysis. Deposits in the terminals of a circumferential ditch around a possible ‘ritual’ structure and chamber might be expected to reflect possible uses of the structure; perhaps debris from feasting or sacrificial offerings may have been involved during periods of use, together with any potential domestic detritus from the workshop structure. Layers of animal bone found in the ditch terminal (Harrison 2005: 9), could reinforce the concept of feasting, seasonal celebrations or some form of structured deposition perhaps taking place at the site at some stage. Grant suggests that animal sacrifices may represent animals that were of no use or were burdensome to a community (1984: 225-226); such as, perhaps, infant and juvenile calves, possibly male, brought from adjacent settlements for slaughter at the ritual structure. These factors, combined with the lack of any obvious local settlement, must render analysis of the mortality findings from Mine Howe somewhat tenuous; there may be a problem of equifinality, in that the bone deposition could be from a combination of processes giving an aggregate result which could produce an erroneous inference (Halstead 1998: 5).

12.2: Howe

As mentioned in section 4.4, the excavation at Howe, near Stromness, was carried out between 1978 and 1982; the excavation report was published in 1994 (Ballin Smith). A number of phases were identified, based in general on the structural remains. These are listed in table 12.5, giving the approximate period for each phase.

Table 12.5: Periods of occupation based on phases at Howe (Ballin Smith 1994).

Phase	Period
3	Early Iron Age
4	Early Iron Age
5	Early Iron Age
6	Early Iron Age
7	Middle Iron Age
8	Late Iron Age farmstead and settlement
9	Modern

For the purposes of this study, three temporal phases will be analysed: Early Iron Age (phases 3-6 above); Middle Iron Age (phase 7) and Later Iron Age (phase 8). A conflation of Mid to Later Iron Age phases will also be prepared for later comparison of inferences with those from the equivalent conflated phase from Mine Howe.

12.2.1: Howe: Early Iron Age phases

Figure 12.5 shows the mortality profile based on bovine tooth-wear analysis for the Early Iron Age Phases at Howe.

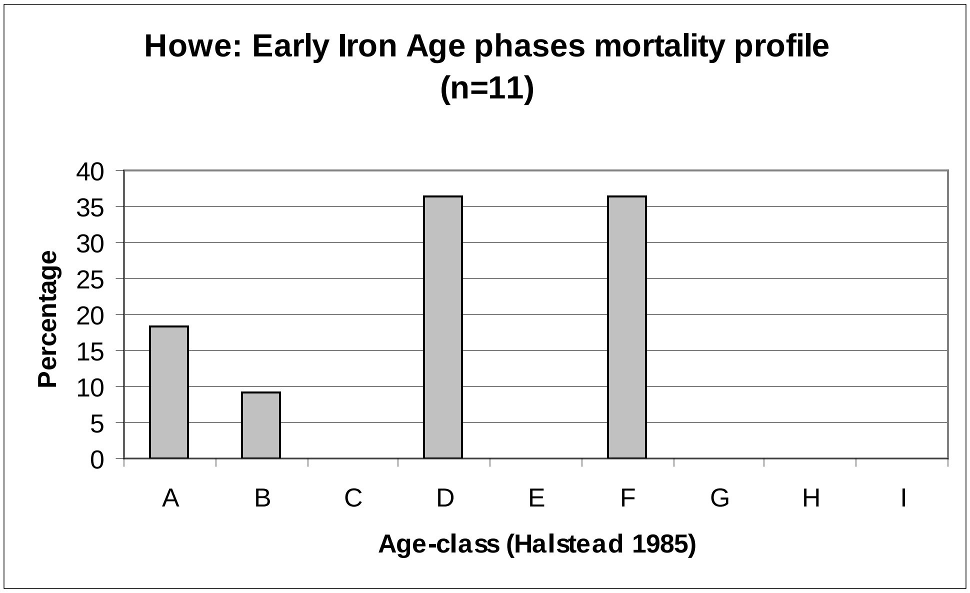


Figure 12.5: Howe: bar-chart showing bovine mortality profile of Early Iron Age phases based on tooth wear analysis (n=11).

This limited profile (n=11) shows peaks of attrition at age-class ‘D’ (18-30 months) and ‘F’ (young adult) (Halstead 1985), together with the death of around 25% of the population in neonate classes ‘A’ & ‘B’. As such it might be taken to represent exploitation for ‘meat’, shown by the deaths of prime animals in age-class ‘F’, combined with ‘milk’, indicated by the neonate peaks (Payne 1973). The peak at age-class ‘D’ (18-30 months) could also represent culling the herd for meat; in modern dairy herds, calves not required as dairy replacements may be reared for beef and killed at 1-2 years (Webster 1999: 49). Vigne & Helmer’s Neolithic dairying paradigm, mentioned in section 2.2.1, is also a possibility in this case, as no cattle survive beyond age-class ‘F’, when, it was suggested, worn-out cattle were slaughtered. However, the peak indicating early death of calves in age-class ‘A’, and that of deaths at 18-30 months are less suggestive of this pattern (Vigne & Helmer 2007: 29).

Validity of the 3 potential cases where shed teeth may have been counted would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 37.5%. The overall total of potential double counting through all age-classes is 4 (36.4%). If all these cases applied, however, this would reduce the number of valid individuals to 7, probably rendering the profile insufficient for satisfactory interpretation.

Only a single mandible from this temporal phase was suitable for radiography. This resolved as a probable ‘new-born’ death after tooth-development analysis.

12.2.2: Howe: Middle Iron Age phases

The majority of material from Howe for tooth-wear analysis came from phase 7 (n = 93), spanning the Middle Iron Age. Figures 12.6 shows the mortality profiles based on tooth wear data from this phase.

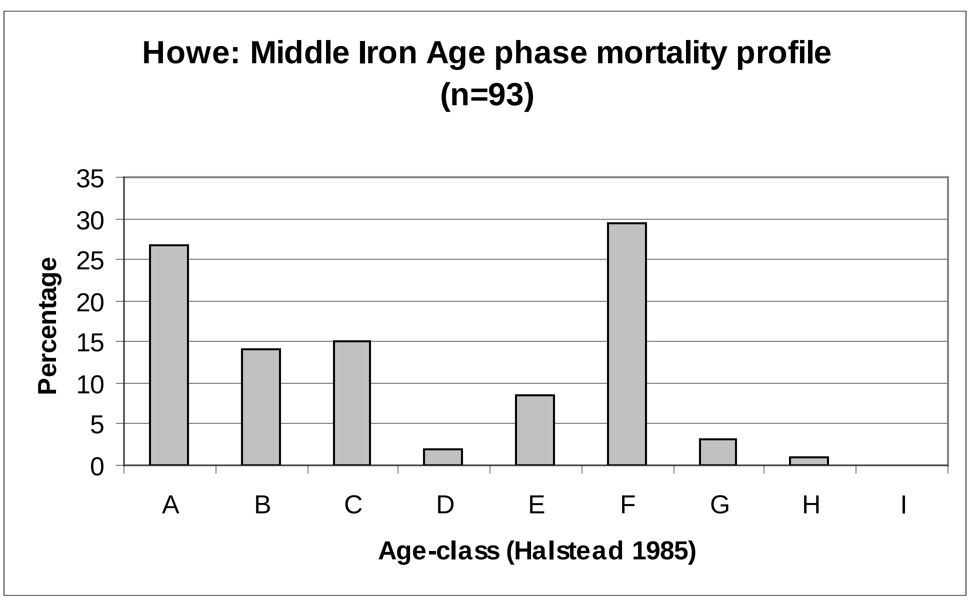


Figure 12.6: Howe: bar-chart showing bovine mortality profile of Middle Iron Age phase based on tooth wear analysis (n=93).

The two major peaks of mortality in age-class A (0-1 month) and age-class F (young adult) (Halstead 1985: 219, table 35), (table 8.4), seem to indicate another combined meat/milk cattle exploitation strategy. More than 25% of the population appear to have been slaughtered within the first month of age, perhaps to maximise milk for human consumption, while the later peak of nearly 30% could indicate animals taken for meat in their prime. Very few animals appear to have survived beyond the 'young adult' cull into age-classes G, H & I; hardly enough to represent a milking herd, perhaps representing breeding stock only; however, material from adult animals may have been deposited elsewhere, at an outlying farm supplying Howe. Hence this mortality profile might represent a 'meat' pattern only; the peak of mortality during the first month may be attritional deaths rather than anthropogenic slaughter.

Validity of the 7 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 17.1%. The overall total of potential double counting through all age-classes is 23 (24.7%). If all these cases were valid, this would, however, only marginally alter the distribution pattern in figure 12.6; hence the interpretation given above would remain largely intact.

The peak in age-class 'F' fits Vigne & Helmer's Neolithic dairying paradigm (2007: 29); post-lactational slaughter could also be indicated by the deaths in 'B' & 'C'. This hypothesis appears to be partly reinforced by the tooth-development analysis of neonate mandibles and mandible fragments taken from this phase at Howe (n=14) (figure 12.11), since examination of radiographs of these elements revealed that 18% of the phase population were juveniles (age-category 'JUV'). However, 'LFNB' and 'NBNN' individuals represent 21% of the phase population, having perhaps succumbed to one or another of the abortifacients listed in table 12.2, or via maternal causes, such as uterine infections, or dietary insufficiency as a result of a lack of green feed following poor forage collection the previous year. This can lead to vitamin A deficiency in the dam resulting in the birth of dead or weak calves, which then succumb rapidly. Surviving neonate individuals were unlikely to have been subject to an anthropogenic cull to maximise milk availability from their respective dams for human consumption, since at this very early stage at or after birth, it has been suggested that, in unimproved cattle, milk let-down would not yet have been securely established (Halstead 1998: 6; Payne 1973: 281).

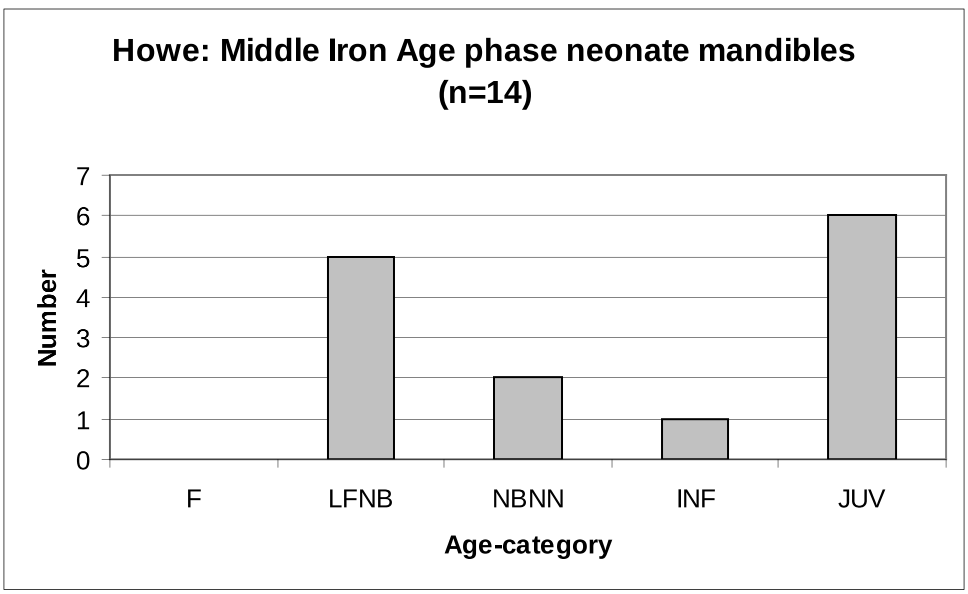


Figure 12.7: Howe: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from Middle Iron Age phases (n=14).

'Broch 2', extant in phase 7 (Middle Iron Age) had what were interpreted as yards and byres (figure 4.12); animals may have been stalled for the winter (Smith 1994: 149).

Evidence, in the form of straw with adherent dung, was found and interpreted to be from a milk-fed calf (Dickson 1994: 126-127), from which calf-rearing might be inferred; these may have been slaughtered as ‘juveniles’ in the autumn, or died from colitis or salmonellosis.

The single example of potential double-counting among the material examined for tooth development was diagnosed as ‘juvenile’, as mentioned in section 11.3.2. Its provenance or otherwise would have had little impact on interpretation.

12.2.3: Howe: Later Iron Age phase

The mortality profile of phase 8 of the Howe assemblage, dating from the Late Iron Age, and associated with the farmstead and settlement is presented in figure 12.8.

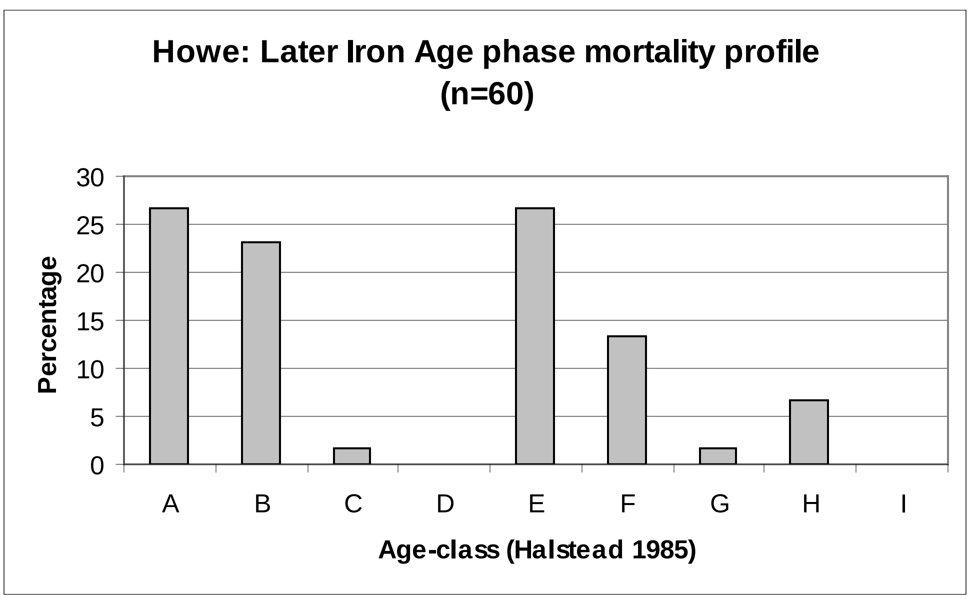


Figure 12.8: Howe: bar-chart showing bovine mortality profile of Later Iron Age phase based on tooth wear analysis (n=60).

After more heavy mortality among the neonates of age-class A (0-1 month), in this case there were also many deaths among age-class B (1-8 months) (Halstead 1985: 219, table 35). Together these represent half of the mortality among the cattle population; this would be a typical figure for anthropogenic slaughter. However, contrary to Payne's 'milk' model (1973), there is little mortality among animals of age-classes C & D; this is succeeded by another peak (>25% of the population) at age class E (30-36 months).

This would seem to indicate animals being taken for slaughter at early maturity, perhaps in autumn culls to conserve fodder over the winter. A reasonable number of animals seem to have survived into age-classes 'F', 'G' & 'H' (though none to age-class 'I' (senile)); these may represent milking/breeding cattle. Hence this profile could again be interpreted as representing a combined milking/meat palaeoeconomy. Validity of the 3 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 10.3%. The overall total of potential double-counting through all age-classes is 7 (11.7%). If all these cases were valid, this would, however, only marginally alter the distribution pattern in figure 12.8; hence the interpretation given above would remain largely intact.

Figure 12.9 represents the age-diagnoses inferred from radiographs taken of neonatal mandibles from the Howe phase 8 assemblage, based on the criteria published by Brown & Chapman (1991a, b).

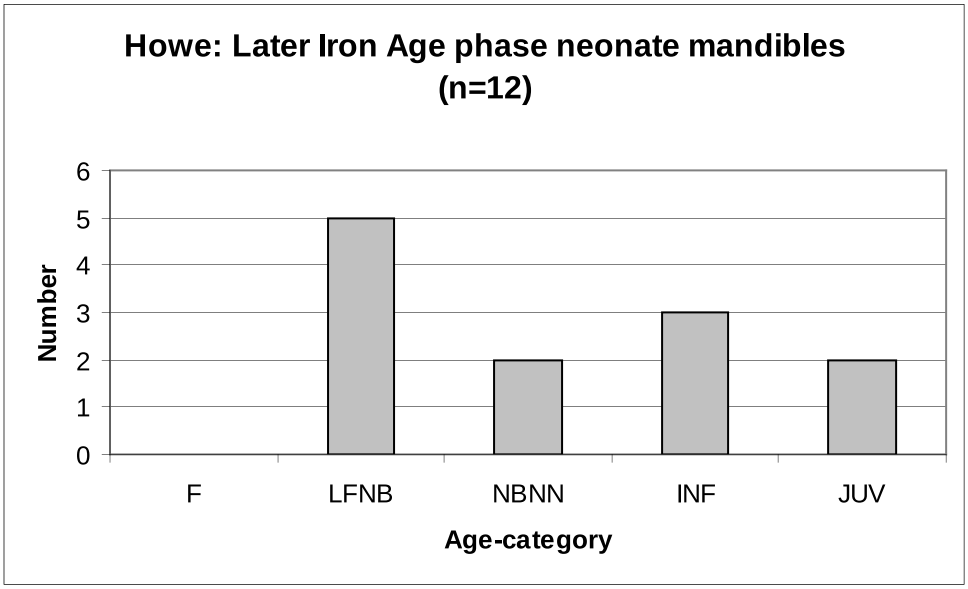


Figure 12.9: Howe: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Later Iron Age phases (n=12).

The pattern appears to indicate a more serious calf health problem in the later Iron Age than in the earlier period. The late foetuses/new-born (LFNB) animals may have aborted or been born dead through Listeriosis, Mycotic abortion, *Arcanobacterium pyogenes* infection, Salmonellosis, Brucellosis or Leptospirosis (table 12.2). Stillbirths may also have been the result of maternal nutritional insufficiency. A single fruiting body of *Juniper communis* was found, unburnt, in a hearth in phase 8 (Dickson 1994: 132); this plant, as well as having medicinal qualities, is also a bovine abortifacient; its presence here may indicate that the plant was available locally, and could have represented a threat to browsing pregnant animals. Animals categorised with an age-at-death of ‘LFNB’ or ‘NBNN’ represent 33% of the total phase population; ‘LFNB’ individuals, almost certainly abortions, stillbirths, or died at or around birth were 23% of the population.

12.2.4: Howe: combined Mid-Later Iron Age phases

Figure 12.10 shows the mortality profile for the combined Middle and Later Iron Age Howe assemblages. These figures include material from phases 7, 7/8 and 8 (the animal population in this phase combination is greater than the sum total of the two phases (7 & 8) discussed above in sections 12.2.2 & 12.2.3, since animals categorised as 7/8 are included).

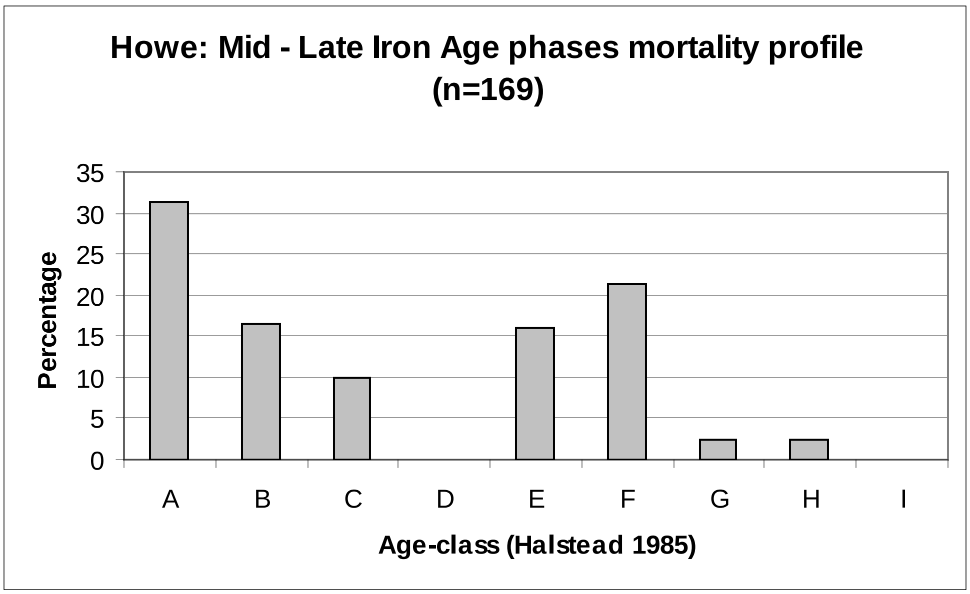


Figure 12.10: Howe: bar-chart showing bovine mortality profile of Mid-Later Iron Age phase based on tooth wear analysis (n=169).

As can be seen, the conflated profile resembles that from the Middle Iron Age phase (figures 12.6) in most respects. There are peaks in age-classes ‘A’ (0-1 month) and ‘F’ (young adult), and also lesser maxima in classes ‘B’ (1-8 months) ‘C’ (8-18 months) & ‘E’ (30-36 months), mirroring the early pattern, probably indicating a combined meat-milk economy. Vigne & Helmer’s Neolithic dairying paradigm (2007) may, however, also be indicated here, with age-classes ‘B’ and ‘C’ as candidates for post-lactational slaughter, while age-classes ‘F’, ‘G’ & ‘H’ could indicate worn-out dairy cows. Alternatively, this could indicate autumn slaughter of fattened calves. Validity of the 10 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 14.1%. The overall total of potential double counting through all age-classes is 37 (21.9%). If all these cases were valid, this would, however, only marginally alter the distribution pattern in figure 12.10 due to their distribution throughout age-cohorts with the earlier age-classes gaining slightly at the expense of those from 'D' to 'I'; hence the interpretation given above would remain largely intact.

The histogram showing the age-distribution of neonate mandibles for the combined assemblage (figure 12.11), however indicates that nearly half of those examined, those in the 'late foetus/new-born' age-category, were highly likely to have been attritional deaths rather than human culls.

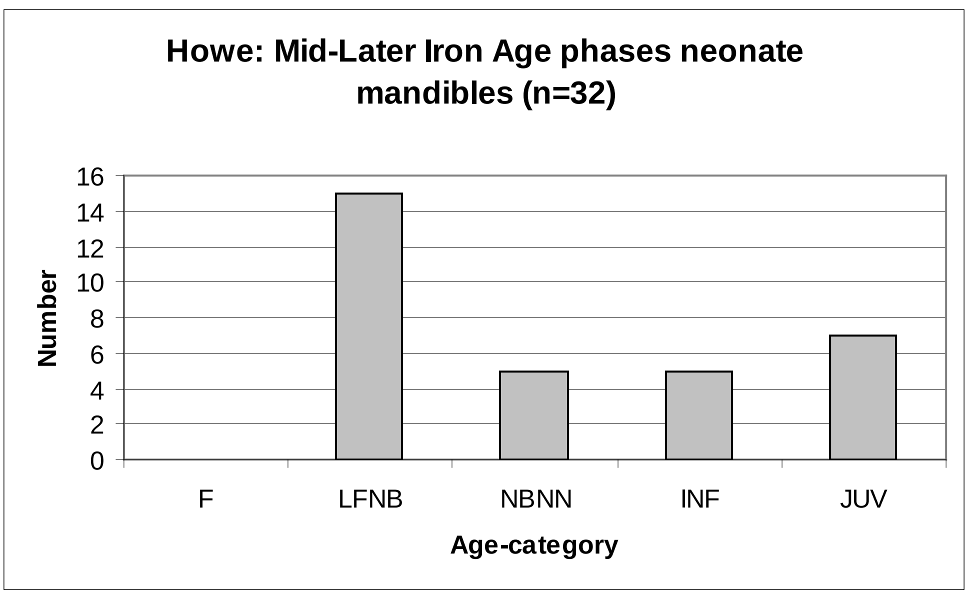


Figure 12.11: Howe: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Mid-Later Iron Age phases (n=32).

These ‘LFNB’ animals probably correlate with the individuals diagnosed as age-class ‘A’ (Halstead 1985) by tooth-wear analysis in figure 12.10. Unless infectious agents, such as those listed in table 12.2, were involved, deaths may have been the result of poor nutrition in pregnant dams over winter, with insufficient green feed resulting in iodine and vitamin A insufficiencies; a deficiency of the former results in the pituitary increasing the production of thyrotrophic hormone. Living calves die if chilled (Andrews 1986: 238). Pregnant cows need at least twice the vitamin A of non-pregnant animals; deficient dams may abort late, due to placental degeneration, or produce weak calves; the colostrum will also be vitamin A deficient, so surviving calves may succumb rapidly (Andrews 1986: 245). ‘LFNB’ and ‘NBNN’ deaths represent 33% of the combined phase populations; ‘LFNB’ individuals alone, almost certainly abortions, stillbirths, or died at or around birth were 25% of the population. Two potential examples of double-counting, one juvenile and one late-foetus-new-born (LFNB) were present in the assemblage examined for tooth-development from this temporal phase (section 11.3.2). Their validity would have little or no effect on interpretation.

12.2.5: Howe: summary

Using tooth-wear analysis and Payne’s models (1973) the palaeoeconomy at Howe in each of the temporal phases discussed appears to have involved the exploitation of cattle for both milk and meat. Use of the tooth-development methodology, however, seems to have made these diagnoses less secure, as in each case a high proportion of neonates were inferred to have died at birth. This does not preclude dairying, but it does appear to indicate that husbandry practices and environmental conditions may have been poor, as would perhaps be expected in marginal contexts as on Orkney, hence the deaths would have been the result of environmental determinism, as suggested by McCormick (1998: 51). Surviving calves may have been kept alive, both to prolong lactation and promote let-down and to be fattened for the autumn cull before winter.

The published animal bone report on Howe recognises the high infant mortality rate among cattle, and also suggests this was due to poor husbandry rather than killing off the animals deliberately for meat. It notes that defective animals were not culled, but allowed to survive to maturity (Smith 1994: 148-9). Lactating cattle could have been used to provide milk for human consumption for a period at least once a year, but "whether prolongation of lactation in cows was considered worth the effort is open to doubt" (*ibid.*151). Smith may be implying that stratagems such as dummy calves or cow-blowing were unlikely to have been utilised. She also emphasises the extent to which cattle were multi-functional: as well as meat and milk, providing traction for ploughs and carts, skins for clothing and leather goods, and dung for manure (*ibid.*). None of the findings in this study contradict her analysis.

12.3: Tofts Ness

Toft's Ness, Sanday, was excavated between 1983 and 1988; occupation was identified between the Neolithic and Early Iron Ages (Dockrill 2007), as discussed in section 4.5. Suitable bovine study material was recovered from 5 temporal phases at Toft's Ness; these corresponded to the periods indicated in table 12.6.

Table 12.6: Periods of occupation based on phases at Toft's Ness (Dockrill 2007).

Phase	Period
1	Neolithic
3	Early Bronze Age
4	Late Bronze Age
5	Intermediate phase
6	Early Iron Age

For the purposes of the analysis, phases 1, 3 & 4 were combined into a Neolithic-Bronze Age grouping, while phase 6 was analysed as Early Iron Age. There was insufficient material for analysis in the Intermediate phase.

12.3.1: Tofts Ness: Neolithic & Bronze Age phases

Figure 12.12 shows the mortality profile histogram, based on tooth-wear analysis (after Grant 1982; Payne 1973) for Neolithic and Bronze Age phases at Toft's Ness.

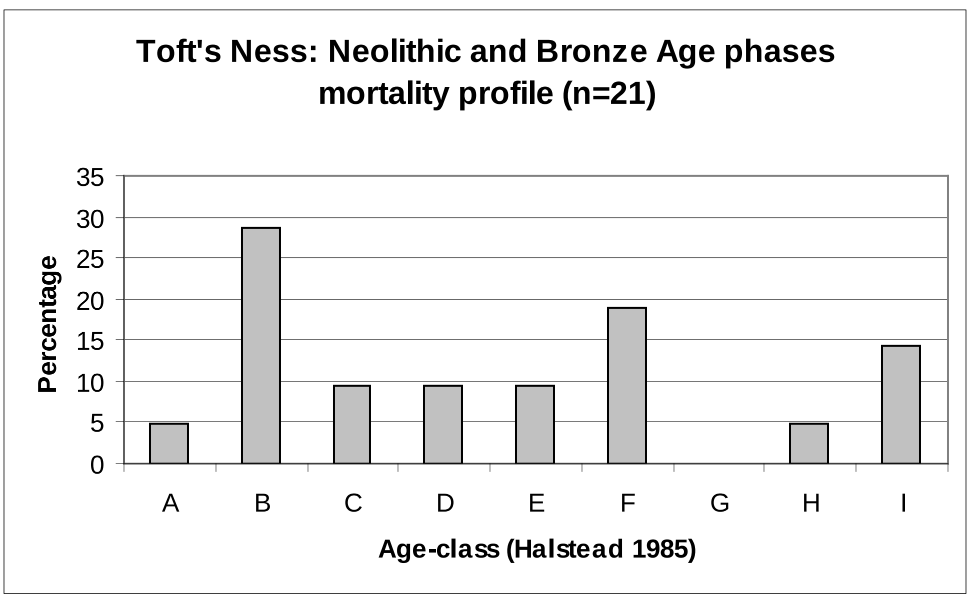


Figure 12.12: Toft's Ness: bar-chart showing bovine mortality profile of Neolithic and Bronze Age phases based on tooth wear analysis (n=21).

This profile appears to resemble the paradigm suggested by Vigne & Helmer (2007: 29) for dairying in the Neolithic, where calves are slaughtered at 5-9 months once the lactation of their dams is complete, the presence of the calves ensuring continued let-down of milk, and allowing a part-share for human consumption. This would account for the peak of deaths in age-class 'B' (Halstead 1985). The second maximum on the histogram at age-class 'F' might in this case represent a cull of worn-out dairy- or breeding cows. However, a reasonable proportion of animals (around 20%) appear to have survived into old age and senility (age-classes 'H' & 'I'). Validity of the 4 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 33.3%. If all these cases were valid, this would marginally alter the distribution pattern in figure 12.12 towards the more juvenile age-groups; however, the interpretation given above would probably remain largely intact.

Figure 12.13 shows a bar-chart of the age-category distribution of mandibles and fragments diagnosed by tooth-development methodology (based on tooth development criteria published by Brown & Chapman 1991a, b). Only a limited number of mandibles (n=5) were available in these phases, and probably indicate attritional deaths over a range of ages. Palaeoeconomic interpretations based on these reduced figures must be very tentative.

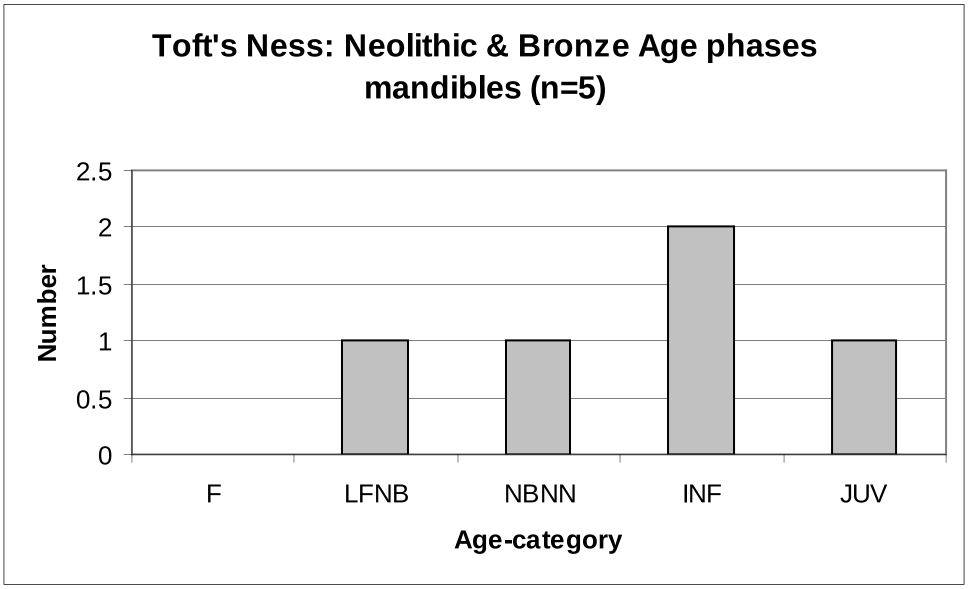


Figure 12.13: Toft's Ness: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from Neolithic & Bronze Age phases (n=5).

Possible abortifacients for the putative late abortion (LFNB) might include *Neospora caninum*, since examples of the canine primary host were recovered in the Neolithic and Bronze Age phases (Nicholson & Davies 2007: 174). Another possibility would be *Arcanobacterium pyogenes*; this organism, which causes sporadic abortion, can be acquired through foul-in-the-foot ulcers (Canant 1985: 108), which is often associated with dairying, as inferred in this phase, through husbandry practices such as mud and dung caking, and stony cow tracks. 'LFNB' and 'NBNN' individuals comprise 19% of the total phase population.

12.3.2: Tofts Ness: Early Iron Age phase

Figure 12.14 shows the mortality profile for the Early Iron Age phase at Toft's Ness, based on the results of tooth-wear analysis.

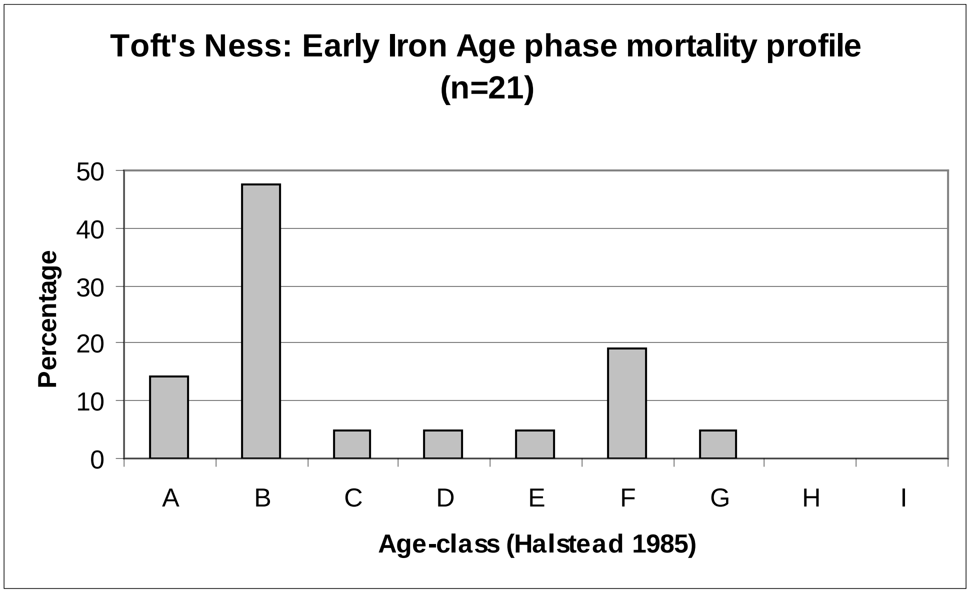


Figure 12.14: Toft’s Ness: bar-chart showing bovine mortality profile of Early Iron Age phase based on tooth wear analysis (n=21).

This result appears similar to that for the Neolithic and Bronze Age phases (figure 12.13), with peaks of death in age-classes ‘B’ (48% of total population) & ‘F’ (19%) (Halstead 1985). However, the proportion dying in the early age-classes is well in excess of that for the preceding phases; in the Neolithic and Bronze Ages the total for ‘A’ & ‘B’ was 33%, while in the Early Iron Age, this proportion was nearly doubled at 62%, while in both phases around the same proportion of young adults (18-19%) were being slaughtered in age-class ‘F’ (Halstead 1985: 219, table 35) (table 8.4). This could represent a dairying palaeoeconomy, with a particularly heavy slaughter of neonates after milk let-down was established, and cows rigorously slaughtered at 5 years or so as worn-out. This mortality pattern also resembles that for Neolithic dairying suggested by Vigne and Helmer (2007), described in the preceding section in the discussion of the Neolithic and Bronze Age assemblages at this site; in this case, however, most of the post-lactation calves appear to be in age-class ‘B’ rather than ‘C’, and the dairy cows would all appear to have been slaughtered by 5 years, which more closely follows the paradigm. Validity of the single potential case where a shed tooth may have been counted would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 14.3%; this would, however, only marginally alter the distribution pattern in figure 12.14; hence the interpretation given above would remain largely intact.

The bar-chart representing age-diagnoses based on examination of radiographs of neonate mandibles for tooth-development (using the criteria published by Brown & Chapman 1991a, b), should help clarify this (figure 12.15). For a ‘milking’ economy, there should be a peak of slaughter commencing around 10-15 days, representing the earliest age that let-down in the dam was secure (based on modern unimproved cattle) (Halstead 1998: 6). This is represented by the ‘infant’ age-category using this methodology. Meanwhile for the Vigne & Helmer paradigm, post-lactation slaughter would commence at 5-9 months (2007: 29). If represented here at all, such animals would appear in the ‘juvenile’ age-category.

In fact, the bar-chart does appear to shows a peak of mortality the ‘infant’ category, which correlates with ‘milking’; fewer juveniles were diagnosed than would have been expected with Vigne & Helmer (2007). Hence an interpretation of the distribution might be that it represents ‘milking’ with some resort also to ‘meat’.

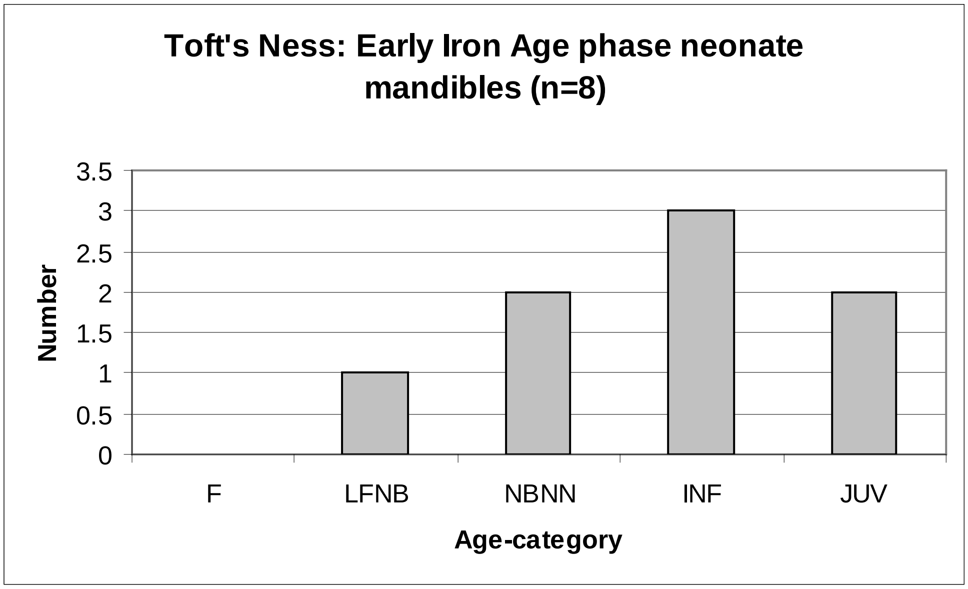


Figure 12.15: Toft’s Ness: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Early Iron Age phase (n=8).

However, the numbers involved in this analysis (n=8) make any inferences somewhat tenuous; the 3 cases of ‘infant’ (2-4 weeks) mortality could easily have been the result of attritional death, Salmonellosis or pneumonic infections might have been implicated. The ‘late foetus/newborn’ and ‘new-born/neonate’ deaths may again have been the result of dietary insufficiency, leading to vitamin A deficiency, which causes late abortions and weak or dead calves at birth, particularly in heifers (Andrews 1986: 245). ‘LFNB’ and ‘NBNN’ individuals represent 29% of the phase population; the ‘LFNB’ individual, almost certainly an abortion, stillbirth, or which died at or around birth represents 10% of the population.

12.3.3: Toft's Ness: summary

The use of tooth-wear analysis for age-diagnosis on bone assemblages allocated to these two temporal phases from Toft's Ness has produced bovine mortality profiles which both appear to resemble the paradigm suggested by Vigne & Helmer (2007: 29) for dairying in the Neolithic, which implies that the presence of the calf was necessary to maintain milk let-down. In both the Neolithic/Bronze Age and Early Iron Age phases the highest proportion of neonate deaths appeared to be 'infants' (2-4 weeks), however, which appears to contradict this paradigm, since calves would have been expected to survive at least till juvenile. However, the low numbers involved in the tooth-development analyses make any inferences placed on this evidence somewhat tenuous. In both cases there appeared to be evidence for deliberate slaughter in mature cattle around 5 years of age, presumably slaughtered for meat.

In the Neolithic/Bronze Age phases, a relatively high proportion (14%) of adults were allowed to survive into senility, beyond the age at which they would be productive for meat or milk. This population might represent individuals used for traction, such as ploughing or drawing carts (Hambleton 1999: 78).

These considerations suggest that farmers at Toft's Ness may have behaved pragmatically and reactively, using such animals that survived as circumstances permitted, for milk, meat and for tractive effort. Additional slaughter of young animals would have been precluded since many would have succumbed to environmental factors in this marginal location. The fact that human settlement at the site probably did not appear to continue beyond the Early Iron Age is probably indicative of this marginality.

The published cattle and sheep husbandry report on the excavation at Toft's Ness (Serjeantson & Bond 2007: 202-206), within the excavation report (Dockrill 2007) differentiates the palaeoeconomics of bovine husbandry between the temporal phases. In the Neolithic and Bronze Age, it was suggested that milk was shared with the live calf by controlled access in an non-intensive regime, animals being kept on after weaning until the grass failed in autumn (*ibid*: 206). In contrast, a subsistence economy in the Iron Age was said to allow slaughter of a proportion of calves as soon after birth as lactation had been established in the dam; as well as maximising milk for human consumption this could have provided meat at the leanest time of the year, and a skin for hide or vellum. Rennet could also be harvested from the stomach (*ibid.*) for use in cheese-making.

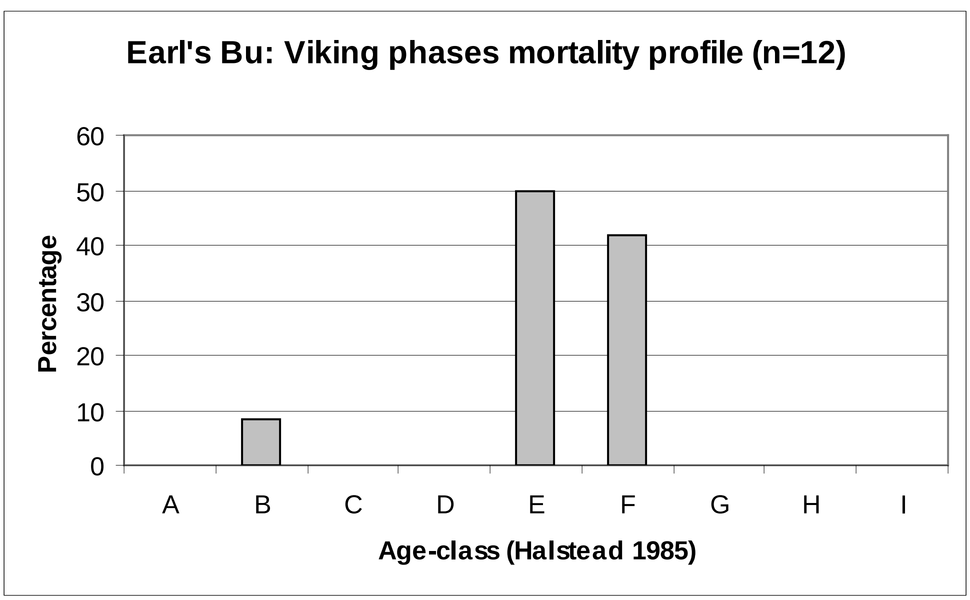
In general terms, the published interpretation for the Neolithic and Bronze Age phases, briefly described above, agrees with that of this study, corresponding well with the Neolithic milking model proposed by Vigne & Helmer (2007). Serjeantson & Bond's interpretation for the Early Iron Age (2007: 206) appears to correspond to some extent with Payne's 'milk' model (1973) of animal exploitation; although this conclusion appears to be corroborated by the data presented here, the numbers involved in the radiographic analysis are insufficient to draw firm inferences.

12.4: Earl's Bu

The excavation of Late Norse middens at Earl's Bu, leading to the discovery of a putative horizontal mill, took place in 1988-1989, and was described in section 4.6. Two temporal phases were identified from the animal bone assemblage for the purposes of this study, a Viking phase underlying and preceding a Late Norse (13/14th century) phase (Mainland 2009 pers. comm.). Unfortunately, the number of mandibles, mandible fragments or dP4/M3 teeth from each of these phases was somewhat limited (Viking: n=12; Late Norse n=8).

12.4.1: Earl's Bu: Viking phases

Figure 12.16 shows the mortality profile based on tooth-wear analysis expressed as a bar-chart of age-classes (Halstead 1985).



12.16: Earl's Bu: bar-chart showing bovine mortality profile of Viking phases based on tooth wear analysis (n=12).

These data appear to indicate that the majority of animals slaughtered at Earl's Bu in the Viking period were young adults, almost certainly killed for meat. Apart from the single age-class 'B' (1-8 months), which could have been a veal-calf, the lack of animals in other age-classes also appears to indicate that this profile could represent biased sampling, in this case probably animals brought from elsewhere to the high-status site for feasting purposes. Validity of the 3 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 27.3%; if these cases were valid, this would, however, only slightly alter the distribution pattern in figure 12.16; hence the interpretation given above would remain largely intact.

Tooth-development analysis of the single neonate produced a diagnosis of 'new-born/neonate' (0-7 days old); this does not accord with the tooth-wear-based diagnosis of an age-class 'B' calf (1-8 months; Halstead 1985), but instead appears to represent a stillborn or very young calf, perhaps from a cow brought in for slaughter. Reference has already been made to the anomalous results from this individual, TN9, in section 11.3.3.

12.4.2: Earl's Bu: Late Norse phases

The bar-chart in figure 12.17 represents the age-class distribution diagnosed by tooth-wear analysis of bovine material from Late Norse phases at Earl's Bu.

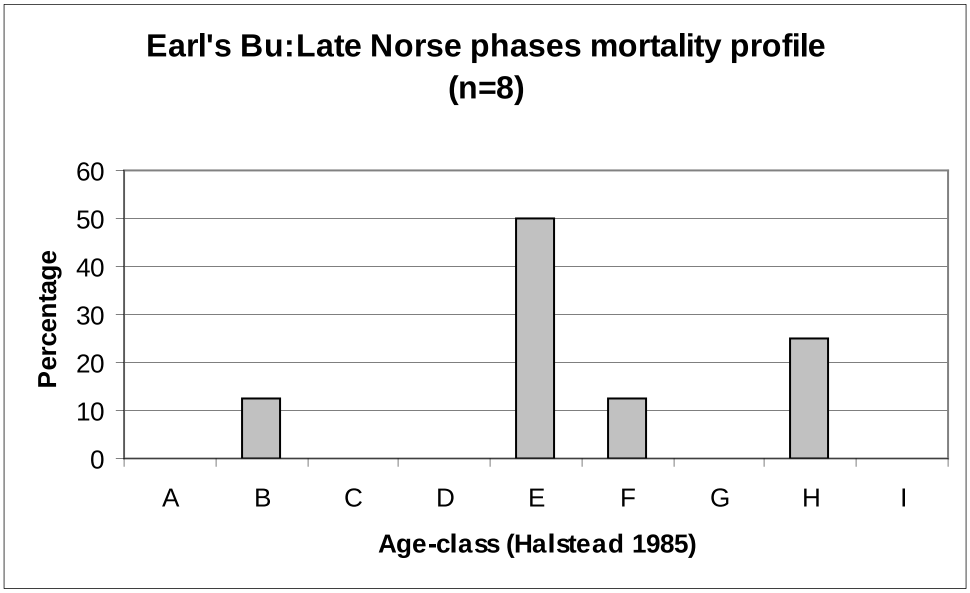


Figure 12.17: Earl's Bu: bar-chart showing bovine mortality profile of Late Norse phases based on tooth-wear analysis (n=8).

Apart from the single neonate, which could be a veal calf, this profile again shows adult animals, probably brought in for slaughter and consumption in the putative 'Earl's Hall' (discussed in section 4.6). A partial assemblage may again be indicated; these animals were probably reared on a farm associated with the hall, or on one in the local area, or brought in as tribute. In this case the neonate resolves as 'infant' (2-4 weeks old) by tooth-development, which is again probably too young for a veal-calf. Validity of the 3 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 42.9%. The overall total of potential double counting through all age-classes is 4 (50%). If these cases were valid, this would probably render the distribution pattern in figure 12.17 impossible to interpret due to limited population (n=4).

12.4.3: Earl's Bu: summary

In contrast to the other sites studied, the animal remains recovered from both Viking and Late Norse phases at Earl's Bu appear to originate from cattle that were utilised for meat. However, it is unlikely that they represent an entire population; the middens in this excavation consisted of dumps from buildings including the Earl's Hall (Batey & Morris 1992: 33), so were probably formed, in part, from the detritus of feasting rather than from a stock-farm. Hence comparisons with Payne's (1973) animal exploitation models should be treated with caution.

12.5: Snusgar

Excavations at Snusgar, so far unpublished and incomplete, commenced in 2003 on the site of a supposed Norse fortification and find-site of a silver hoard (section 4.7). Material consisting of 16 mandibles, fragments and loose dP4 or M3 teeth were identified from a single 'Norse' phase in the excavations at Snusgar, in trenches '1' & '3', dug in an area representing a possible fortification (Mainland & Ewens 2006). Figure 12.18 shows a bar-chart indicating the percentage population in each of 9 age-classes (Halstead 1985), diagnosed from this dental material using tooth-wear analysis (Grant 1982).

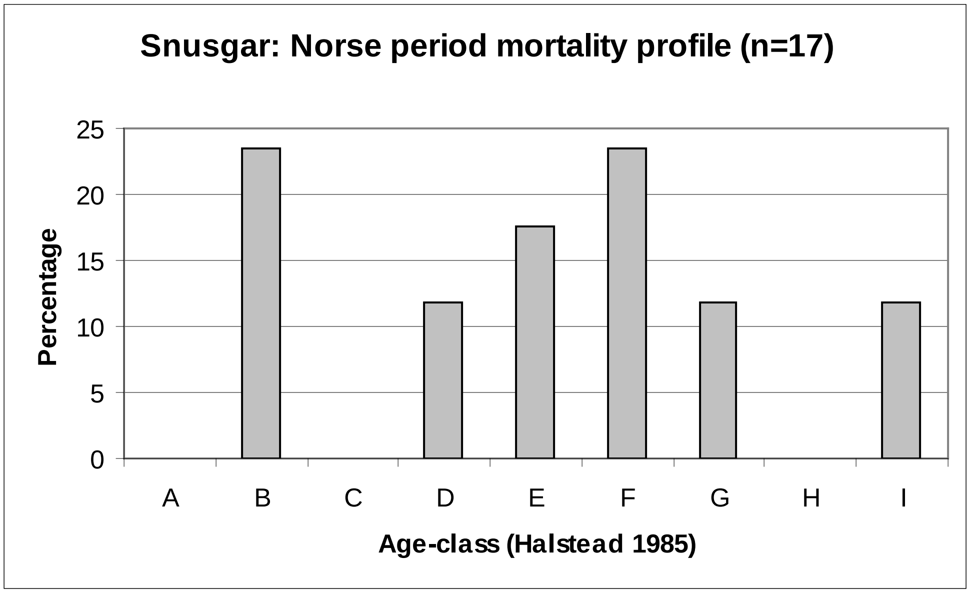


Figure 12.18: Snusgar: bar-chart showing bovine mortality profile based on tooth wear analysis (Norse material) (n=17).

This profile appears to resemble most closely the paradigm for ‘meat’, apart from the early peak in age-class ‘B’ (1-8 months). Otherwise the periods of maximum slaughter (‘E’ & ‘F’; 30-36 months - young adult) correspond well with Payne’s ‘meat’ model ‘A’ (1973: 282, FIG 1) (figure 2.4). The neonate deaths could be attritional, or represent calves fattened for post-lactational slaughter. Validity of the single potential case where a shed dP4 may have been counted would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 7.7%. The overall total of potential double counting through all age-classes is 3 (17.6%). If all these cases were valid, this would, however, only marginally alter the distribution pattern in figure 12.18; hence the interpretation given above would remain largely intact.

Tooth-development analysis was limited to 4 of the neonate animals from this phase; figure 12.19 shows the distribution in age-categories:

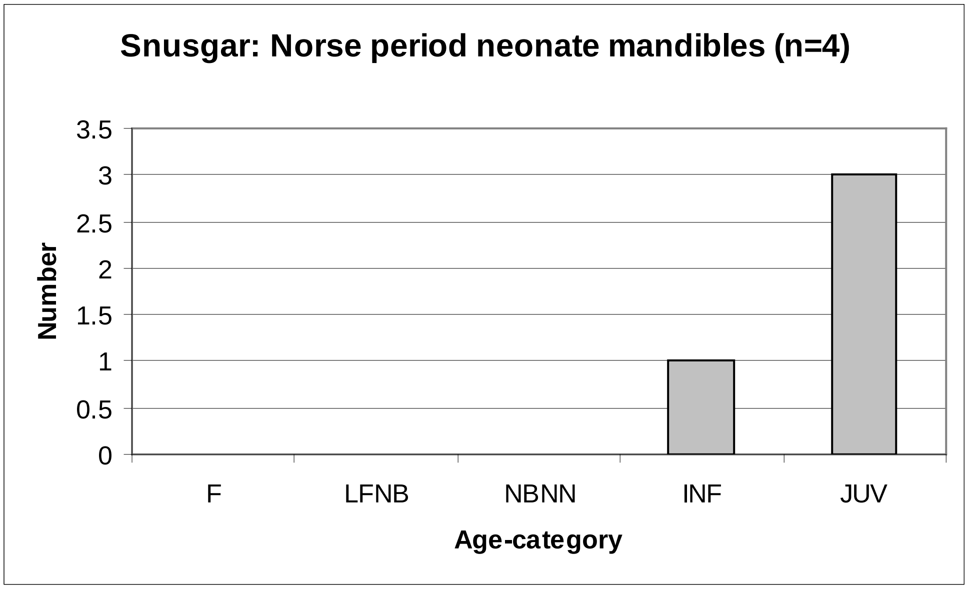


Figure 12.19: Snusgar: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles (n=4).

As can be seen 3 of these 4 individuals resolve as ‘juvenile’ (> 1 month old) and are possible candidates for a calves fattened for autumn slaughter. The ‘infant’ may have been an attritional death, perhaps due to calf pneumonia (table 12.3). Since these excavations are incomplete, these results must be treated with caution, as they may only represent a partial population. However, there does appear to be an indication of exploitation of cattle for meat, accompanied by some neonate attrition, which may prevail when the excavation is complete.

12.6: Pool

Details of the excavations at Pool, Sanday, between 1983 and 1988 are given in section 4.3. Four main periods of occupation of the site were identified: Neolithic (site excavation phase groups 1-4); Iron Age (phase groups 5-6); a transitional period when Viking influence was indicated (phase group 7); and the Later Norse period (phase group 8). Subgroups within each main excavation phase were identified and recorded. For the purposes of this study, 4 temporal phase groupings were identified from suitable bovine bone material at Pool, corresponding to the periods indicated in table 12.7. Modern (site excavation phase 10) and unassigned material was excluded from the study.

Table 12.7: Periods of occupation based on phases at Pool (Hunter 2007).

Phase	**Period**
5	Early Iron Age
6	Later Iron Age
7	Iron Age/Scandinavian interface
8	Norse
10	Modern

12.6.1: Pool: Early Iron Age phase

Unfortunately, only 5 suitable bovine mandibles, mandible fragments, or dP4/M3 loose teeth were identified from the Early Iron Age phase at Pool. Age-class diagnosis using tooth-wear analysis (after Payne 1973: Grant 1982; Mulville *et al*. 2005; Halstead 1985) was as follows (table 12.8):

Table 12.8: Age-class distribution of bovine material diagnosed by tooth-wear analysis from the Early Iron Age at Pool (n=5) (Grant 1982: Halstead 1985).

Age Class	**Suggested age**	**Count**	**Percentage of total**
A	0-1 MONTHS	1	20
B	1-8 MONTHS	1	20
D	18-30 MONTHS	1	20
E	30-36 MONTHS	2	40
TOTAL		5	100

The individual in age-class 'A' from the Early Iron Age in table 12.5 above resolved as 'newborn/neonate' (0-7 days old), and the age-class 'B' calf as 'juvenile' using tooth-development analysis (based on Brown & Chapman 1991a, b). These data are too limited to make any but the most general of inferences about the palaeoeconomics bovine husbandry of the Early Iron Age at Pool, but do not conflict with the 'meat/milk' paradigm (Payne 1973) discussed above at other Orkney sites. The single case where double-counting may have taken place,, would, if valid, have no effect on this.

12.6.2: Pool: Later Iron Age phases

The bar-chart in figure 12.20 represents the bovine mortality profile for the Later Iron Age at Pool.

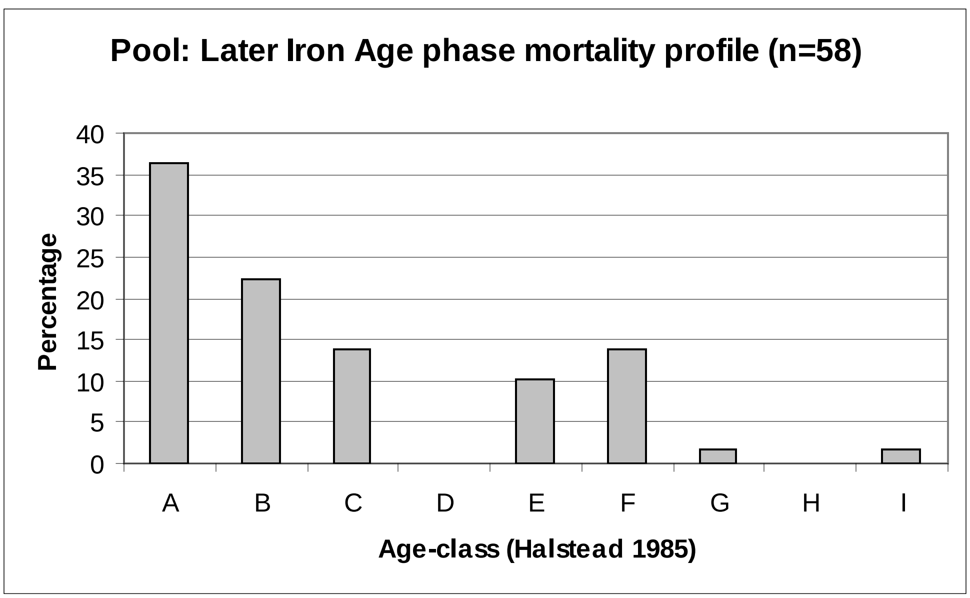


Figure 12.20: Pool: Bar-chart showing bovine mortality profile of the Later Iron Age phase based on tooth wear analysis (n=58).

This pattern appears to be a reasonably close approximation to the ovine Payne 'milk' model. There is a slight peak of mortality in age-class 'F' which may represent a meat harvest, perhaps a late autumnal cull to conserve fodder for the winter. The peaks in age-classes ‘A’ and ‘B’ are as would be expected if males and excess females were culled as neonates, once lactation in the dam was secure, in order to maximise milk for human consumption. Validity of the single potential case where a shed tooth may have been counted would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 6.3%. The overall total of potential double counting through all age-classes is 9 (15.5%). If all these cases were valid, this would, however, only marginally alter the distribution pattern in figure 12.20; hence the interpretation given above would remain largely intact.

The corresponding bar-chart representing neonate age-diagnoses by examination of radiographs for tooth-development, based on criteria published by Brown & Chapman (1991a, b) is shown below (figure 12.21).

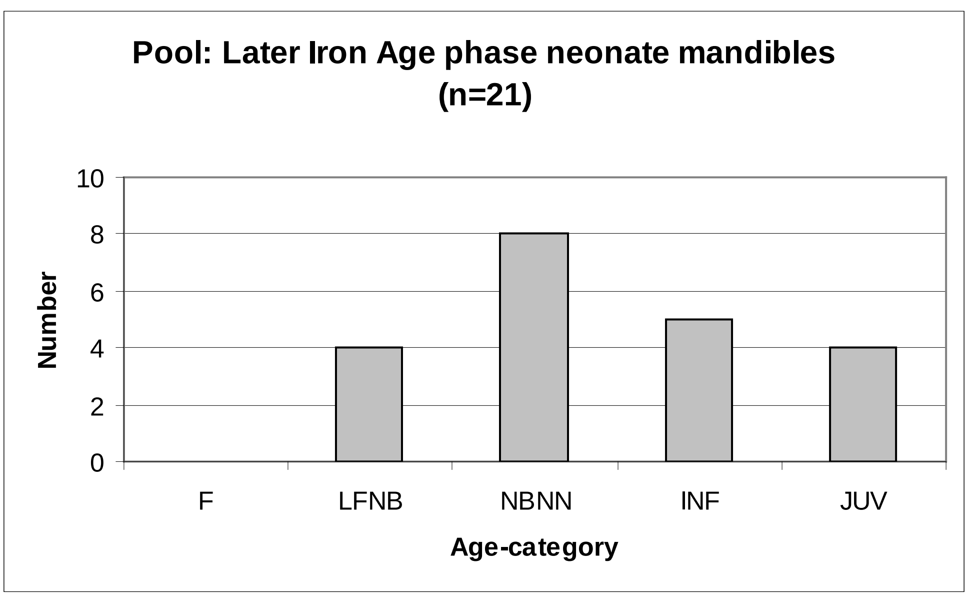


Figure 12.21: Pool: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Later Iron Age phase (n=21).

As can be seen, most of the neonate material originally diagnosed as age-classes 'A' & 'B' by tooth-wear analysis now resolves as 'late foetus/newborn' or 'newborn/neonate'. According to data published by Halstead (1998), very few of these animals were likely to have been candidates for slaughter to maximise milk, as, at their time of death, the maternal lactation would have not been established; this only occurs around 10-15 days post-natal, with the live calf having had free access to the udder (Halstead 1998: 6). This does not preclude milking at Pool in this period, but makes the likelihood of calf-less dairying, as discussed by Legge (1981a, b; 1989; 2005) and others, less likely. Milking for human consumption was probably a pragmatic strategy adopted together with occasional slaughter of prime animals for beef, and based on the principle of 'one teat for the calf, three teats for the bucket' (Kelly 2000: 41). The death of so many calves around birth indicates that cattle husbandry was probably at its most basic. Difficult calvings may have led to dystocia. Infections leading to third-trimester abortion, such as brucellosis, leptospirosis, salmonellosis or listeriosis (table 12.2), may also have been prevalent at the time. 'LFNB' and 'NBNN' individuals comprise 38% of the phase population; 'LFNB' individuals, almost certainly abortions, stillbirths, or died at or around birth were 13% of the death-population. Two potential examples of double-counting, one new-born-neonate (NBNN) and one late-foetus-new-born (LFNB) were present in the assemblage examined for tooth-development from this temporal phase (section 11.3.6). Their validity would have little or no effect on interpretation.

12.6.3: Pool: Scandinavian Interface phase

The bovine mortality profile based on tooth-wear analysis for the interface of transition from the Iron Age to the Scandinavian era (site phase 7) is shown as a bar-chart in figure 12.22.

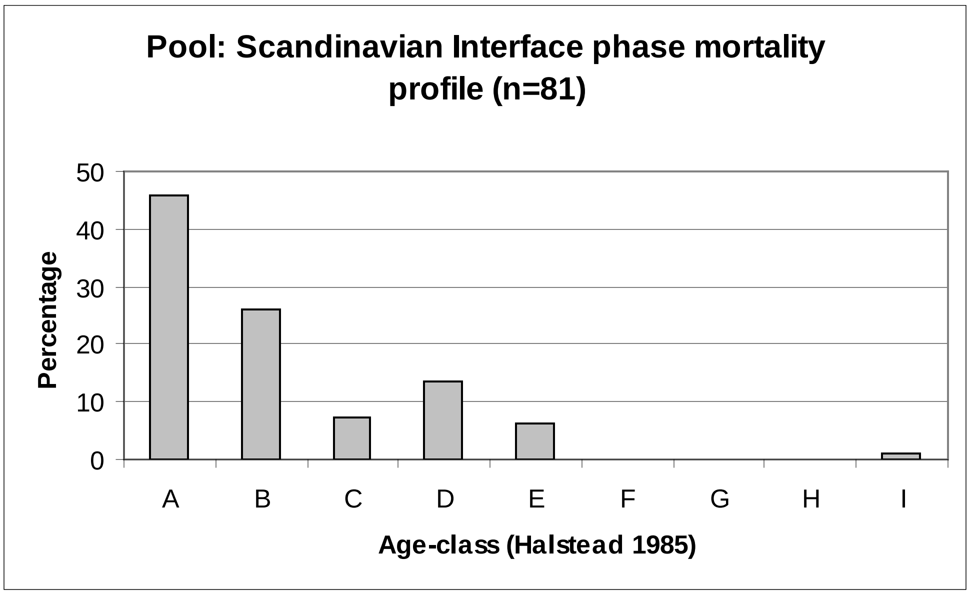


Figure 12.22: Pool: Bar-chart showing bovine mortality profile of the Scandinavian Interface phase based on tooth-wear analysis (n=81).

Levels of neonate mortality in this phase were exceptionally high at 89% of the total population (age-classes ‘A’ + ‘B’); only one animal survived beyond age-class ‘E’ (30-36 months) (Halstead 1985). There is no dramatic peak of mortality in age-classes ‘D’, ‘E’ or ‘F’ to suggest slaughter for ‘meat’. The results from this phase were not anomalous due to low numbers, as the population was adequate (n=81). Although the neonate mortality might suggest ‘milking’, there does not appear to be an adequate population of adults to support this interpretation, or to produce this quantity of neonate calves. It may be that calves were kept for veal and deliberately slaughtered early, possibly in the autumn to conserve winter fodder. Another possibility might be that this does not represent the entire death population during this period, a time of Viking raiding and settlement. Some proportion of adult cattle may have been stolen, demanded as tribute, held remotely in safe-keeping, or slaughtered elsewhere, or otherwise removed from the site, which must have been vulnerable to attack as it was adjacent to the shore-line. Validity of the 5 potential cases where shed teeth may have been counted would reduce the total from age-classes 'D' to 'I' (Halstead 1985) by 29.4%. The overall total of potential double counting through all age-classes is 12 (14.8%). If all these cases were valid, this would shift the distribution pattern in figure 12.22 further towards the left, increasing the percentage of neonate mortality; however, the interpretation given above would remain largely intact.

Neonate age-diagnoses for the Scandinavian transitional period at Pool, inferred from tooth-development analysis, are represented in the bar-chart shown as figure 12.23.

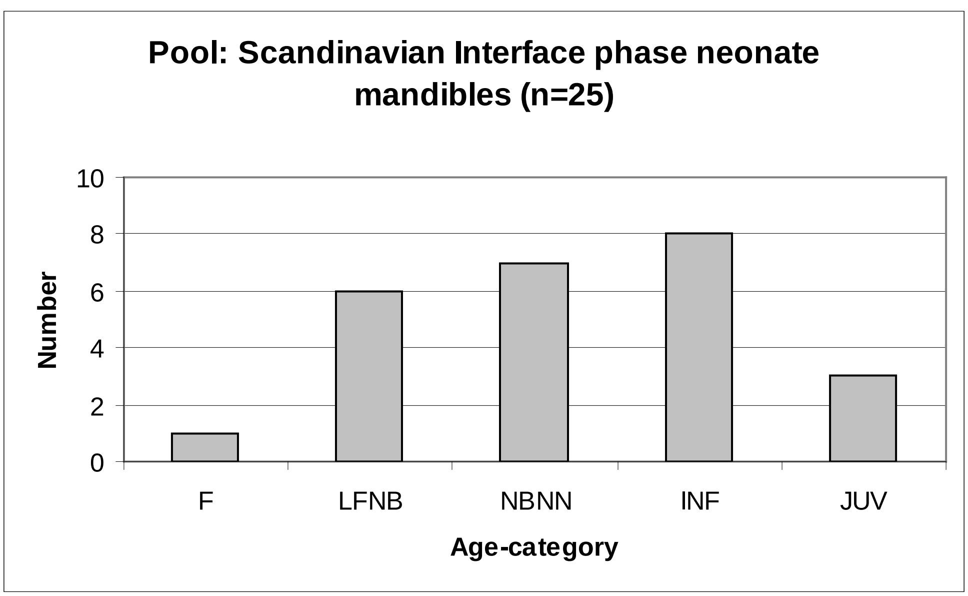


Figure 12.23: Pool: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Scandinavian Interface phase (n=25).

A high proportion of abortion, still-birth and dystocia is again indicated, as with the Later Iron Age phases. This shows that animal husbandry practices were again probably inadequate, or the persistence of some epizootic abortifacient, such as *Brucella abortus* (table 12.2). These deaths would probably have meant that maintaining a stable herd was unsustainable. For veal production, as suggested above, it might be expected that most of the neonates would resolve as 'juveniles'; these results make this inference unlikely. The 'new-born/neonate' (NBNN) deaths, representing 16% of the phase population, may, in part, have been the result of dietary deficiency in the dam, perhaps compounded by low-level infections of *Escherichia coli* or *Staphylococcus aureus.* The single second-trimester abortion (4-6 months gestation) could have been caused by IBR (infectious bovine rhinotracheitis) or *Campylobacter* species infections (table 12.2); 'F' & 'LFNB' individuals, almost certainly abortions, stillbirths, or died at or around birth represented 16% of the phase population.

Again the most likely inference regarding the palaeoeconomy of the period of Scandinavian transition at Pool is probably a combined meat and milk economy, with the pragmatic utilisation of animals to cope with a high rate of attrition around birth. There does, however, appear to be a lack of mature animals to support this hypothesis, as discussed. Some selective slaughter, possibly of males, to maximise milk for human consumption, may be indicated by the 8 individuals in the 'INF' (2-4 weeks) category, although this is unlikely, because of the high level of deaths at or before birth; every surviving animal would probably have been retained to maintain livestock levels.

12.6.4: Pool: Norse period phase

Figure 12.24 is a bar-chart representing the mortality profile based on ages-at-death predicted by tooth-wear analysis, for the bovine assemblage from the Norse period phase at Pool.

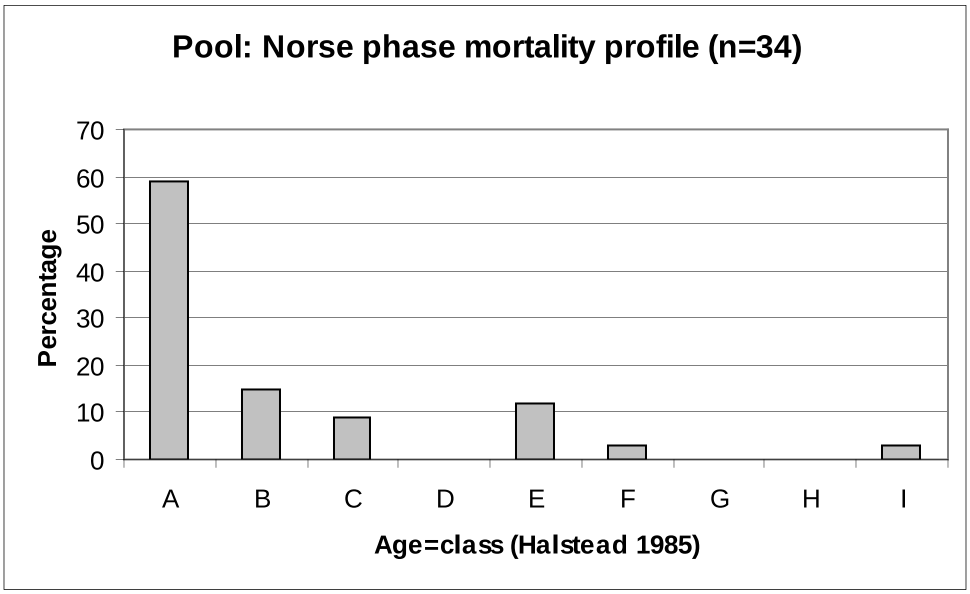


Figure 12.24: Pool: Bar-chart showing bovine mortality profile of the Norse phase based on tooth wear analysis (n=34).

This result is similar to that for the Scandinavian interface; there is again an unsustainably high level of neonate death (59% of the death population), and a dearth of adults. ‘Milking’ still seems the most likely inference, perhaps with a few adults culled for ‘meat’ in age-class ‘E’ (30-36 months) (Halstead 1985). There are 3 potential cases where shed teeth may have been counted; if valid, this would reduce the total from age-classes ‘D’ to ‘I’ (Halstead 1985) by 50%. The overall total of potential double counting through all age-classes is 5 (14.7%). If all these cases were valid, this would shift the distribution pattern in figure 12.24 further towards the left, increasing the percentage of neonate mortality; however, the interpretation given above would remain largely intact.

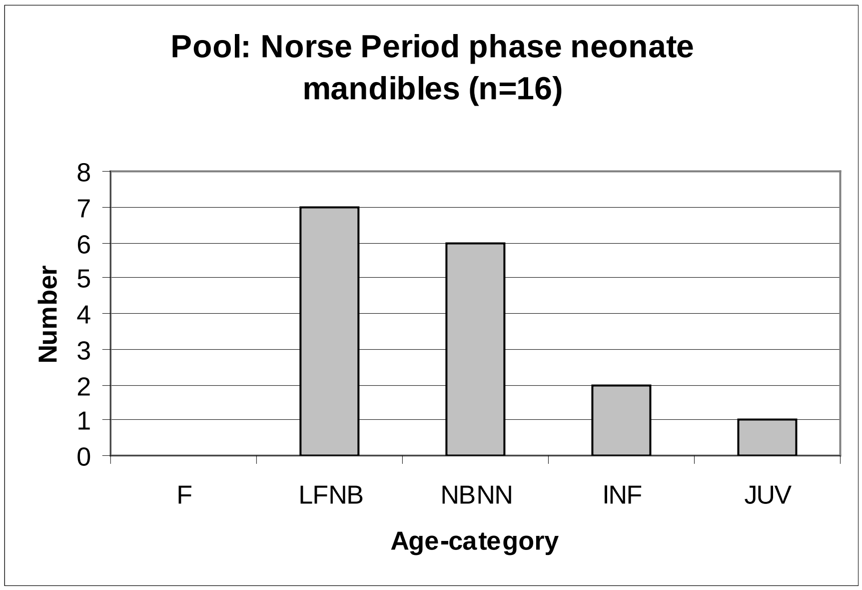


Figure 12.25: Pool: Bovine age-category distribution bar-chart based on tooth development analysis of neonate mandibles from the Norse phase (n=16).

The bar-chart based on tooth-development of neonate jaws is shown in figure 12.25, and its distribution shows around 70% of the phase population resolving as ‘new-born’, either as ‘LFNB’ or ‘NBNN’; ‘LFNB’ individuals, almost certainly abortions, stillbirths, or died at or around birth were 38% of the population. Material from dogs was recovered from Norse phases at Pool (Bond 2007: 210), hence *Neospora caninum* might have been implicated, among other agents, in the putative bovine abortions indicated in figure 12.25 (Dubey 2003: 2, figure 1) (fig 6.1). Newborn animals may have succumbed due to dietary insufficiency in the dam; neonates to early-onset environmental infections through faecal contamination, such as enterotoxigenic *Escherichia coli,* or clostridial enteroxaemia type A.

There appears to be little evidence of juvenile slaughter, although this may be a problem of equifinality; juveniles may have been traded, or slaughtered elsewhere in, perhaps, an increasingly developed social structure than that existing in earlier phases.

A single example of potential double-counting among the material examined for tooth development from this temporal phase was diagnosed as new-born-neonate (NBNN), as mentioned in section 11.3.6. Its provenance or otherwise would have had little impact on interpretation.

12.6.5: Pool: summary

Bovine age diagnoses from Pool display a dramatic degree of mortality among very young animals, coupled with a smaller peak of mortality around 3 years of age, except in the case of the Scandinavian interface phase, where there is only a single animal surviving beyond 30 months of age (figure 12.22). Inferences loosely based on Payne's ovine models (1973) would suggest, except in the phase specified, an economy based on milking was exercised at the site, with some culls for meat around 3 years of age. However, age-diagnoses based on tooth-development criteria suggest that, in all phases, many of the neonates died around the point of birth, which suggests these were non-deliberate deaths, since the inception of lactation in the 'unimproved' cattle of the time may have required the presence of the calf up to at least 10 days of age (Halstead 1998: 6). This could indicate that husbandry practices were less proactive, where calves might be slaughtered to maximise milk supply, than reactive, dealing pragmatically with any calves that survived the trauma of birth. It is suggested that the bone assemblage that was excavated representing the Scandinavian interface phase may be a case of partial or biased survival, where the remains of adult cattle are missing due to one or more of a number of reasons which may be related to events occurring during the transition from Iron Age to Viking settlement.

Published evidence from cattle tooth-wear analyses at Pool (Serjeantson & Bond 2007: 221-225), part of the site excavation report (Hunter 2007), is used to infer that an economy intensively based on milk and milk products existed at Pool during phases 6 to 8 (Later Iron Age, Scandinavian interface and Norse period). This, it was said, was influenced by a limited amount of grazing land, an adequate meat supply and a lack of demand for veal. Very early slaughter of calves, apart from maximising milk for human consumption, allowed the consumption of a certain amount of meat, welcome at the end of winter, a skin, perhaps for vellum, and rennet from the stomach for use in cheese manufacture.

As discussed above, the results of this study also lead to an inference of milking at this site during the phases mentioned, but the more precise age-diagnosis of very young animals enabled by the tooth-development technique seems to indicate that subsistence was somewhat more marginal than one that which would permit intensive dairying as described in the published report. Many of the neonate deaths at Pool in age-classes ‘A’ & ‘B’ (Halstead 1985) in figures 12.20, 12.22 & 12.24 were more likely to have been the result of environmental determinism (McCormick 1998) rather than anthropogenic slaughter.

It will be noted in the same figures that in each phase one or more adult animal that had been allowed to survive to senility is recorded. This may represent a prized bull or animal used for traction in ploughing or pulling a cart. However, this could also indicate a reluctance to dispose of a worn-out animal, which contributed towards the kudos of its owner in a society that prized cattle above other species, often to the detriment of the animals, due to insufficient grazing (Armit 2005: 64). Such a society might be hesitant in killing healthy calves at the start of their lives.

12.7: The Bedern, York

Analysis of the age-diagnoses for mandibles and fragments from the archaeological control site at The Bedern was discussed in section 11.3.4; no palaeoeconomic interpretation was possible as only a small proportion of the bovine assemblage was examined.

12.8: Palaeoeconomic inferences for contemporaneous site phases

In three eras, the Early Iron Age, Later Iron Age and Norse period, the temporal phase coincided for each of three of the study sites; the brief discussions below highlight any similarities or significant differences between the palaeoeconomic exploitation of cattle at each contemporary phase.

EARLY IRON AGE: Pool, Howe, Toft's Ness

There was insufficient material for comment from this phase at Pool (section 12.4.1). For Howe (section 12.2.1), the overall pattern resembled Vigne & Helmer's Neolithic dairying paradigm (2007: 29), or, otherwise, a meat/milk pattern (based on Payne (1973)). Toft's Ness (section 12.3.2) was a similar pattern in the Early Iron Age, although the neonate age resolution provided by tooth-development seemed to support Payne's 'milk' paradigm

(1973), in that a high proportion were 'infant' deaths (2-4 weeks), so possible candidates for slaughter; however, these deaths could also have been attritional.

LATER IRON AGE: Pool, Mine Howe, Howe

At Pool (section 12.6.2), 38% of the population appeared to have died at or around the point of birth, hence were probably attritional deaths, precluding the 'slaughter' paradigm which is strongly indicated by the survivorship profile based on tooth-wear analysis (figure 12.20); meat/milk is indicated, the latter supported by the multiple attritional deaths, with a pragmatic use of the animals that survived. At Mine Howe, 'meat' seemed to be more prominent than 'milk' in this phase; this may have been related to the special circumstances inferred for the site, as discussed in section 12.1 *et seq.* At Howe in the Later Iron Age (section 12.2.2), 33% of bovine deaths were 'new-born' calves and hence likely to have been attritional, indicating a particularly severe calving problem, probably related to poor nutrition; overall, pragmatic meat/milk harvesting appeared to be the norm, the latter probably contributing to husbandry problems. This pattern of exploitation appears to have been a common factor at these sites during this phase, apart from, perhaps, the special circumstances which may have applied at Mine Howe.

NORSE: Pool, Earl's Bu & Snusgar

70% of the death population in the Norse period at Pool were late foetal, newborn, or early neonates; the survivorship trace was suggestive of milking, using Payne's model (1973) (section 12.4.4). Only a single neonate calf was demonstrated in the Late Norse phase at Earl's Bu (n=8), where the survivorship curve was suggestive of meat consumption (section 12.5.2); at Snusgar in the Norse phase this was also the pattern (n=17), 3 of the 4 infant mandibles examined using tooth development analysis were diagnosed as ‘juvenile’ animals (section 12.5). These data seem to validate the contention that both Earl’s Bu and Snusgar were high-status sites, where cattle-rearing may not have been local; animals perhaps being brought to the sites for consumption.

The findings from Earl’s Bu and Snusgar reflect tooth-wear data from bovine mandibles recovered from excavations at Bornais, South Uist, Western Isles, where material from Norse phases also did not tend to correspond to the ‘milk’ paradigm: only 30% of the mandibles were age-classes ‘A’ or ‘B’. Iron Age phases followed the ‘milk’ pattern, with 57% of material being diagnosed as age class ‘A’ or ‘B’ (Mulville 2005: 173; Sharples 2005; Halstead 1985; Payne 1973).

It would be of interest to examine the neonate mandibles from Bornais using the tooth-development-radiography technique, as described in sections 8.8.3 & 10.4.1, which might help further to resolve the palaeoeconomic interpretation by distinguishing newborn and foetal material which, due to extreme youth, might not have been the subject of slaughter, as discussed in section 12.1 *et seq*. Use of the technique on material excavated from other contemporary Northern and Western Isles sites and elsewhere, where elevated numbers of neonates have been recovered, would perhaps further contribute to the resolution of the ‘milking’ issue, using the arguments rehearsed herein.

12.9: Published report comparisons.

Of the three published site reports, the authors of the mammal bone reports on cattle and sheep husbandry at both Pool and Toft's Ness (Serjeantson & Bond 2007a; Serjeantson & Bond 2007b) adhere to the neonate slaughter template for the interpretation of bovine husbandry, suggesting at both sites that dairying was the ultimate palaeoeconomic object, and that this was practiced with increasing intensity over time. The implication in these reports is that milk let-down was possible without the presence of the calf, with or without resort to some of the stimulatory means mentioned earlier (section 2.3.1). This contrasts with the findings of the analysis of neonate material using tooth development, where, in most cases, a high proportion have been shown to be potentially too young to merit slaughter, although a milking inference was not disputed.

The Howe report is more reticent (Smith 1994); more pragmatic bovine husbandry is suggested, for meat, milk and traction. Neonate deaths are attributed to attritional factors rather than slaughter. Evidence that animals were retained alive despite injury or defect rather than slaughtered is reported. The Howe report accords most closely with the palaeoeconomic inferences for the site drawn in this study.

12.10: Brief summary of palaeoeconomic inferences at the study sites.

The palaeoeconomics of the study sites appear to fall into 3 clear groupings. Pool, Toft's Ness and Howe all appeared to favour a combined meat and milk economy throughout the temporal phases analysed; however, perhaps as a result of attempting dairying with malnourished animals, the neonate attrition rate was very high in all phases. Hence, husbandry decisions probably had to be both pragmatic and reactive at these marginal sites. This accords well with Julie Bond’s summary of island biogeography “in order to avoid risk, economies (in both the Northern and Western Isles) would be broad-based rather than specialised, leading to an apparent conservatism and a lack of major changes” (Bond 2002: 179). Similar economics may have applied at Mine Howe, but, because of the possible ritual nature of the site, special practices such as sacrifice and feasting may have taken place. There was also a possibility that animals brought from elsewhere for local consumption might have skewed the assemblage formation.

A skewed recovery was likely to have applied with the Earl’s Bu assemblage, which appears to have comprised, in part, of the detritus from the high-status Earl’s Hall, together perhaps with material from the local working farm site where animals were husbanded; hence palaeoeconomic inferences based on mortality profiles may be invalid. This may also apply at Snusgar where the material studied probably also represents only a partial assemblage from the early stages of an excavation.

12.11: Summary of neonate age diagnosis results.

As has been described, after submitting the archaeological bovine bone assemblages to tooth-wear analysis, based on the method of Grant (1982), and age-class diagnosis (Halstead 1985), a total of 180 mandibles and mandible fragments from all sites and phases that had been age-classified as ‘A’ or ‘B’ (and in a few cases ‘C’) were radiographed, and, using the modified tooth-development technique (based on Brown & Chapman 1991a, b), put into five age categories; in some cases directly, in others into a range of categories (usually where only a limited range of teeth was available for analysis). Age-range diagnoses were subsequently resolved into single age-categories based on the proportionality of unequivocal results in the phase involved, as described in section 10.4.1.

Based on cases where both tooth-wear and tooth-development results were unequivocal (from table 11.61; juveniles in age-class ‘C’ (Halstead 1985) were excluded), the latter methodology was able to focus age-diagnosis as follows (n=74):

- 43% were diagnosed as foetal (F) or foetal/newborn (LFNB): from gestation to birth.
- 20% were diagnosed as early neonates (NBNN): between birth and 2 weeks.
- 26% were diagnosed as infant (INF): between 2 and 4 weeks.
- 11% were diagnosed as juvenile (JUV): more than 1 month old (the upper age-limit of the technique).

These results (discussed for quality in section 11.3.1) demonstrate the ability of the tooth-development technique to resolve the wide initial age-cohort inherent in the tooth-wear method (age-class ‘A’ (0-1 month) (Halstead 1985)). All the individuals diagnosed as foetal or new-born, 43% of the total, might tentatively be excluded from consideration when considering neonate slaughter to maximise milk harvest, since they died before what has been reported as the minimum age at which continuity of lactation in the dam can be assured in unimproved cattle (Halstead 1998: 6). If animals diagnosed as early neonates are included (<14 days old), this figure rises to 63%. Thus, if between two-fifths and twothirds of the newborn calves were routinely dead before lactation was established, this could explain why recourse was perhaps made to some of the let-down stimulation techniques, such as the dummy calf (using the skin of the appropriate dead infant), or ‘cow-blowing’, as described by Amoroso & Jewell (1963). If effective, this might have salvaged the lactation.

Discussions have been presented above for each site-phase concerning the fate of neonates; in each case a proportion could have been slaughtered for milk, but, in general, the trends indicate that the proportion of attritional neonate death was so high that further killing would have been unlikely. At the majority of the sites, in most phases, dairying of some kind was probably being practiced, as was fattening animals for meat consumption, and the use of bovine traction for carts and ploughs. The study of dairy husbandry and its attendant animal health issues in chapters 5 & 6 seems to indicate that these elevated neonate mortalities in the Northern Isles may well have been a result of dairying, but, through poor hygiene and husbandry practices inherent in milking in antiquity, through attrition rather than slaughter. Thus the ‘milk’ model of survivorship stands, but its association with the rationale of Payne’s (1973) ‘kill-off’ pattern has become problematic.

12.12: Overarching inferences.

For the majority of phases, in the majority of sites studied, apart from Earl’s Bu and Snusgar, as discussed above (section 12.10), ageing data from tooth-development analyses seems to indicate that bovine stock may have been subject to high mortality at and around birth, comprising around 20-30% of the total bovine population. This appears to preclude anthropogenic slaughter of the majority of neonates to stimulate the inception of milk let-down, rather suggesting that most neonate deaths were the result of environmental factors, such as poor hygiene, debility in the dam, perhaps through mastitis-mediated low-grade infections, undernourishment, or epizootic disease.

What this study has attempted to suggest is that the level of neonate mortality may have been exacerbated by the practice of milking. Human contact with cows and calves through hand-milking and restraint may have resulted in the transfer of debilitating micro-organisms, which, coupled with nutritional deficiencies, elevated stress-levels and the metabolic drain of lactation, may have led to a situation where cows had a tendency to abort, or produce stillborn calves. Surviving calves were likely to be 'poor-doers', succumbing within a few days of birth. Hence, perhaps, 'environmental determinism' is replaced by 'palaeoeconomic determinism'. A 'meat-only' exploitation strategy would involve far less interference and human contact, even where animals were kept indoors through the winter, although nutritional insufficiencies from a possible lack of fodder, leading perhaps to a lack of vitamin A or iodine, would apply equally, unless, as was likely, diet was supplemented by seaweed.

Hence the basic tenet of 'anthropogenic slaughter of neonates to maximise milk' could perhaps be replaced by 'milking-mediated neonatal mortality' in Payne's 'milk' model (1973: 283, figure 2); the pattern of age-at-death in populations indicating the exploitation of cattle remaining the same. 'Neonate mortality' is consolidated into each of Payne's (1973) models for milk, meat, and wool (figures 2.3, 2.4 & 2.5); in the latter two cases at around 10%; what is suggested here is that the quota allowed for ‘neonate mortality’ for the milk model (not including ‘lamb (calf) killing’) should be extended for cattle, to a level approaching the total mortality in the first month in figure 2.3 (circa 50%). The relative ease of let-down in sheep-milking, due to differences in physiology, compared to cattle-milking, discussed in section 6.2.1, may be a contributory factor in the construction of the original models, resulting in less ‘milking-mediated’ mortality in neonate sheep. Whether cows would let-down milk or not without the presence of the calf cannot be inferred from this study; however, with the level of calf mortality indicated in the archaeological contexts concerned, there must have been a high incentive for the use of substitute animals, dummy calves, cow-blowing and other strategies (as described in section 2.3.1) in desperate attempts to recover the lactation of cattle with dead, aborted or stillborn offspring.

The age-at-death diagnosis results from Mine Howe, Howe, Toft’s Ness and Pool seem to indicate, to a greater or lesser extent depending on the site or temporal phase, pastoral farming at a subsistence level in a marginal environment, which, either through ubiquitous infections (such as those listed in tables 12.2 & 12.3), or maternal nutritional insufficiency, caused a heavy death-toll in calves, particularly around the vulnerable time of birth. The surviving animals may have been retained alive, and perhaps, shrouded in a dead calf’s skin, utilised to facilitate milk let-down in calf-less cows. Towards the end of lactation in the autumn, fattened juvenile calves may have been selectively slaughtered for meat, in order to conserve fodder resources over the winter months, as suggested by Vigne & Helmer (2007). Female calves may have been nurtured to provide the kernel of a new milking- or breeding-herd; selected males, probably castrated, fattened and consumed at 2- or 3-years-old, retained as bulls for breeding, or 'broken' for tractive effort.

This implies a picture of pragmatic, reactive animal husbandry, where milk was harvested where possible, but where animals were put to best use according to conditions prevailing at the time. Some cattle may indeed have been less recalcitrant about releasing their milk without the stimulation of a calf. Selective slaughter, perhaps of young animals, may have occurred in periods of dearth in late winter, to eke out fodder supplies for pregnant cows, or to satiate otherwise starving humans. Studies, discussed in section 2.3.6, involving the analysis of ceramic sherds for lipid residues (for example, Copley *et al.* 2003) have suggested the exploitation of animal milk was practiced throughout Britain in the Neolithic, Bronze and Iron Ages. The extent of milk usage and consumption cannot be inferred using this method, however, nor can the transformation of milk into butter and cheese. Milk may have been an occasional adjunct for human consumers, resorted to in infancy and ill-health rather than a dietary staple. As reported by McCormick (2006: 167), milk usage could even have been confined to the attempted sealing of unglazed pottery.

Two review articles, those of Mulville *et al.* (2005), and Halstead (1998), have discussed the high levels of neonate calf death in the Northern and Western Isles, inferred through data from many published studies. A number of factors potentially influencing neonate mortality were listed and discussed therein, including site marginality, fodder production, animal housing, climate and latitude, 'natural' infant mortality, and, inevitably, anthropogenic slaughter, allied to calf-less milk let-down. Apart from the last, all of these factors could apply equally to keeping cattle for meat or milk. All may have influenced the results cited in this chapter to a greater or lesser extent. What this study suggests is that an additional factor should also be considered: bovine debility and mortality mediated by the human interference inherent in the practice of dairying (including the husbandry of calves separated from their dams). This additional factor, it is suggested, is what might differentiate the survival of dairy calves from beef calves; as already cited, even currently, 1 in 6 dairy calves die in the UK, compared to 1 in 14 beef calves (DEFRA 2006).

Globally, incorporating this factor does not affect Payne's models (1973) or their interpretation, merely the rationale behind the peak of neonate mortality in the 'milk' model. Indeed, deliberate neonate calf slaughter of unwanted males is not refuted; merely that the degree of any such slaughter is likely to have been tempered by existing losses through the aetiologies described.

To differentiate between cattle exploitation strategies, a 'holistic' approach should perhaps be applied to site investigations, involving multi-disciplinary analyses, including, for example, ceramic analyses for lipids and other organic derivatives (for example, Copley *et al.* 2003; Craig *et al.* 2005), material culture studies (for the Howe excavation: Smith 1994: 163 *et seq.*), isotopic analyses (investigating, for example, calf weaning age (Balasse & Tresset 2002)), palynological investigations, perhaps for evidence of the cultivation of fodder crops (for Howe: Dickson 1994), examination of on-site structural remains for evidence of putative animal housing and stalling (as reviewed by Armit (2005: 26-42)), local topographic and meteorological data (such as Hanssen Kolland 1982), and historiographic research (for example, Fenton 1997, Omand 2003), together with animal population data inferred from all the techniques discussed in this study, including tooth-development methodology for resolution of neonates. Palaeopathological and population studies of human remains, where available, might indicate age-patterns of mortality or bone lesions, which might be associated with milk-mediated zoonoses, such as tuberculosis; ancient DNA (aDNA) analysis on suitable material might even give direct evidence of this (Mays 2005). Rather than relying on individual methodologies or groups of related methodologies for interpretations, more reliable inferences of animal exploitation strategies, such as ‘meat’ or ‘milk’ might then be ‘teased out’ from a synthesis of all the data derived from these sources, amongst which accurate neonate age diagnosis, via tooth-development analysis, would be a most effective tool.

CHAPTER 13: SYNTHESIS

13.0: Introduction

This thesis set out to investigate the phenomenon of unusually elevated proportions of neonate calves in bovine mortality profiles through the study of six Orkney sites with temporal phases dating from the Neolithic to the Norse period. Four of these study sites were shown to exhibit the expected high levels of neonate mortality using conventional tooth-wear analysis (Mine Howe: 40% neonates overall, Howe: 47%, Toft's Ness: 42% & Pool: 63%) (after Grant 1982; Halstead 1985); the remaining two sites, Snusgar (23.5% neonates) and Earl's Bu (12% neonates) did not conform so closely, and were found to differ in several significant aspects. The Bedern, York, a further site with an emphasis on neonates, was used as a control. This assemblage was chosen to provide a complete contrast with the Orkney sites, being urban, ecclesiastic, Mediaeval, landlocked and from a different geographical latitude; it was hoped that any common factor exclusive to the Orkney material would have been highlighted through examination of mandibles from this site.

Mandibles and mandible fragments from neonates diagnosed by tooth-wear analysis from these assemblages were then submitted to further age-diagnosis techniques; in particular, an adaptation of a method based on tooth-development in adult red and fallow deer (Brown & Chapman 1991a, b), modified here for the bovine deciduous dentition. The development of this methodology, which involved the acquisition of a collection of modern attested-age bovine neonate material, has been described in the methodological chapters 8 & 10.

Age-diagnosis using tooth-development analysis has enabled recognition of a differential distribution in the archaeological assemblages of animals in five neonate age-categories, namely foetuses (F), late foetuses/newborn animals that died just before birth (LFNB), animals that died just after birth and in the first week or so of life (NBNN), calves that lived for 2 to 4 weeks (INF), to older juveniles (JUV) (a separate 'died at birth' category was obviated as being too transitory). This contrasts with tooth-wear analysis where the same individuals would have been classed as age-class 'A' (0-1 month) or age-class 'B' (1-8 months) (Halstead 1985: 219, table 35), despite the recent suggested modification, discussed and adopted here, where some class 'B' individuals were reclassified as 'A' (Mulville *et al*. 2005: 171) (sections 3.4, 8.5 & 9.1).

These new neonate age-categories have been used to differentiate animals that might have been slaughtered to maximise milk supply for human consumers from those for whom such a death was unlikely; based on the premise that the presence of the suckling infant calf was necessary for at least the first 10 days to initiate and maintain lactation, as reported in an ethnographic study of husbandry using unimproved cattle (Halstead 1998: 6). This means that animals diagnosed as foetuses, or that died at or around birth, probably died of 'natural' causes.

This has prompted speculation concerning the modes of these 'natural' deaths. Chapter 5 contained a discussion of a range of aetiologies for abortion and neonate death in calves, and in the succeeding chapter some of the bovine health and welfare issues that might be inferred for dairy husbandry in antiquity were described. Health issues for adult dairy cattle were considered, since they can also contribute to the patterns of neonatal disease associated with dairying. Hence it was possible to make speculative inferences for each study site temporal phase concerning local veterinary health issues associated with dairying.

In this final chapter of the study some of the arguments that have been elaborated throughout are collated and summarised, beginning with a critical discussion of the frequently-adopted inference of anthropogenic slaughter of bovine infants or neonates to maximise milk harvest, as described by Payne as his ovine 'milk production kill-off pattern' (1973: 281-283, fig 2), as adopted by, for example, Legge (1981a: 86-87, 1981b: 172, 1989: 226-227, 2005: 12) and Serjeantson & Bond (2007a: 224-225; 2007b: 205-206). A critical review of the different methodologies attempted herein follows, which suggests in what ways, with hindsight, the study could have been better performed, such as extending the age-range of control animals. Finally, further work in response to some of the findings of this study is suggested, for example, applying the tooth-development methodology to other assemblages on a wider scale, or to different species.

13.1: The fate of neonates?

For many zooarchaeologists, the interpretation of cattle mortality profiles within archaeology relies on the assumption that Payne's (1973) ethnographic observations of sheep husbandry, whereby, under a milking regime, lambs surplus to breeding requirements will be culled shortly after birth, can be applied equally to cattle. However, it seems illogical to nurture a cow through its pregnancy for 9 months, only to slaughter the offspring at birth, particularly when farming under straitened circumstances in marginal environments, as probably applied in many of the Orcadian site contexts in this study. Calves represent a relatively small threat to milk output: weaning can supervene after a few weeks, leaving an exploitable extended lactation. After birth of a calf around May, the lactation can be continued, milking twice a day, through the summer, stimulated by the presence of the calf, kept within the view of the cow, but with only limited access to the udder, with the cow drying off at the approach of winter. This was the practice in early Christian Ireland (Kelly 2000: 41). It has been shown experimentally that allowing calf suckling before milking, or the simple presence of the calf during milking, can elevate the amount of saleable milk, together with its fat content, even in modern ‘improved’ cattle (Combellas, 2003: 227).

Ethnographic parallels also do not appear to favour the ‘infant slaughter theory’; for example: “skeletal remains from calf losses as high as one-third could give the (mistaken) impression that young animals had been preferentially killed” (Ryder, 1981b: 329 (Dyson-Hudson study of Karimojong tribe in Uganda)). Historiographic references to let-down stimulation strategies (for example the dummy calf) (Lucas, 1989, 51) could equally have been initiated by the death, not slaughter, of the calf. Indeed, much of the historiographic evidence for male calf slaughter at birth seems to come from cases of extreme poverty and human near-starvation at subsistence level (especially 18-19th century Irish) where survival was dependent on the milk supply, rather than a ‘dairying’ economy. The fact that it was reported at all may indicate that this was not the norm, but something unusual to English ears (Lucas 1989: 52-53).

The male calf was of value: it could be fattened for meat, castrated and ultimately used for traction as an ox, or was a potential bull for breeding. In patriarchal cattle-centric societies such as those in the archaeological study contexts (Armit 2005: 64; Kelly 2000: 27-29), the destruction of an infant bull seems illogical. In Walter of Henley's 'Seneschaucy' (13th century), 'culling' involved fattening up unwanted stock on good pasture, to make a quick sale. These comprised old and weak oxen, those with bad teeth, old, feeble or barren cows, worthless heifers which did not thrive, and any other worthless young beasts who would not grow (Oschinsky 1971: 275). Killing new-born male calves to maximise the milk supply was not mentioned.

Indoor calving and calf rearing could have exacerbated mortality and abortion, particularly in deep-litter conditions, through poor hygiene. Bunching of penned calves to prevent access to the udder can precipitate disease outbreaks of such organisms as enterotoxigenic *Escherichia coli*, or its ancient correlate (Webster 1984: 126). This is often due to the innate sucking behaviour; calves will suck, lick and chew inanimate objects. Given access to other calves, they will suck ears, tails, navels, teats and pizzles; the latter may also involve urine drinking. Such 'vices' can exacerbate risk of the rapid spread of disease among the bunch (Webster 1984: 149-150). The presence of infant material around sites could be indicative of attrition due to some of these close management practices. Mastitis, commonly associated with poor dairy hygiene and hand milking, has been shown to increase the risk of abortion, and hence loss of future lactation, in modern cattle, by a factor of 2.7 (Risco, 1999: 1684); calves suckling mastitic udders are also at an obvious risk of acquired infection.

There is no transfer of maternal antibody through the placenta to the bovine foetus; calves are dependent on ingesting enough colostrum in the first 18-24 hours of life in order to receive enough protective immunoglobulin for defence against environmental pathogens (Guidry 1985: 230; fig. 7.1). There is a possibility that this vital colostrum was not always fed to calves in antiquity, as it was thought in some cultures (such as Rome or Early Mediaeval Ireland, where literary sources have survived (Forster & Heffner 1968; Kelly 2000)) to be harmful. In parts of present-day Turkey, farmers believe colostrum itself to be responsible for neonatal diarrhoea; calves are therefore not allowed to suckle for the first few days of life (Koç & Gökce 2007: 210); this must severely jeopardise their chances of survival.

Comparisons of calf mortality figures with those for sheep to ascertain differential husbandry practices may sometimes be problematic, as lambing may have taken place in the field, where it is unlikely that skeletal remains would be recovered in archaeological excavations. As has been discussed, lambs are more sensitive than calves to low environmental temperature at birth (Webster 1983: 662, table 16.6; 664; table 16.7) (table 2.1). This is particularly relevant when considering Orcadian contexts, where wind-chill can considerably reduce the ambient temperature. Halstead (1998: 12) considered the implications of low ovine neonate recovery in wheelhouse and broch sites in the Western Isles; he discounted biased retrieval because of the intensity of sieving used, which would have revealed neonate bone fragments. However, local husbandry practices might have involved supervised lambing at some point distant from the settlement site (Mulville *et al.* 2005: 172), such as a lambing pen or other ephemeral structure, which may not have been excavated, where the remains of aborted and stillborn lambs might be expected to have accumulated. Unattended stillbirths and lamb deaths in the field might also leave no trace due to scavenger activity. Hence ovine mortality figures may be the result of biased sampling from an incomplete death population.

In modern British cattle husbandry, a 3-5% abortion rate (Boyd & Gray 1992: 469) plus at least 5-6% mortality in neonate calves (Webster 1984: 3; DEFRA 2003) is considered 'normal'. In 5-10% of births dystocia arises, from which only a proportion of calves may survive (Leaver 1999: 39). Hence, in antiquity, if a largish proportion, certainly considerably more than 10%, of calves are already likely to have been lost through abortion, dystocia and neonate death, is it logical to kill off 50% of the survivors? Even if they are males, they can be fattened for meat or used as oxen. Perhaps in circumstances of environmental extremis, where insufficient fodder is available, and the dam cannot provide sufficient milk, slaughter of the calf might be justifiable; this argument was promulgated by McCormick (1998).

In the ancient contexts under discussion, trade and exchange of animals and dairy products would probably have been limited, except perhaps during the Later Iron Age, or the Norse period, particularly at high-status Earl's Bu, where there may have been a demand for meat from settlements in the surrounding hinterland as a form of tribute. Mine Howe, as an earlier ‘ritual’ site, might also have been a focus for votive offering and feasting. Although circumstances such as these would not constitute a ‘market’ as such, these external demands might have influenced the retention of surplus calves. In modern dairying, where milk let-down can proceed without the presence of the calf, retention of the male calf (and a proportion of the females) can be subject to market forces, such as the demand for veal, with the possibility of live calf exports. Breeds such as the Holstein (the commonest British dairy animal at present) are not suitable for beef, since, by selective breeding and genetic manipulation, all of the animal’s energy has been directed into producing milk, at the expense of muscle; hence the male calves are of little value except for veal (BBC 2009; Vernelli 2005).

Payne’s models were formulated by ethnographic studies of modern sheep-herding (Payne 1973). Is it valid to use them for cattle? In the period studied, cattle, as oxen, would probably have been the main source of motive power for transport and, crucially, ploughing. Pathological evidence from adult cattle bones recovered from these sites, for example at Pool (Bond 2007c: 234) and Tofts Ness (Bond 2007b: 200), indicate arthritic lesions, such as articular surface grooving and eburnation, possibly resulting from the use of cattle for traction. Hence, whatever the ‘main’ exploitation pattern, whether for meat or for milk, a certain minority of the animals in the herd, probably male, may also have been used for traction. It seems highly unlikely that all of the herd would be so used, as would have been the case for wool in sheep, except where very few cattle were kept. Hence, can the use of cattle solely for traction as a mortality model be considered equivalent to that for the exploitation of sheep for wool? Should the models for cattle perhaps be: meat/traction, milk/traction, and, possibly, meat/milk/traction? The last is probably the most likely paradigm for small marginal settlements in the Neolithic, Iron Age and Early Mediaeval periods, such as those considered in this study, except Earl's Bu, Mine Howe and, perhaps, Snusgar, where circumstances reflecting the higher status of the site may have applied. In a combined exploitation strategy such as meat/milk/traction, however, Payne's models would appear to be no longer valid.

'Natural' mortality, not involving slaughter, must be a potential source of bovine neonate material in archaeological site bone assemblages. This is occasionally acknowledged and discussed in site reports; some authors even mention foetal as well as neonate death (for example, Smith 1994: microfiche 1: D5; 1: E13). The potential causes of this mortality are rarely discussed except in general terms, such as lack of feed, adverse weather, or poor management. Mention of microbiological pathogens and abortifacients has been noted only infrequently in an extensive search of the archaeological literature, except in terms of zoonotic effects on human populations (Brothwell 1988), by diseases such as TB or brucellosis.

How many of the neonate bones in assemblages could be accounted for by such environmental attrition and disease? Neonate calf death by 'natural' mortality is indistinguishable from slaughter archaeologically – except perhaps in cases of intact deposition or lack of butchery marks. However, abortions are rarely the result of deliberate anthropogenic activity. Their identification in assemblages might give an idea of the overall attritional rate in neonate calves in general.

Age-diagnosis results of bovine neonates from most phases in the majority of the archaeological sites in this study, using the modified tooth-development technique described herein (from Brown & Chapman 1991a, b), have differentiated a range of age-cohorts at each, including some that could well have been candidates for anthropogenic culling to maximise milk production. However, although few definitive foetuses were found, a common feature of many of the site phases has been high levels of mortality among new-born animals, as indicated below; this would most likely have prevented the initiation of lactation in the corresponding maternal animal; as cited by Halstead (1998: 6): in ‘unimproved’ cattle, the lactation must be securely initiated by suckling of the offspring, allowing removal of the calf by around the 10th day after birth at the earliest.

Thus the investment of care in a pregnant cow would have been negated as far as the milk supply was concerned; unless she had become infertile and culled, she would have to endure a further pregnancy before her lactation could be exploited after about a year. Such was the proportion of mortality at birth, that in most site-phases further deaths, anthropogenically mediated, would probably have threatened the viability of the herd. This is not to suggest that a milking emphasis to cattle husbandry was not consciously pursued at these sites, or that killing decisions were not made or influenced by the sex of the animal. Such an emphasis and such decisions, however, were probably driven by pragmatism.

13.2: Methodological issues: critical reviews of the methodologies utilised in the study

Criticisms are based on the use of the technique for age-diagnosis of neonate material, rather than age-diagnosis in general, and reinforce those given in the methodological chapters 8 & 10, as well as suggesting how use of the technique could have been improved in the study. Results from the archaeological assemblages obtained using different techniques were compared in section 11.3, *et seq.*

Metrical technique: The main disadvantage with metrical techniques appears to be that they depend on knowledge of the breed concerned for accuracy; known-age control examples from the same breed are required for the compilation of reference tables or formulae. As has been discussed, modern cattle may in general be much larger than those in antiquity. It would be very difficult to obtain known-age foetal and neonate material from possible correlates, such as the Irish Black, Dexter, or perhaps Chillingham Wild White cattle (Hall 2006), for use as control material.

An additional problem with metrical analyses is that in order to utilise them to their full potential, intact elements are required; in the archaeological contexts under discussion, mandibles were often found fragmented, particularly from neonate material where calcification is incomplete. As has been described, the technique was modified to accommodate fractured material, although, inevitably, this may have prejudiced results to a certain extent.

Tooth-wear analysis: This well established technique has been demonstrated to be reasonably accurate and easy to use; however, where foetal or neonate material is concerned, it is unable to differentiate the ages of animals before tooth-wear commences. As mentioned, there has been some debate concerning the inception of wear (Mulville *et al*. 2005: 171), but for the control material used in these analyses, none was demonstrable on mandibles aged less than 7 days. There is a degree of subjectivity involved in deciding wear-stages; a set of controls read ‘blind’ by every operator would perhaps provide some degree of quality assurance.

The accuracy of tooth-wear analysis may be compromised if the subject animals consumed herbage from gritty or sandy soil, which can cause excessive wear (O’Connor 2000: 89), perhaps resulting in an over-aged analysis. This would be generally inapplicable to foetuses and neonates which lacked wear; those commencing wear on the dP4, classed as wear stage ‘a/b’ or ‘b’ as discussed in section 10.3 (Mulville *et al*. 2005: 171), might be affected to some extent

Tooth-development analysis: This technique formed the focus of the methodological aspect of this study. Using radiography gave a clear indication of the development stage of each tooth while still in the mandible, including those which had not yet emerged. The technique was easy to perform, but required the use of specialised equipment and, ideally, a dedicated radiography suite.

There were some difficulties encountered in identifying the various tooth-development stages, as defined by Brown & Chapman (1991); some judgements were fairly subjective. An attempt was made to regularise this in one case, as described in section 8.6. The data obtained from tooth-development scores is ordinal, but with varying ratios, hence it was possible to apply only basic mathematical techniques, such as confidence intervals, for a limited statistical analysis. This was reflected in the diagnostic results: ages were specified as categories, such as ‘late foetus/newborn’ or ‘juvenile’ rather than precise ages. The close propinquity of natal events produced conflated cohorts, such as ‘late foetus/newborn/neonate’, as in some cases the technique was unable to differentiate between these stages.

The known-age control material, upon which the interpretative tables were based, was composed of modern stock; a variety of breeds, both beef and dairy, were represented. One major difficulty was the lack of representation of certain age-groups; this produced uncertain data in some cases, but was a factor of the sample collection. The material represented the throughput of the VLA diagnostic laboratory, so the age of specimens was entirely due to happenstance. However, the majority of material appeared to reflect in age the majority of the archaeological material from the study sites, although more representatives of 2-, 3- and 4-weeks of age would have been desirable.

One opportunity that was missed at the time would have been to observe the eruption of the dentition through the gingival surface, before defleshing. Unfortunately, the significance of the difference between eruptions *per os* and *per gingival*, as reported in the literature, was not realised till later in the study. As mentioned, material from stock that closely resembles ancient animals, such as Irish Blacks or Chillingham Wild White cattle, would have been desirable, but obtaining these would also be problematic.

13.3: Issues arising from the study; potential further work

A number of physiological and microbiological issues of particular interest in archaeology have arisen as a result of this study. Some merit consideration for future archaeozoological studies, while others may provide new methodologies for neonate age-diagnosis.

13.3.1: Application of the tooth-development methodology to other sites

One possibility for further study would be the extension of the technique to sites where milking has already been inferred in site reports, both in the North Atlantic region and elsewhere, in order to assess the proportion of foetal and newborn animals contributing to neonate attrition. An important extension of this would be to assess the foetal/newborn mortality in contexts where milking was not inferred, to establish whether the modern differential between dairy and beef calf mortality (1 in 6 dairy; 1 in 14 beef (DEFRA 2006)) applied in the past. This might provoke discussion on the global implications for the diagnosis of milking using tooth-wear and Payne's (1973) models.

13.3.2: Lameness: Lameness is the most important current welfare issue in dairying (Watson 2007). As has been described, this issue arises primarily through forcing the animal to endure conditions that in the wild or feral state it would avoid, such as uneven, stony, muddy cow tracks or yards, standing for long periods in slurry, urine, mud and other effluvia, and having no dry comfortable lying area available. Once established, hoof lameness is difficult to cure, even with modern medications, and results in reduced milk yield, loss of weight and reduced fertility. In the past, this problem can only have been worse than today, without modern veterinary care and medications.

Some understanding and reconstruction of past husbandry techniques would be necessary in any study of lameness, including, for example, the use and morphology of byres for daily milking, whether the animals were tethered in the field, and milked *in situ*, the practice of summer transhumance and whether the animals were stalled indoors over winter. It might even be possible to reconstruct a contemporaneous cow-track, as animal pathways can be extremely persistent in unploughed land. All these factors could have had an influence on the occurrence and severity of pedal lameness. It would, however, be tenuous to associate severe pedal lameness with dairying, since animal handling in a 'meat-only' regime might mimic some of the factors listed above.

An understanding of any bone pathologies associated specifically with pedal lameness in cattle by examination of suitable modern post-mortem material would thus be of interest, particularly if it enabled differentiation of lesions caused by pedal lameness (perhaps resulting from osteomyelitis through 'super-foul' infections) from lesions associated with traction-associated lameness (as described by, for example Johannsen (2005); Isaakidou (2006)).

13.3.3: Colostrum uptake: As reiterated frequently in this study, adequate colostrum consumption is of crucial significance to the calf, without which it has little resistance to disease in the neonatal stage, as calves have no conferred cross-placental maternal antibody at birth (Guidry 1985: 230; fig. 7.1). Further historiographic and ethnographic research might clarify attitudes to colostrum in antiquity.

13.3.4: Mastitis: As has been shown, mastitis, a major cause of debility in cattle, is usually anthropogenically mediated; in the past, with little or no hygiene in practice and no mechanical alternative to hand milking, it must have been widespread. It may also have been a major source of zoonotic infection, such as TB or brucellosis, for human consumers of milk. A technique for demonstrating the past existence of TB by amplification of their DNA from human and animal material is now in use (Spigelman & Donoghue 2003: 175-188; Mays 2005); and may soon be extended to include other species of microbial pathogen.

13.3.5: Possible appearance of the neonatal line in the bovine dentition: The neonatal line is distinguishable around 7-10 days after birth in human infants (Smith & Avishai 2005: 84). Establishment of the corresponding timing for bovines could be a useful tool in age-diagnosis of neonate material from archaeological sites, particularly as loose teeth are particularly durable. Unfortunately as it involves sectioning of the tooth, the technique generally used in demonstrating the neonatal line is highly invasive and requires some degree of expertise to perform. The acquisition of a selection of modern bovine mandibles of known age from birth to 2 or 3 weeks would be a necessary precursor to any future study.

13.3.6: Application of the tooth-development technique to other ungulate species: The obvious candidate of most interest would be the sheep. However, an assemblage of known-age foetal and neonate material might be more problematic than for cattle, since accurate service dates are unlikely to be available, and foetal and neonate lambs are rarely submitted for analysis to the VLA laboratories unless an epidemic infection is suspected. The best means would probably be to obtain material direct from individual flocks. Ovine foetal and neonate mandibles are more fragile than those of the bovine, and would probably be less likely to survive taphonomic processes; recovery of such material may also be affected by assemblage formation processes, such as off-site field-births and lambing sheds, as discussed by Halstead (1998).

13.3.7: 'Holistic' approach: As has been shown in the methodological chapters of this study, the tooth-development methodology (adapted from that of Brown & Chapman 1991a, b) is not a 'stand alone' technique; assemblages must first be examined by tooth-wear analysis (after Grant 1982; Halstead 1985; Mulville *et al.* 2005) in order to select suitable neonate material for radiographic examination. It is also suggested herein that putative foetal mandibles diagnosed by tooth-development are subsequently examined using Gjesdal's (1969) developmental sequence in order to provide a more accurate gestation age.

As discussed in the previous chapter, (section 12.12), the tooth-development (and tooth-wear) methodologies, designed for accurate ageing of cattle populations, should similarly be included among a battery of different techniques and observations applied at excavations; each of which could then be given due weight in overarching conclusions concerning contextual human social and economic activity in antiquity.

13.4: Conclusion and overview

In accordance with its overall aims (section 1.2), this study has had dual aspects: a methodological investigation attempting to clarify bovine age diagnosis around the time of birth, using material recovered from archaeological contexts, and a study of archaeological, historiographic, ethnographic, agricultural and veterinary literature in order to discover what factors might have contributed to the death of calves at this early stage of their lives, together with anything that might be specifically associated with dairying in antiquity which might have caused debility in bovines. This was contextualised using bovine bone assemblages from six Orcadian sites with temporal phases dating from the Neolithic to the Norse period, where, in each case, specific temporal- and location-based inferences were drawn, sometimes including tentative suggestions of the disease agency involved.

The methodological aspect described the development of a technique enabling diagnosis of neonates to be sub-categorised in five age-cohorts. The allocation of an individual into one of at least two of these cohorts casts doubt on the possibility of it being a subject of 'kill-off' through dairy practices described in the 'milk' model of animal exploitation (Payne 1973). On the contrary, death was probably mediated through the local environmental conditions that applied at the time, and was almost certainly a disappointment to the human pastoralists of the settlement concerned. 167 neonate age-diagnoses were carried out drawn from the six study assemblages; it is estimated that 43% of the animals concerned were from foetal and new-born age categories and diagnosed to have died by attrition rather than slaughter.

The literary aspect of the study revealed many possible environmental and microbiological causes for early death and debility in calves. An exploration of the practice of hand milking showed that this could have been associated with multiple risk factors, such as mastitis, affecting not only the cow and her calf but also the human milk consumer.

While the regular slaughter of calves at an early age, in order to promote milk harvest for dairying activity, has not been disproved, on some of the marginal Orkney sites studied here, new-born calf attrition, probably mediated by a lack of adequate suitable fodder for the dam through the latter stages of her pregnancy, reached such high levels in some temporal phases that slaughter of additional animals would probably have been highly disadvantageous for the viability of the cattle-herd. It is suggested instead that the pastoralists of Orkney made pragmatic use of whatever survived, using animals both for secondary products such as milk and tractive effort, and also for direct consumption as meat.

In focussing on the potential deleterious effects on the animal participants of the anthropogenic exploitation of bovine milk in antiquity, this study has attempted to fill a perceived gap in published archaeological literature, and has also revealed the significance of several important veterinary factors in dairying, such as the effects of lameness, and also the significance of colostrum consumption in the new-born calf, that were not otherwise widely promulgated therein.

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APPENDICES

APPENDIX I: DEFRA proforma

SUPPLY OF BOVINE FOETAL HEAD AND FORELEG FOR ARCHAEOLOGICAL RESEARCH

Date:

VLA Laboratory identity and reference:

Breed:

Sex:

Beef or dairy herd:

County/parish:

FOR FOETUSES:

Stage of gestation (months/trimester):

FOR NEONATE CALVES:

Castrated (yes/no):

Housing:

Dietary regime:

Age:

APPENDIX II: COSHH assessment for defleshing, incorporating Standard Operating Procedure (SOP)

ASSESSMENT OF HEALTH RISK ASSOCIATED WITH A PROPOSED SCHEME OF WORK

Preparation of Bovine Foetal Material for Radiographic Analysis of Mandibles

Control of Substances Hazardous to Health (COSHH) Regulations

BIOLOGICAL AND CHEMICAL

SECTION A

Department:	Archaeological, Geographical and Environmental Sciences
Location of work:	Phoenix NE 1.34 ‘wet’ laboratory
Personnel involved (including status) in proposed work:	Geoffrey Davis (PG research student); Ingrid Mainland (Supervisor); Usha Gohil (Technician)
Title of proposed work:	Preparation of bovine foetal material for radiographic analysis of mandibles.
Aim of the work:	Removal of soft tissue to allow bone analysis
New experiment procedure **Yes**	Established Experiment/procedure **No**

CHEMICAL AGENTS			Hazard (CHIP descriptions)												Quantities (numerical value)	
Substances used or formed during experiment	Substance (CAS#)	Form	Explosive	Oxidising	Extremely flammable	Highly flammable	Very toxic	Toxic	Carcinogen	Mutagen	Harmful	Corrosive	Irritant	Dangerous for the environment	OES	Amounts used
10% buffered formaldehyde		liquid					*	*			*	*	*			2 x c10 litres per session (see SOP)

BIOLOGICAL AGENTS			Quantities (numerical value)
	Hazard	Hazard Group	Max volume to be handled
Procedure involves defleshing of bovine foetal material. Material will be pre-soaked in 10% buffered formaldehyde before processing, hence microbiological contamination is likely to be minimal.	Handling and defleshing of samples	Category 1 and below Unlikely to cause disease.	Two samples to be processed at a time.

Information sources used: Chemical data sheet .
Anticipated frequency of the work (and duration of exposure): 3 hours per day up to three times per week

SAMPLE COLLECTION AND STORAGE:

Material will be collected by the research student in deep-frozen form and delivered by direct transit to the 'wet' laboratory NE 1.34 double-bagged in rigid plastic box containers lined with a further bag. Double-bagged material will be stored in a padlocked freezer within liner bag until processed. Freezer will be exclusively used for this project, and labelled accordingly. Boxes and freezer will be wiped down and decontaminated with 1% 'Virkon S' solution inside and outside after use.

PROCEDURES:

To be undertaken within operating Class 1 cabinet in 'wet' laboratory NE 1.34. Personnel involved will wear fastened 'Howie' type laboratory coat, safety glasses and rubber gloves. Cabinet will be pre-equipped with 2 lidded 15 litre rigid plastic boxes containing 10 litres 10% buffered formaldehyde as fixing baths, spare gloves, forceps, clinical waste bin, tape, scissors, scalpels, wash bottles containing dilute detergent and disinfectant (1% 'Virkon S' solution), trays and paper towels. Cabinet will also contain two electric slow cookers. Each working area will be marked with the reference number of individual sample.

STANDARD OPERATING PROCEDURE:

1. Transfer double sample bags containing frozen foetal material from lining bag in freezer to cabinet. Remove outer bag to clinical waste. After piercing inner bag several times with scissors to allow liquid access and egress, submerge in bath of 10% buffered formaldehyde and allow to fix for a minimum of 2 weeks. Rinse scissors with 1% 'Virkon S' to decontaminate.
2. Remove bag from bath, allow contents to drain, transfer to paper-tissue lined tray, open, and remove foetal material onto tray. Discard plastic wrapping to clinical waste bin. With scissors and forceps, remove as much skin and soft tissue as possible from mandible area of head and from foreleg. Dispose of removed soft tissue and paper tissues into clinical waste bin. Wipe down tray and instruments with detergent solution.
3. Place head and leg in slow cooker, half-fill with water, cover, and switch on at low heat.
4. Spray work surface and tray with dilute detergent solution, together with used scissors and forceps. Wipe down surface and instruments with paper towels, dispose of into clinical waste bin.
5. Examine at hourly intervals to assess extent tissue around mandible and metacarpal has loosened (will vary between samples), and water level within cooker. Top up with water if necessary.
6. When tissue appears fully loosened, switch off cooker, remove material to tray and allow to cool. Remove remainder of tissue from mandible and metacarpal using scissors, forceps and scalpel if necessary. Set these bones aside to dry out on paper towels, labelled with reference number.
7. Dispose of remaining material, including skull, into clinical waste bin, together with any free tissue in cooker. Dispose of cooker liquid contents down sink with copious water to dilute. Clean cabinet working area, tray, cooker bowl and instruments as in 4) above. Dispose of used scalpel blades into sharps bin.
8. When clinical waste or sharps bin is full, or when operations are complete, seal bag with biohazard tape and securely fit box lid. Notify Usha Gohil, chemistry technician responsible for laboratory, who will arrange for collection and disposal of waste bags by incineration under standard protocols.
9. Replace 10% buffered formaldehyde fixative after 5 uses. Dispose of spent fixative to liquid waste container. Notify Usha Gohil, chemistry technician responsible for laboratory, who will arrange for disposal of liquid waste.
10. A notebook record of all operations will be maintained.

Are quantities and dilutions described above as well as Good Laboratory Practice sufficient to minimise any risk to health? **YES**

- If the answer to the above is '**YES**' then no further assessment under COSHH is necessary. However, it is considered Good Practice to complete this assessment form.
- If the answer to the above is '**NO**' then complete the whole form, then sign and pass to Ben Stern or Carl Heron.

Are there less hazardous alternatives available – **NO** If '**YES**', give reason for not using:

Control measures to be adopted to minimise biological risk:

Samples fixed in 10% buffered formaldehyde for 2 weeks to allow adequate penetration.

Use of Class 1 cabinet, gloves, laboratory coat.

Samples opened in cabinet.

Hand washing after operations

Adoption of good laboratory practice.

Required checks and their frequency, on the adequacy and maintenance of control measures during the course of the experiment/procedure:

Gloves checked for leaks before use.

Cabinet operation and flow checked before use.

Slow-cooker water level checked every hour while cooking.

Protective clothing, gloves changed as required during operations.

Cabinet and equipment cleaned as required during operations.

Formalin accumulation monitored with formalin meter periodically.

Procedure record maintained in workbook.

Is health surveillance necessary? (See A.C.O.P.) **NO**
If '**YES**' state type and send copy to University Health Service:

SECTION B

Additional relevant information. Including other hazards not covered by COSHH regulations:

SECTION C

Disposal procedures during and at the end of proposed work. Solid waste to be disposed of into clinical waste bin. When full or procedures complete, bag to be sealed with 'biohazard' tape and lid fitted securely to seal container. Used 10% buffered formaldehyde to be disposed of as liquid waste. Usha Gohil, technician responsible for room, to be contacted to arrange collection and disposal of liquid waste and clinical waste.

SECTION D: EMERGENCY PROCEDURES

Spillage/uncontrolled release: 10% buffered formaldehyde: Dilute spill with copious water; mop with paper towels.
Fire: Not applicable
Personnel exposure - Treatment to be adopted: 10% buffered formaldehyde: Eye contact: flush eye with water for several minutes. Call for medical help if required. Skin contact: wash with soap and water. If signs of burns, reddening, seek medical help if required.
Shutdown procedure for equipment/machinery etc. Not applicable
Emergency contact: Telephone number: Belinda Hill Ext. 5212 Graham Seed (University safety officer) Ext. 3738 Security Ext. 4499

Name of assessor: GEOFFREY DAVIS Status: PG Research student …………………………… Signed: …………………………… Date: ……………………………	Co-ordinator, compiler and recorder of COSHH assessments (Carl Heron or Ben Stern): Signed: …………………………… Date: ……………………………

APPENDIX III: Tooth-wear analysis record form

GEOFFREY DAVIS: Bovine foetal mandible survey 2006-2008; wear stage assessments

SITE: **CODE:** **DATE:**

Key: Ø = unerupted, C = crypt, V = visible, E = erupting, ½ = half-erupted, a = unworn

Ref	Phase	Find	Side	dp2/P2	dp3/P3	dp4/P4	M1	M2	M3	MWS	Comments
											et seq.

APPENDIX IV: Radiography protocols

Protocol for operation of X-ray unit

1: Warm-up procedure

1. Switch unit on at wall, turn power key on
2. The tube voltage display will light
3. Turn KVP control knob clockwise until tube voltage display reads approximately 50
4. Set time for 2 minutes
5. Press green start button
6. If 'x-ray on' button or 'tube current indicator' do not light consult trouble-shooting chart
7. When warm-up period is complete the unit will automatically turn off the x-ray beam
8. Turn KVP control knob anti-clockwise until tube voltage indicator reads 00
9. The unit may now be used to radiograph specimens

2: Taking an exposure using upper cabinet

1. The shelf should normally be on the lowest pair of side supports in the upper cabinet
2. The film cassette and object should be placed immediately below the beam centre and within the beam spread as indicated on the shelf

3. Close door carefully and completely
4. Select appropriate time and tube voltage
5. Press start button
6. When exposure is complete turn KVP control knob anticlockwise until tube voltage indicator reads 00
7. Do not turn power key off between exposures

Protocol for X-ray film processing

Remember to use safety specs when processing film

1. DEVELOP FOR 5 MINUTES Agitate for the first 30 seconds to remove air bubbles, and then for the first 10 seconds of each successive minute.
2. STOP FOR 2 MINUTES Agitate for the first 30 seconds
3. FIX FOR 15 MINUTES Agitate for the first 30 seconds
4. WASH FOR 30 MINUTES

Drain films over tanks for a few seconds before transfer to avoid mixing the chemicals. Take care not to splash the walls. Replace lids on tanks after use; make sure the lids on the small tanks are firmly sealed.