

**SOME TAPHONOMIC EFFECTS OF SCAVENGING CANIDS ON THE BONES  
OF UNGULATE SPECIES:  
SOME ACTUALISTIC RESEARCH AND A ROMANO-BRITISH CASE STUDY**

by

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of the requirements for the degree of  
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## Dedication

This thesis is dedicated to my family:  
to my parents Pat and Herrick Stallibrass,  
and to my sister Elizabeth, to thank them for all  
their support and encouragement over the years  
(Perhaps now I'll be able to get a proper job).

**SOME TAPHONOMIC EFFECTS OF SCAVENGING CANIDS ON THE BONES OF  
UNGULATE SPECIES: SOME ACTUALISTIC RESEARCH AND A ROMANO-BRITISH  
CASE STUDY**

Bones of dogs are found on most archaeological sites of holocene date in several continents. The presence of tooth marks on the bones of other species often suggests that a recovered assemblage has undergone scavenging by canids and may be taphonomically biased.

An actualistic study monitored the destruction, weathering and burial of bones of modern sheep and deer that had died naturally and been scavenged by foxes. The assemblages recovered after three years are biased severely towards certain element types and have suffered the preferential loss of young bones or epiphyses. Sub-collections within the sheep assemblage indicate that relative frequencies of elements are different in residual and carnivore-transported assemblages.

Comparisons with work by other researchers indicate that:

- (1) inherent factors influence element survival rates, and
- (2) the patterns of element frequencies in assemblages from carnivore-scavenged carcasses are consistent across a wide range of environmental settings.

The results of the actualistic study were applied to some Romano-British material from a military site in northern Britain. Several of the ungulate bones show tooth marks and patterns of breakage that are very similar to those observed in the actualistic study. It is very likely, therefore, that this assemblage was scavenged by dogs (bones of which were also recovered). The relative frequencies of elements of the sheep-goat and cattle assemblages match those of the modern sheep assemblage, suggesting that whole carcasses of both species were deposited at the site. The paucity of certain element types can be explained by the activities of scavenging canids together with a bias against the recovery of smaller bones, and need not be the result of cultural practices such as trading.

A new method is suggested for the demographic analysis of archaeological faunal assemblages that overcomes some of the biases caused by the preferential loss of unfused epiphyses.

Susan Mary Stallibrass  
September 1986

### Declaration

I hereby declare that this thesis submitted for a Ph.D. degree at the University of Sheffield is not substantially the same as any I have submitted for a degree, diploma or other qualification at any other university.

I further declare that no part of this thesis has already been or is being concurrently submitted for any such degree, diploma or qualification.

The work and results embodied in this thesis are the result of my own work except where stated or acknowledged in the text and bibliography.

Sue Stallibrass

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**CONTENTS LIST**

**CHAPTER 1: AN INTRODUCTION TO THE STUDY**

A BRIEF SUMMARY OF THE STUDY.....1

    BACKGROUND.....1

    THE AIMS AND OBJECTIVES OF THIS STUDY.....6

    THE STUDY.....7

    THE VALIDITY OF USING FOXES AS AN ANALOGY FOR DOGS.....8

AN ARCHAEOLOGICAL APPLICATION OF THE PRINCIPLES ESTABLISHED  
BY THIS ACTUALISTIC STUDY.....9

    SUMMARY.....11

**CHAPTER 2: AN INTRODUCTION TO THE ACTUALISTIC STUDY AREAS**

    INTRODUCTION.....13

    1. THE SHEFFIELD SHEEP SURVEY AREA.....13

        THE LANDSCAPE.....13

        THE SHEEP.....15

        THE SCAVENGERS.....15

        (1) & (2) humans and dogs.....15

        (3) Foxes.....16

        (4) Badgers.....16

        (5) Stoats.....17

        (6) Birds.....17

        Summary of potential scavengers.....17

        THE TIMING OF THE STUDY.....18

        METHODS OF RECORDING IN THE FIELD.....18

        SUB-DIVISIONS OF THE COLLECTION.....20

        RECORDING OF THE COLLECTION IN THE LABORATORY.....21

    2. THE GRIZEDALE SURVEY AREA AND COLLECTIONS.....21

        INTRODUCTION.....21

        FIELD RECORDING METHODS.....22

        ANALYSES USING THE GRIZEDALE COLLECTIONS.....23

        SUMMARY.....23

**CHAPTER 3: AN INTRODUCTION TO THE DATA AND VARIABLES EXAMINED IN THE SHEFFIELD SHEEP AND GRIZEDALE DEER STUDIES**

INTRODUCTION.....	25
AIMS AND OBJECTIVES OF THE ACTUALISTIC STUDY.....	26
THE VARIABLES OBSERVED TO BE IMPORTANT IN THE ACTUALISTIC STUDY...27	
Internal and external variables.....	27
Quantification of the variables.....	28
Disarticulation.....	28
The interaction of the variables.....	29
THE PRESENTATION OF THE RESULTS.....	29
THE BONE COLLECTIONS.....	31
THE SHEFFIELD SHEEP COLLECTIONS.....	31
<b>The S146 sub-collection.....</b>	<b>32</b>
The total Sheffield sheep collection.....	33
Bones that were observed but not collected.....	33
THE GRIZEDALE DEER COLLECTIONS.....	34
The animals.....	34
Timespan.....	35
METHODS OF ANALYSIS.....	35
Element types.....	35
Minimum Numbers of Individuals.....	37
Methods of calculation.....	37
The S146 sub-collection MNI.....	37
The total non-carcass collection MNI.....	38
Element frequencies.....	39
Introduction.....	39
Measures of element frequencies.....	39
<b>Raw frequencies.....</b>	<b>39</b>
<b>Brain's Index.....</b>	<b>39</b>
Spatial distribution of elements.....	41
Percentages of attacked bones of each element type.....	41
Visual patterns of damage.....	42
Fusion state.....	43
Completeness categories.....	43
SUMMARY DATA FOR THE BONE COLLECTIONS.....	43
A comparison of the rates of attack and the average numbers of bones per individual in the different collections and sub-collections...44	
The carcass collection.....	44
The non-carcass sub-collections of sheep bones.....	45
STATISTICAL TECHNIQUES USED IN THIS STUDY.....	46
An introduction to the statistical limitations of the data.....	46
The choice of statistical techniques.....	47
The statistical significance of the results.....	48
SUMMARY.....	49

**CHAPTER 4: ELEMENT FREQUENCIES IN THE SHEFFIELD SHEEP CARCASS COLLECTION**

INTRODUCTION.....	51
THE ARCHAEOLOGICAL RELEVANCE OF THIS STUDY.....	53
THE OBSERVED FREQUENCIES OF ELEMENT TYPES IN THE SHEFFIELD SHEEP CARCASS COLLECTION.....	54
HYPOTHESES REGARDING FACTORS THAT MAY HAVE INFLUENCED THE OBSERVED ELEMENT FREQUENCIES.....	55
Introduction.....	55
Hypothesis 4:1 There is a cultural bias against the recovery of small bones.....	55
Correlation of element size and frequency.....	55
The influence of other factors, i.e.: structure, meat cover, marrow content, articulations and consumption, on the recovered element frequencies.....	57
1) Disarticulation.....	57
<b>Cervical, thoracic and lumbar vertebrae.....</b>	58
<b>The astragalus.....</b>	59
2) Hypothesis 4:2. Small, attractive, fragile elements are consumed by scavenging carnivores.....	59
<b>The hyoid.....</b>	59
<b>The ribs.....</b>	60
3) Hypothesis 4:3. The removal of easily disarticulated elements or units.....	62
<b>Anatomical groups of elements.....</b>	62
<b>Marrow content.....</b>	63
<b>Disarticulation pattern of limb bones.....</b>	63
THE RELEVANCE OF NON-CULTURAL DISARTICULATION PATTERNS OF SHEEP CARCASSES TO ARCHAEOLOGICAL ASSEMBLAGES.....	65
1) Natural disarticulation of animals on archaeological sites.....	66
(a) <b>All individuals of a species.....</b>	66
(b) <b>Certain individuals of a species.....</b>	66
2) The influence of anatomical considerations on butchery practices.....	67
<b>Butchering versus disjoints.....</b>	67
<b>Lower limbs.....</b>	68
OBSERVED PATTERNS OF WEATHERING AND BURIAL OF ELEMENTS.....	69
BURIAL.....	70
The effects of removal on the burial of elements.....	70
1) Spatial separation.....	70
2) The relative chances of removed and non-removed items becoming buried.....	71
The effects of the presence of non-bone carcass remains.....	72
The effects of element type.....	73
The effects of vegetation conditions.....	74
RATES OF BURIAL.....	75

WEATHERING.....76  
 Types of weathering.....76  
 The relationship of timespan and the degree of weathering observed....78  
 SUMMARY.....79

**CHAPTER 5: ELEMENT FREQUENCIES IN THE GRIZEDALE ROE DEER AND RED DEER CARCASS COLLECTIONS**

INTRODUCTION.....84

SIMILARITIES AND DIFFERENCES BETWEEN THE SHEFFIELD AND GRIZEDALE  
 SURVEY CONDITIONS.....85  
     Similarities.....85  
     Differences.....85  
 Expected differences in element frequencies between the Grizedale  
 and Sheffield carcass collections.....87

OBSERVED ELEMENT FREQUENCIES.....88

    ROE DEER.....88  
     Expectation 1: There will be more bones per individual  
     in the roe deer than in the sheep carcass collection.....88  
     Expectation 2: There will be a greater range of relative  
     frequencies of elements in the roe deer collection than in the sheep  
     carcass collection, which will emphasise the differences between  
     anatomical units.....89  
     Anatomical units.....89  
     Individual element types.....90

    RED DEER.....91  
     Expectation 3: There will be more bones per red deer  
     individual than per roe deer individual.....91  
     Relative frequencies of the 26 element types.....92  
     Anatomical units.....93

    SUMMARY.....95

**CHAPTER 6: ELEMENT FREQUENCIES IN THE SHEFFIELD SHEEP NON-CARCASS COLLECTIONS**

INTRODUCTION.....98

THE HYPOTHESES.....100

THE STATISTICS.....101

FOX DEN FINDS.....102

**Skulls**.....102

    THE QUESTIONS.....103  
     Question 1: Do the 'articulated and isolated fox den groups  
     contain similar distributions of elements?.....103

LIST OF CONTENTS

LIST OF CONTENTS

Results.....103  
 Conclusions.....104  
     Question 2: Do the combined fox den sub-collections  
         complement the sheep carcass collection?.....105  
 Results.....105  
 Conclusions.....107  
     Question 3: Do the combined fox den sub-collections  
         complement the S146 sub-collection?.....107  
 Limitations of the data.....107  
 Results.....108  
 Conclusions.....109

                    GENERAL ISOLATED FINDS.....109  
     Question 4: Does the general isolated finds sub-collection  
         resemble the residual material of the carcass collection,  
         or the transported material of the fox den sub-collections,  
         or a mixture of the two?.....110  
 Results.....110  
 Conclusions.....111

                    RESIDUAL VERSUS TRANSPORTED ASSEMBLAGES.....112  
 Results.....113  
 Conclusion.....115

                                    SUMMARY.....115

**CHAPTER 7: RATES OF ATTACK IN THE CARCASS AND NON-CARCASS COLLECTIONS OF SHEEP AND DEER BONES**

                                    INTRODUCTION.....117

                    CHEWED BONES IN ARCHAEOLOGICAL ASSEMBLAGES.....118

                                    QUESTIONS.....119  
     Question 1: Is the percentage of bones attacked correlated  
         with the number of bones per individual?.....120  
 Results.....120  
 Conclusions.....121  
     Question 2A: Are some element types more likely to be attacked  
         than others?.....122  
 2A: Results.....122  
 2A: Conclusions.....124  
     Question 2B: Is an element's rate of attack linked to its  
         attractiveness (as measured by its meat cover?.....124  
 2B: Results.....125  
 2B: Conclusions.....125  
     Question 3: Is the percentage of an element type that is attacked  
         correlated with the relative frequency of that element type?.....126  
 Results.....126  
 Conclusions.....129  
     Question 4: Is the attack rate of an element type correlated  
         with its degree of completeness? (i.e.: if an element is more  
         frequently attacked, is it more likely to be partially destroyed?)...130  
 Methods.....130

Results. A: A comparison of element types within a collection.....	131
Results. B: A comparison of elements between collections.....	132
Conclusions.....	134

SUMMARY.....	135
--------------	-----

**CHAPTER 8: PATTERNS OF ALTERATION TO THE 26 ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION CAUSED BY CARNIVORE DAMAGE AND WEATHERING PROCESSES**

INTRODUCTION.....	138
-------------------	-----

QUESTIONS.....	139
----------------	-----

QUESTION 1: WHAT FORMS OF ALTERATION ARE TYPICAL OF CARNIVORE DAMAGE?...	140
METHODS.....	140
DEFINITIONS OF THE SIX TYPES OF DAMAGE RECORDED.....	140

QUESTION 2: WHAT FORMS OF ALTERATION ARE TYPICAL OF WEATHERING PROCESSES?.....	144
DEFINITIONS OF THE TWO TYPES OF WEATHERING EFFECTS RECORDED.....	144

QUESTION 3: WHICH AREAS OF EACH ELEMENT TYPE ARE MOST LIKELY TO BE ALTERED, AND IN WHAT WAYS?.....	146
METHODS.....	146

PATTERNS OF ALTERATION TO THE 26 ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION.....	148
---	-----

Comparisons with observations made by Haynes (1980, 1981, 1982, 1985) and Binford (1981).....	148
---	-----

Observations of the Sheffield sheep bones.....	150
--	-----

MANDIBLE.....	150
SCAPULA.....	150
HUMERUS.....	151
RADIUS.....	152
ULNA.....	153
METACARPAL.....	154
PELVIS.....	154
FEMUR.....	155
TIBIA.....	157
METATARSAL.....	157
HYOID.....	158
ASTRAGALUS.....	159
CALCANEUM.....	159
NAVICULAR-CUBOID.....	159
PATELLA.....	160
PROXIMAL PHALANGE.....	160
MEDIAL PHALANGE.....	161
DISTAL PHALANGE.....	161
ATLAS.....	161
AXIS.....	162
CERVICAL VERTEBRAE.....	162
THORACIC VERTEBRAE.....	162
LUMBAR VERTEBRAE.....	163
SACRUM.....	163

RIBS.....	164
STERNEBRAE.....	165

GENERAL COMMENTS.....	165
-----------------------	-----

SUMMARY.....	170
--------------	-----

## CHAPTER 9: CHARACTERISTICS OF BONE BREAKAGE AND BONE LOSS OBSERVED IN THE SHEFFIELD SHEEP TOTAL COLLECTION

INTRODUCTION.....	171
-------------------	-----

QUESTIONS.....	172
----------------	-----

QUESTION 1: HAS TRAMPLING AFFECTED THE BREAKAGE PATTERNS?.....	173
Conclusions.....	174

QUESTION 2: HAVE SPLIT LINES (CAUSED BY WEATHERING) AFFECTED THE BREAKAGE PATTERNS?.....	175
Results.....	175
Discussion.....	175
Implications for archaeological sites.....	177
Conclusions.....	177

QUESTION 3: HOW DOES THE LEVEL OF INTENSITY OF DAMAGE AFFECT THE RELATIVE FREQUENCIES OF ELEMENT PARTS?.....	178
---	-----

THE OBSERVED SEQUENCE OF BONE DESTRUCTION.....	178
THE ABILITY OF CANIDS TO SPLINTER BONES OF UNGULATES.....	179
The relative sizes of canid and ungulate species.....	179
Splintering observed in the Sheffield sheep study.....	181
The interaction of butchery, cooking, weathering, trampling and carnivore scavenging on the breakage of bones.....	182
Conclusions.....	182
The ability of canids to consume bones.....	183
Conclusions.....	183

THE EFFECTS OF VARYING LEVELS OF INTENSITY OF DAMAGE OBSERVED IN THE SHEFFIELD SHEEP COLLECTION.....	187
Introduction.....	187
The observed relative frequencies of element parts in the Sheffield sheep collection.....	188
1: The total collection.....	188
Implications for analyses of archaeological faunal assemblages.....	189
2: The non-carcass versus the carcass collections.....	191
Conclusions.....	194

QUESTION 4: ARE UNFUSED EPIPHYSES MORE LIKELY TO BE DESTROYED THAN FUSED EPIPHYSES?.....	195
Introduction.....	195
Results.....	197
Conclusions.....	199

SUMMARY.....	200
--------------	-----

**CHAPTER 10: THE MAIN FINDINGS OF THE ACTUALISTIC STUDY AND AN  
INVESTIGATION OF THE ROLES OF INHERENT FACTORS**

INTRODUCTION.....	204
SUMMARY OF THE FINDINGS OF THE ACTUALISTIC STUDY.....	206
1: AN EVALUATION OF THE EFFECTS OF A BIAS AGAINST THE RECOVERY OF SMALL BONES.....	207
Methods.....	207
Results.....	208
Conclusions.....	210
2: THE RELATIONSHIP OF MEAT COVER TO PERCENTAGES OF ATTACKED ELEMENTS IN THE SHEFFIELD SHEEP TOTAL COLLECTION, USING DATA PUBLISHED BY BINFORD (1978).....	210
A: MEAT UTILITY INDEX (MUI).....	210
Introduction.....	210
Results.....	211
B: MEATWEIGHTS.....	213
Introduction.....	213
Results.....	213
Consumption.....	214
Access to elements.....	214
Meatweight calculations.....	216
CONCLUSIONS.....	216
3: THE RELATIONSHIP OF MEAT COVER TO ELEMENT FREQUENCIES.....	217
Introduction.....	217
Results.....	218
4: A COMPARISON OF THE SHEFFIELD SHEEP DATA AND BINFORD'S (1978) MARROW CAVITY VOLUME FIGURES.....	219
Introduction.....	219
Results.....	219
Conclusions.....	220
5: A COMPARISON OF THE SHEFFIELD SHEEP DATA WITH BRAIN'S COLLECTION OF GOAT BONES FROM VILLAGES OF HOTTENTOTS IN THE NAMIB DESERT AND WITH HIS SPECIFIC GRAVITY FIGURES (BRAIN 1969 & 1984).....	220
Introduction.....	220
Damage to goat bones by the Hottentot people.....	221
Element frequencies of Brain's goat bones.....	223
Brain's element frequencies and specific gravity values.....	224
6: A COMPARISON OF THE SHEFFIELD SHEEP DATA WITH BULK DENSITY FIGURES (FROM LYMAN 1982 & 1985).....	225
Introduction.....	225



2: COLLECTIONS AFFECTED BY HUMANS AS WELL AS BY CANIDS.....	246
INTRODUCTION.....	246
BINFORD AND BERTRAM'S (1977) COLLECTION OF SHEEP BONES FROM TWO NAVAJO SETTLEMENTS, BRAIN'S (1969) COLLECTION OF GOAT BONES FROM HOTTENTOT VILLAGES, AND THE SHEFFIELD SHEEP COLLECTION.....	247
THE MAKAPANSGAT ASSEMBLAGE OF FOSSIL UNGULATE BONES.....	248
CONCLUSIONS.....	251
IMPLICATIONS FOR ARCHAEOLOGICAL ASSEMBLAGES.....	253

**CHAPTER 12: AN ARCHAEOLOGICAL CASE STUDY USING DATA FROM A ROMANO-BRITISH SITE IN CASTLEFORD, WEST YORKSHIRE, ENGLAND**

INTRODUCTION.....	257
THE SITE, METHODOLOGY AND MATERIALS.....	259
The Romano-British site of Castleford, West Yorkshire.....	259
Recording methods for the archaeological data.....	260
Fragment shapes.....	260
Element frequencies.....	261
Details of the variables used in this study.....	261
<b>Columns 12-14: Species identifications.....</b>	261
<b>Columns 15-17: Element type.....</b>	262
<b>Column 19: Completeness category.....</b>	262
<b>Columns 20-22: Fusion.....</b>	263
<b>Columns 60-61: Chewing.....</b>	263
<b>Column 68: Size group.....</b>	263
The materials.....	264
THE QUESTIONS.....	264
QUESTION 1: HAVE THE BONES BEEN SCAVENGED BY CANIDS?.....	264
Results.....	264
Evidence for the presence of dogs.....	265
Rates of chewing.....	266
Patterns of damage.....	267
Causes of fragmentation.....	267
<b>Sheep-goat fragments.....</b>	268
<b>Cattle fragments.....</b>	270
Conclusions.....	271
QUESTION 2: DO THE FREQUENCIES OF ELEMENTS RESEMBLE THOSE IN THE SHEFFIED SHEEP COLLECTION?.....	272
The calculation of element frequencies.....	272
Results.....	275
Brain's Index values of sheep-goat bones at Castleford Site 1 compared with those of the Sheffield sheep collection.....	275
Brain's Index values for cattle bones at Castleford Site 1 compared with those of the Sheffield sheep collection.....	277

LIST OF CONTENTS

LIST OF CONTENTS

Element frequencies for sheep-goat and cattle bones at Castleford Site 1 and their relationships with average intact sizes and with bulk density values (using Lyman, 1982).....278

1) The operation of a size bias in the recovered collections.....278

2) The relationships of element frequencies with their bulk density values (using Lyman, 1982).....280

    Conclusions.....281

QUESTION 3: DO THE FREQUENCIES OF ELEMENTS RESEMBLE THOSE IN BRAIN'S (1969) COLLECTION OF GOAT BONES FROM HOTTENTOT VILLAGES?.....282

    Results.....282

    Frequencies using epiphyses.....282

    Conclusions.....286

QUESTION 4: HAS THERE BEEN A BIAS AGAINST THE PRESERVATION AND RECOVERY OF YOUNGER INDIVIDUALS?.....287

    Introduction.....287

    The use of midshaft diameters and fusion data in the modern Sheffield sheep collection.....288

    Results.....290

    Conclusions.....291

    The use of midshaft diameters and fusion data in the Castleford Site 1 material.....292

        Introduction.....292

        A. The sheep-goat data.....293

        Results.....293

        Conclusions.....294

        B. The cattle data.....294

        Results.....294

        Conclusions.....295

        Discussion.....296

    SUMMARY.....297

**OVERVIEW.....302**

## LIST OF TABLES

- TABLE 3: 1 BASIC DATA FOR CARCASSES
- TABLE 3: 2 BASIC DATA FOR THE SHEFFIELD SHEEP COLLECTIONS
- TABLE 4: 1 FREQUENCIES OF ELEMENTS IN THE SHEFFIELD SHEEP CARCASS COLLECTION (MNI = 21)
- TABLE 4: 2 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE BRAIN'S INDEX VALUES AND AVERAGE INTACT SIZES OF THE 26 ELEMENT TYPES IN THE SHEFFIELD SHEEP CARCASS COLLECTION
- TABLE 5: 1 FREQUENCIES OF ELEMENTS IN THE GRIZEDALE ROE DEER CARCASS COLLECTION
- TABLE 5: 2 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE FREQUENCIES OF ELEMENTS (USING BRAIN'S INDEX VALUES) IN THE SHEFFIELD SHEEP AND GRIZEDALE ROE DEER CARCASS COLLECTIONS
- TABLE 5: 3 A CHI SQUARED ANALYSIS OF THE RAW FREQUENCIES OF ELEMENTS IN THE SHEFFIELD SHEEP AND THE GRIZEDALE ROE DEER CARCASS COLLECTIONS
- TABLE 5: 4 CHI SQUARED ANALYSIS OF THE NUMBERS OF ATTACKED ELEMENTS IN THE GRIZEDALE ROE DEER CARCASS COLLECTION
- TABLE 5: 5 FREQUENCIES OF ATTACKED ELEMENTS IN THE GRIZEDALE RED DEER CARCASS COLLECTION
- TABLE 6: 1 RAW FREQUENCIES AND RANK ORDERS OF ELEMENTS IN THE FOUR SUB-COLLECTIONS OF THE SHEFFIELD SHEEP NON-CARCASS BONES
- TABLE 6: 2 FREQUENCIES OF SKULLS IN ALL OF THE SHEFFIELD SHEEP COLLECTIONS
- TABLE 6: 3 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL UNITS, IN THE 'ARTICULATED' AND ISOLATED FOX DEN SUB-COLLECTIONS
- TABLE 6: 4 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL PARTS, IN THE COMBINED FOX DEN SUB-COLLECTION AND THE SHEEP CARCASS COLLECTION
- TABLE 6: 5 DIFFERENCES IN RANK ORDERS OF RAW FREQUENCIES OF ELEMENTS IN THE COMBINED FOX DEN SUB-COLLECTION AND SHEFFIELD SHEEP CARCASS COLLECTION
- TABLE 6: 6 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL PARTS, IN THE COMBINED FOX DEN SUB-COLLECTION AND THE S146 SUB-COLLECTION

## LIST OF TABLES

## LIST OF TABLES

TABLE 6:7 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL UNITS, IN THE GENERAL ISOLATED SUB-COLLECTION AND THE CARCASS COLLECTION

TABLE 6:8 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL PARTS, IN THE GENERAL ISOLATED FINDS AND COMBINED FOX DEN SUB-COLLECTIONS

TABLE 6:9 CHI SQUARED ANALYSIS OF RAW FREQUENCIES OF ELEMENTS, GROUPED INTO ANATOMICAL UNITS, IN THE RESIDUAL COLLECTIONS (I.E. THE CARCASS AND S146 COLLECTIONS) AND THE TRANSPORTED COLLECTIONS (I.E. THE FOX DEN AND GENERAL ISOLATED SUB-COLLECTIONS)

TABLE 6:10 DIFFERENCES IN RANK ORDERS OF RAW FREQUENCIES OF ELEMENTS IN THE RESIDUAL AND TRANSPORTED COLLECTIONS

TABLE 7:1 PERCENTAGES OF ELEMENT TYPES SHOWING SIGNS OF CARNIVORE ATTACK IN THE ROE DEER, RED DEER AND SHEEP CARCASS COLLECTIONS AND THE NON-CARCASS SHEEP COLLECTION

TABLE 7:2 CHI SQUARED VALUES OF ELEMENTS IN THE SHEFFIELD SHEEP CARCASS COLLECTION, SHOWING DEVIATIONS FROM THE NUMBERS OF ATTACKED AND INTACT BONES EXPECTED BY THE NULL HYPOTHESIS

TABLE 7:3 CHI SQUARED VALUES OF ELEMENTS IN THE GRIZEDALE ROE DEER CARCASS COLLECTION, SHOWING DEVIATIONS FROM THE NUMBERS OF ATTACKED AND INTACT BONES EXPECTED BY THE NULL HYPOTHESIS

TABLE 7:4 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE MEAT UTILITY INDEX (MUI) VALUES AND PERCENTAGES ATTACKED OF ELEMENTS IN THE SHEFFIELD SHEEP CARCASS COLLECTION

TABLE 7:5 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE PERCENTAGE ATTACKED AND THE BRAIN'S INDEX VALUE OF THE 26 ELEMENT TYPES IN THE SHEFFIELD SHEEP CARCASS COLLECTION

TABLE 7:6 THE DISTRIBUTION OF COMPLETENESS CATEGORIES FOR THE 26 ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION

TABLE 7:7 WHOLE BONE EQUIVALENT VALUES (WBEs) FOR THE TWELVE MEDIUM AND LARGE ELEMENT TYPES IN THE SHEFFIELD SHEEP CARCASS, NON-CARCASS AND TOTAL COLLECTIONS

TABLE 8:1A MANDIBLES: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

TABLE 8:1B A COMPARISON OF THE DEGREES OF DAMAGE AND WEATHERING IN THE CARCASS AND NON-CARCASS COLLECTIONS

## TABLE 8:2 DETAILS OF DAMAGE TO MANDIBLES

- 8:2A. DAMAGE TO THE SYMPHYSIS
- 8:2B. DAMAGE TO THE HORIZONTAL RAMUS
- 8:2C. DAMAGE TO ANGLE OF JAW
- 8:2D. DAMAGE TO THE CORONOID PROCESS
- 8:2E. DAMAGE TO CONDYLE

## TABLE 8:3A SCAPULAE: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

## TABLE 8:3B COMPARISON OF DEGREES OF DAMAGE AND WEATHERING OF THE CARCASS AND NON-CARCASS SCAPULAE

## TABLE 8:4 DETAILS OF DAMAGE TO SCAPULAE

- 8:4A. DAMAGE TO THE GLENOID CAVITY AND THE NECK
- 8:4B. DAMAGE TO THE PROXIMAL TUBEROSITY
- 8:4C. DAMAGE TO THE SPINE
- 8:4D. DAMAGE TO THE DISTAL BORDER OF THE BLADE
- 8:4E. DAMAGE TO THE CENTRE OF THE BLADE

## TABLE 8:5A HUMERI: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

## TABLE 8:5B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING OF THE CARCASS AND NON-CARCASS HUMERI

## TABLE 8:6 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO HUMERI IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- 8:6A PATTERNS OF ALTERATION TO THE PROXIMAL TUBEROSITIES
- 8:6B PATTERNS OF ALTERATION TO THE PROXIMAL EPIPHYSIS
- 8:6C PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT
- 8:6D PATTERNS OF ALTERATION TO THE MID SHAFT
- 8:6E PATTERNS OF ALTERATION TO THE DISTAL SHAFT
- 8:6F PATTERNS OF ALTERATION TO THE DISTAL EPIPHYSIS

## TABLE 8:7A RADII: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

## TABLE 8:7B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING OF THE CARCASS AND NON-CARCASS RADII

## TABLE 8:8 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO RADII IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- 8:8A. RADII: PATTERNS OF ALTERATION TO THE PROXIMAL EPIPHYSIS
- 8:8B. RADII: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT
- 8:8C. RADII: PATTERNS OF ALTERATION TO THE MID SHAFT
- 8:8D. RADII: PATTERNS OF ALTERATION TO THE DISTAL SHAFT
- 8:8E. RADII: PATTERNS OF ALTERATION TO THE DISTAL EPIPHYSIS

## TABLE 8:9A ULNAE: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

## LIST OF TABLES

## LIST OF TABLES

TABLE 8:9B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING IN THE CARCASS AND NON-CARCASS ULNAE

TABLE 8:10 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO ULNAE IN THE TOTAL SHEFFIELD SHEEP COLLECTION

8:10A. ULNAE: PATTERNS OF ALTERATION TO THE OLECRANON

8:10B. ULNAE: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT

8:10C. ULNAE: PATTERNS OF ALTERATION TO MID SHAFT

8:10D. ULNAE: PATTERNS OF ALTERATION TO THE DISTAL SHAFT

TABLE 8:11A METACARPI: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

TABLE 8:11B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING OF THE CARCASS AND NON-CARCASS METACARPI

TABLE 8:12 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO METACARPI IN THE TOTAL SHEFFIELD SHEEP COLLECTION

8:12A. METACARPI: PATTERNS OF ALTERATION TO THE PROXIMAL EPIPHYSIS

8:12B. METACARPI: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT

8:12C. METACARPI: PATTERNS OF ALTERATION TO MID SHAFT

8:12D. METACARPI: PATTERNS OF ALTERATION TO THE DISTAL SHAFT

8:12E. METACARPI: PATTERNS OF ALTERATION TO DISTAL EPIPHYSIS

TABLE 8:13A PELVES: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

TABLE 8:13B COMPARISONS OF DEGREES OF DAMAGE AND POSSIBLE WEATHERING OF THE CARCASS AND NON-CARCASS PELVES

TABLE 8:14 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO PELVES IN THE TOTAL SHEFFIELD SHEEP COLLECTION

8:14A. PATTERNS OF ALTERATION TO THE ILIUM

8:14B. PATTERNS OF ALTERATION TO SHAFT OF ILIUM

8:14C. PATTERNS OF ALTERATION TO THE ACETABULUM

8:14D. PATTERNS OF ALTERATION TO THE ISCHIUM

8:14E. PATTERNS OF ALTERATION TO THE SHAFT OF THE ISCHIUM

8:14F. PATTERNS OF ALTERATION TO THE PUBIS

8:14G. PATTERNS OF ALTERATION TO THE SHAFT OF THE PUBIS

TABLE 8:15A FEMORA: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL SHEFFIELD SHEEP COLLECTION

TABLE 8:15B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING OF THE CARCASS AND NON-CARCASS FEMORA

TABLE 8:16 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO FEMORA  
IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- 8:16A. FEMORA: PATTERNS OF ALTERATION TO THE PROXIMAL TUBEROSITY
- 8:16B. FEMORA: PATTERNS OF ALTERATION TO THE PROXIMAL EPIPHYSIS
- 8:16C. FEMORA: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT
- 8:16D. FEMORA: PATTERNS OF ALTERATION TO THE MID SHAFT
- 8:16E. FEMORA: PATTERNS OF ALTERATION TO THE DISTAL SHAFT
- 8:16F. FEMORA: PATTERNS OF ALTERATION TO THE DISTAL EPIPHYSIS

TABLE 8:17A TIBIAE: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL  
SHEFFIELD SHEEP COLLECTION

TABLE 8:17B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING TO THE  
CARCASS AND NON-CARCASS TIBIAE

TABLE 8:18 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO TIBIAE  
IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- 8:18A. TIBIAE: PATTERNS OF ALTERATION TO THE PROXIMAL TUBEROSITY
- 8:18B. TIBIAE: PATTERNS OF ALTERATION TO THE PROXIMAL EPIPHYSIS
- 8:18C. TIBIAE: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT
- 8:18D. TIBIAE: PATTERNS OF ALTERATION TO THE MID SHAFT
- 8:18F. TIBIAE: PATTERNS OF ALTERATION TO THE DISTAL EPIPHYSIS

TABLE 8:19A METATARSI: AREAS OF DAMAGE AND WEATHERING IN THE TOTAL  
SHEFFIELD SHEEP COLLECTION

TABLE 8:19B COMPARISONS OF DEGREES OF DAMAGE AND WEATHERING OF THE  
CARCASS AND NON-CARCASS METATARSI

TABLE 8:20 DETAILS OF PATTERNS OF DAMAGE AND WEATHERING TO METATARSI  
IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- 8:20A. METATARSI: PATTERNS OF ALTERATION TO THE PROXIMAL  
EPIPHYSIS
- 8:20B. METATARSI: PATTERNS OF ALTERATION TO THE PROXIMAL SHAFT
- 8:20C. METATARSI: PATTERNS OF ALTERATION TO THE MID SHAFT
- 8:20D. METATARSI: PATTERNS OF ALTERATION TO THE DISTAL SHAFT
- 8:20E. METATARSI: PATTERNS OF ALTERATION TO THE DISTAL EPIPHYSIS

TABLE 9:1 FREQUENCIES OF SPLIT LINES AND BONE TUBES FOR THE TEN MAJOR  
ELEMENT TYPES IN THE SHEFFIELD SHEEP COLLECTION

TABLE 9:2 FREQUENCIES OF ELEMENT PARTS RECOVERED IN THE TOTAL  
SHEFFIELD SHEEP COLLECTION, FOR THE TEN MAJOR ELEMENT  
TYPES

TABLE 9:3 RATIOS OF LATER-FUSING TO EARLIER-FUSING EPIPHYSES OF LONG  
BONE ELEMENTS IN THE SHEFFIELD SHEEP CARCASS AND NON-CARCASS  
COLLECTIONS, AND BRAIN'S GOAT BONE COLLECTION

TABLE 9:4 RAW FREQUENCIES AND RANK ORDERS OF ELEMENT PARTS FOR THE  
SEVEN LONGBONE ELEMENTS IN THE SHEFFIELD SHEEP CARCASS AND  
NON-CARCASS COLLECTIONS, AND BRAIN'S GOAT COLLECTION

## LIST OF TABLES

## LIST OF TABLES

- TABLE 9:5 FREQUENCIES OF OCCURRENCE AND LOSS OF PARTS OF THE TEN MAJOR ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION  
(3 pages)
- TABLE 9:6 SUMMARY OF DATA REGARDING RATES OF DESTRUCTION OF FUSED AND UNFUSED EPIPHYSES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 9:7 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF FUSION AGE AND THE DESTRUCTION OF EPIPHYSEAL AREAS IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 10:1 FREQUENCIES OF THE TWENTY-SIX ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION USING ABSOLUTE NUMBERS RECOVERED AND BRAIN'S INDEX VALUES
- TABLE 10:2 MEASUREMENTS OF ENTIRE (FULLY FUSED) BONES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 10:3 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF ELEMENT FREQUENCIES (MEASURED BY BRAIN'S INDEX, USING AN MNI=32) AND ELEMENT SIZES USING THE TWENTY-SIX ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 10:4 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE MEAT UTILITY INDEX (BINFORD 1978) AND THE PERCENTAGE OF BONES ATTACKED FOR 17 OF THE 26 MAJOR ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 10:5 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE RESIDUAL MEAT COVER WEIGHT (BINFORD 1978) AND THE PERCENTAGE OF BONES ATTACKED, FOR 16 OF THE 26 MAJOR ELEMENT TYPES IN THE SHEFFIELD SHEEP TOTAL COLLECTION
- TABLE 10:6 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF BINFORD'S MEAT UTILITY INDICES AND THE FREQUENCIES OF ELEMENTS IN THE TOTAL SHEFFIELD SHEEP COLLECTION EXPRESSED AS BRAIN'S INDICES, USING 17 OF THE 26 MAJOR ELEMENT TYPES
- TABLE 10:7 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE PERCENTAGES OF BONES SHOWING SIGNS OF CARNIVORE ATTACK IN THE TOTAL SHEFFIELD SHEEP COLLECTION AND BINFORD'S MARROW CAVITY VOLUME FIGURES USING 12 OF THE 26 MAJOR ELEMENT TYPES
- TABLE 10:8 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE FREQUENCIES OF ELEMENTS (REPRESENTED BY BRAIN'S INDEX) AND THEIR BULK DENSITIES (AS PUBLISHED IN LYMAN 1982)
- TABLE 10:9 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE PERCENTAGES OF ATTACKED ELEMENT TYPES AND THEIR BULK DENSITIES (AS PUBLISHED IN LYMAN 1982), IN THE TOTAL SHEFFIELD SHEEP COLLECTION

## LIST OF TABLES

## LIST OF TABLES

- TABLE 10:10 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF THE PERCENTAGES OF BONES WITH A FUSION SURFACE REMOVED AND LYMAN'S (1982) BULK DENSITY FIGURES, IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- TABLE 11:1 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF BINFORD'S 24 WOLF KILLS OF CARIBOU (BINFORD, 1981) AND THE 21 SHEFFIELD SHEEP CARCASSES
- TABLE 11:2 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF 2 NAVAJO SITE COLLECTIONS (BINFORD AND BERTRAM, 1977) OF SHEEP BONES AFFECTED BY HUMANS AND DOGS, AND BRAIN'S HOTTENTOT VILLAGE VILLAGE COLLECTION OF GOAT BONES AFFECTED BY HUMANS AND DOGS (BRAIN, 1969)
- TABLE 11:3 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF BRAIN'S HOTTENTOT GOAT COLLECTION (BRAIN, 1969) AND THE TOTAL
- TABLE 11:4 A SPEARMAN'S RANK ORDER CORRELATION ANALYSIS OF BINFORD'S BENT CREEK WOLF DEN COLLECTION OF CARIBOU BONES (BINFORD, 1981) AND THE MAKAPANGAT COLLECTION OF UNGULATE BONES (BRAIN, 1969)
- TABLE 12:1 FREQUENCIES OF IDENTIFIED FRAGMENTS AND OF CHEWED FRAGMENTS IN THE CASTLEFORD SITE 1 COLLECTION OF ROMANO-BRITISH ANIMAL BONES
- TABLE 12:2 WHOLE BONE EQUIVALENT (WBE) VALUES FOR THE ELEVEN MEDIUM OR LARGE ELEMENT TYPES IN THE CASTLEFORD SITE 1 SHEEP-GOAT COLLECTION, AND THE PERCENTAGES OF CHEWED FRAGMENTS AND THE PERCENTAGES OF CHOPPED FRAGMENTS
- TABLE 12:3 WHOLE BONE EQUIVALENT (WBE) VALUES FOR THE ELEVEN MEDIUM OR LARGE ELEMENT TYPES IN THE CASTLEFORD SITE 1 CATTLE COLLECTION, AND THE PERCENTAGES OF CHEWED FRAGMENTS AND THE PERCENTAGES OF CHOPPED FRAGMENTS
- TABLE 12:4 FREQUENCIES OF FRAGMENTS AND ELEMENTS OF SHEEP/GOAT IN THE CASTLEFORD SITE 1 COLLECTION
- TABLE 12:5 FREQUENCIES OF FRAGMENTS AND ELEMENTS OF CATTLE IN THE CASTLEFORD SITE 1 COLLECTION
- TABLE 12:6 THE AREAS USED TO ESTIMATE MINIMUM NUMBERS OF ELEMENTS FOR THE TWELVE MEDIUM OR LARGE ELEMENT TYPES OF SHEEP-GOAT AND CATTLE BONES IN THE CASTLEFORD SITE 1 COLLECTION
- TABLE 12:7 BRAIN'S INDEX VALUES OF THE SHEEP-GOAT AND CATTLE BONES FROM CASTLEFORD SITE 1, USING PROXIMAL AND DISTAL EPIPHYSES
- TABLE 12:8 FREQUENCIES OF FUSED AND UNFUSED EPIPHYSES IN THE TOTAL TOTAL SHEFFIELD SHEEP COLLECTION

**LIST OF FIGURES**

FIGURE 1:1 LOCATION MAP OF THE SHEFFIELD AND GRIZEDALE STUDY AREAS,  
AND THE ROMANO-BRITISH SITE OF CASTLEFORD

FIGURE 2:1 MAPS SHOWING THE MAIN TOPOGRAPHICAL FEATURES OF THE  
SHEFFIELD STUDY AREA AND THE DISTRIBUTION OF FINDSPOTS

FIGURE 2:1A THE SHEFFIELD STUDY AREA

FIGURE 2:1B THE DISTRIBUTION OF FINDSPOTS

FIGURE 2:2 EXAMPLE OF A FIELD RECORDING SHEET

FIGURE 2:3 DISTRIBUTION MAP OF FINDSPOTS IN THE SHEFFIELD STUDY AREA,  
IDENTIFYING THE DIFFERENT TYPES OF FINDS

FIGURE 3:1 FLOW CHART SHOWING SOME OF THE FACTORS OBSERVED TO AFFECT  
THE BONES OF DEAD SHEEP IN THE STUDY AREAS

FIGURE 3:2 FLOW CHART SHOWING HOW SOME OF THE INTERNAL AND EXTERNAL  
FACTORS INTERACT ON THE PRESERVATION, DISTRIBUTION AND  
RECOVERY OF BONES FROM DEAD SHEEP IN THE STUDY AREAS

FIGURE 3:3 EXAMPLE OF A FRAGMENT RECORDING CHART (FOR THE HUMERUS)

FIGURE 5:1 RAW FREQUENCIES OF THE 26 ELEMENT TYPES IN THE GRIZEDALE  
ROE DEER AND RED DEER CARCASS COLLECTIONS

FIGURE 5:2 BRAIN'S INDEX VALUES FOR THE 26 ELEMENT TYPES IN THE  
GRIZEDALE ROE DEER AND RED DEER CARCASS COLLECTIONS

FIGURE 5:3 FIELD SKETCH PLAN OF THE DISTRIBUTION OF ELEMENTS RECOVERED  
FROM A RED DEER CARCASS, GRIZEDALE NUMBER 1979:4

FIGURE 6:1 BRAIN'S INDEX VALUES FOR ELEMENTS IN THE 'ARTICULATED' AND  
ISOLATED FOX DEN SUB-COLLECTIONS

FIGURE 6:2 BRAIN'S INDEX VALUES FOR ELEMENTS IN THE COMBINED FOX DEN  
SUB-COLLECTION AND THE CARCASS COLLECTION

FIGURE 6:3 BRAIN'S INDEX VALUES FOR ELEMENTS IN THE COMBINED FOX DEN  
SUB-COLLECTION AND THE S146 SUB-COLLECTION

FIGURE 6:4 BRAIN'S INDEX VALUES FOR ELEMENTS IN THE GENERAL ISOLATED  
SUB-COLLECTION, THE CARCASS COLLECTION, AND THE COMBINED  
FOX DEN SUB-COLLECTION

FIGURE 6:5 BRAIN'S INDEX VALUES FOR ELEMENTS IN THE RESIDUAL  
ASSEMBLAË (I.E.: THE CARCASS COLLECTION PLUS THE S146  
SUB-COLLECTION), AND IN THE TRANSPORTED ASSEMBLAË  
(I.E.: THE COMBINED FOX DEN AND THE GENERAL ISOLATED  
SUB-COLLECTIONS)

- FIGURE 7:1 SCATTERGRAM SHOWING THE INVERSE CORRELATION BETWEEN THE AVERAGE PERCENTAGE OF ELEMENTS ATTACKED AND THE AVERAGE NUMBER OF BONES PER INDIVIDUAL IN THE THREE CARCASS COLLECTIONS AND THE FOUR NON-CARCASS COLLECTIONS
- FIGURE 7:2 SCATTERGRAM OF THE MEAT UTILITY INDEX (MUI) VALUES AND THE PERCENTAGES OF ATTACKED ELEMENTS IN THE SHEFFIELD SHEEP CARCASS COLLECTION
- FIGURE 7:3 SCATTERGRAM SHOWING THE POOR CORRELATION BETWEEN THE PERCENTAGE OF ELEMENT TYPES ATTACKED AND THEIR BRAIN'S INDEX VALUES, IN THE SHEFFIELD SHEEP CARCASS COLLECTION
- FIGURE 7:4 HISTOGRAMS OF COMPLETENESS CATEGORIES OF THE 12 MEDIUM OR LARGE ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION (2 pages)
- FIGURE 7:5 SCATTERGRAM OF THE RATIOS OF WHOLE BONE EQUIVALENTS (WBEs) TO THE TOTAL NUMBERS OF BONES (I.E.: WBE/N RATIOS) COMPARED WITH THE PERCENTAGES OF BONES ATTACKED, FOR THE 12 MEDIUM OR LARGE ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- FIGURE 7:6 SCATTERGRAM OF THE RATIOS OF WHOLE BONE EQUIVALENTS (WBEs) TO THE TOTAL NUMBERS OF BONES (I.E.: WBE/N RATIOS) COMPARED WITH THE PERCENTAGES OF BONES ATTACKED, FOR THE 12 MEDIUM OR LARGE ELEMENT TYPES IN THE SHEFFIELD SHEEP CARCASS COLLECTION
- FIGURE 7:7 SCATTERGRAM OF THE RATIOS OF WHOLE BONE EQUIVALENTS (WBEs) TO THE TOTAL NUMBERS OF BONES (I.E.: WBE/N RATIOS) COMPARED WITH THE PERCENTAGES OF BONES ATTACKED, FOR THE 12 MEDIUM OR LARGE ELEMENT TYPES IN THE SHEFFIELD SHEEP NON-CARCASS COLLECTION
- FIGURE 7:8 SCATTERGRAM OF THE RATIOS OF WHOLE BONE EQUIVALENTS (WBEs) TO THE TOTAL NUMBERS OF BONES (I.E.: WBE/N RATIOS) COMPARED WITH THE PERCENTAGES OF BONES ATTACKED, FOR THE 12 MEDIUM OR LARGE ELEMENT TYPES IN THE GRIZEDALE ROE DEER CARCASS COLLECTION
- FIGURE 8:1 DIAGRAM SHOWING THE SIX TYPES OF CARNIVORE DAMAGE DEFINED IN THIS STUDY
- FIGURE 9:1 THE RAW FREQUENCIES OF ELEMENT PARTS COMPARED WITH THE MINIMUM NUMBERS OF ELEMENTS FOR THE 10 MAJOR ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- FIGURE 10:1 BRAIN'S INDEX VALUES FOR THE 26 ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION

- FIGURE 12:1 THE RELATIONSHIPS OF BONE COMPLETENESS VALUES REPRESENTED BY THE WBE/N RATIOS) WITH THE PERCENTAGES OF FRAGMENTS SHOWING SIGNS OF CHEWING AND THE PERCENTAGES OF FRAGMENTS THAT HAVE BEEN CHOPPED THROUGH, USING THE 12 MEDIUM OR LARGE ELEMENT TYPES RECOVERED IN THE CASTLEFORD SITE 1 SHEEP-GOAT AND CATTLE COLLECTIONS
- FIGURE 12:2 RAW FREQUENCIES OF FRAGMENTS OF THE 26 ELEMENT TYPES OF SHEEP-GOAT RECOVERED IN THE CASTLEFORD SITE 1 COLLECTION
- FIGURE 12:3 RAW FREQUENCIES OF FRAGMENTS OF THE 26 ELEMENT TYPES OF CATTLE RECOVERED IN THE CASTLEFORD SITE 1 COLLECTION
- FIGURE 12:4 BRAIN'S INDEX VALUES FOR THE 26 ELEMENT TYPES OF SHEEP-GOAT AND CATTLE BONES RECOVERED FROM CASTLEFORD SITE 1
- FIGURE 12:5 COMPARISONS OF THE BRAIN'S INDEX VALUES FOR SHEEP-GOAT AND CATTLE BONES RECOVERED FROM CASTLEFORD SITE 1 WITH THOSE IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- FIGURE 12:6A TOOTH WEAR SCORES (USING GRANT, 1982) COMPARED WITH THE MIDSHAFT DIAMETERS OF VARIOUS ELEMENT TYPES IN THE TOTAL SHEFFIELD SHEEP COLLECTION (3 pages)
- FIGURE 12:6B SEX, FUSION STATE AND ILIAL SHAFT WIDTH DATA FOR THE PELVES IN THE TOTAL SHEFFIELD SHEEP COLLECTION
- FIGURE 12:7 TOOTH WEAR SCORES (USING GRANT, 1982) COMPARED WITH THE MIDSHAFT DIAMETERS OF VARIOUS ELEMENT TYPES IN THE CASTLEFORD SITE 1 SHEEP-GOAT COLLECTION (2 pages)
- FIGURE 12:8 TOOTH WEAR SCORES (USING GRANT, 1982) COMPARED WITH THE WITH THE MIDSHAFT DIAMETERS OF VARIOUS ELEMENT TYPES IN THE CASTLEFORD SITE 1 CATTLE COLLECTION (2 pages)

## LIST OF PLATES

- PLATE 2:1 THE SHEFFIELD SURVEY AREA
- PLATE 3:1 THE LOCATION OF THE S146 GROUP
- PLATE 3:2 TORN FLEECE SCATTERED FROM A SCAVENGED CARCASS
- PLATE 4:1 RESIDUAL REMAINS OF A RECENT SCAVENGED CARCASS
- PLATE 4:2 A DISARTICULATED LOWER HINDLIMB UNIT
- PLATE 4:3 EARLY STAGES OF SCAVENGING OF A CARCASS
- PLATE 4:4 AN ARTICULATED FORELIMB UNIT
- PLATE 4:5 A DISARTICULATED FORELIMB UNIT
- PLATE 4:6 A GENERAL VIEW OF THE BUTCHERY DUMP IN GRIZEDALE FOREST
- PLATE 4:7 DETAIL OF THE GRIZEDALE BUTCHERY DUMP
- PLATE 4:8 RESIDUAL BONES BECOMING BURIED AT A CARCASS SITE
- PLATE 4:9 CARCASS BONES BECOMING OBSCURED BY VEGETATION AND ALGAE
- PLATE 4:10 TRANSPORTED ELEMENTS FROM A FORELIMB UNIT BECOMING BURIED
- PLATE 4:11 ADVANCED STATE OF WEATHERING OF A YOUNG SHEEP SCAPULA
- PLATE 5:1 THE AXIAL/THORACIC UNIT OF A ROE DEER, DISARTICULATING IN SITU
- PLATE 8:1 SIX TYPES OF CARNIVORE DAMAGE: 1. PUNCTURES
- PLATE 8:2 SIX TYPES OF CARNIVORE DAMAGE: 2. MOUTHING MARKS
- PLATE 8:3 SIX TYPES OF CARNIVORE DAMAGE: 3. FLAKE SCARS
- PLATE 8:4 SIX TYPES OF CARNIVORE DAMAGE: 4. SHREDDING
- PLATE 8:5 SIX TYPES OF CARNIVORE DAMAGE: 5. A BROKEN EDGE
- PLATE 8:6 SIX TYPES OF CARNIVORE DAMAGE: 6. A SPIRAL FRACTURE
- PLATE 8:7 TWO TYPES OF WEATHERING ALTERATION: 1. EXPOSED TRABECULA BONE
- PLATE 8:8 TWO TYPES OF WEATHERING ALTERATION: 2. SPLIT LINES
- PLATE 8:9 TYPICAL PATTERNS OF DAMAGE TO MANDIBLES
- PLATE 8:10 PATTERNS OF DAMAGE TO SCAPULAE: 1. TYPICAL DAMAGE
- PLATE 8:11 DAMAGE TO SCAPULAE: 2. ATYPICAL EXAMPLES

LIST OF PLATES

LIST OF PLATES

- PLATE 8:12 PATTERNS OF DAMAGE TO HUMERI
- PLATE 8:13 TYPICAL DAMAGE TO A PROXIMAL HUMERUS
- PLATE 8:14 HEAVY DAMAGE TO RADII
- PLATE 8:15 TYPICAL DAMAGE TO RADII AND ULNAE
- PLATE 8:16 CLOSE-UP VIEW OF TYPICAL DAMAGE TO AN ULNA
- PLATE 8:17 DAMAGE TO METAPODIALS: 1. DORSAL VIEW
- PLATE 8:18 DAMAGE TO METAPODIALS: 2. VENTRAL VIEW
- PLATE 8:19 TYPICAL DAMAGE TO A PELVIS: PUNCTURES
- PLATE 8:20 TYPICAL LIGHT DAMAGE TO PELVES: VENTRAL VIEW
- PLATE 8:21 TYPICAL LIGHT DAMAGE TO PELVES: LATERAL VIEW
- PLATE 8:22 TYPICAL HEAVY DAMAGE TO PELVES
- PLATE 8:23 TYPICAL LIGHT DAMAGE TO FEMORA
- PLATE 8:24 TYPICAL HEAVY DAMAGE TO FEMORA
- PLATE 8:25 TYPICAL LIGHT DAMAGE TO TIBIAE
- PLATE 8:26 CLOSE-UP OF A PARTIALLY DESTROYED PROXIMAL TIBIA
- PLATE 8:27 PATTERNS OF HEAVY DAMAGE TO TIBIAE
- PLATE 12:1 MODERN AND ROMANO-BRITISH EXAMPLES OF HUMERI SCAVENGED  
BY CANIDS
- PLATE 12:2 MODERN AND ROMANO-BRITISH EXAMPLES OF RADII SCAVENGED BY CANIDS
- PLATE 12:3 MODERN AND ROMANO-BRITISH EXAMPLES OF FEMORA THAT HAVE BEEN  
SCAVENGED BY CANIDS, AND WEATHERED

LIST OF APPENDICES

LIST OF APPENDICES

**LIST OF APPENDICES**

APPENDIX I: RAW FREQUENCIES OF ALL SHEEP BONES COLLECTED IN THE  
SHEFFIELD SURVEY AREA

APPENDIX II: RAW FREQUENCIES OF ALL DEER BONES FOUND IN THE  
GRIZEDALE SURVEY AREA

APPENDIX III: SEQUENCE OF DISARTICULATION, REDISTRIBUTION AND BURIAL  
OF ONE OF THE SHEFFIELD SHEEP CARCASSES

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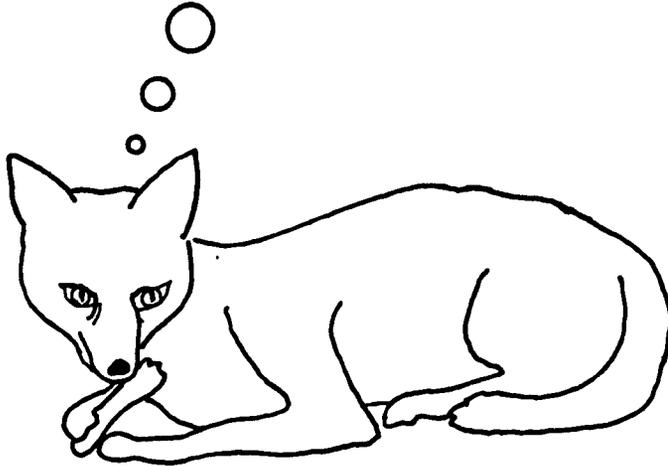
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**HOW MANY  
PROXIMAL HUMERI  
DID YOU THINK THERE WERE?**



**CHAPTER 1: AN INTRODUCTION TO THE STUDY**A BRIEF SUMMARY OF THE STUDY

This study is concerned with the taphonomic effects of scavenging canids on the bones of small ungulates. The main part of the work is the result of a three year actualistic study of the effects of foxes on the bones of hillsheep, roe deer and red deer carcasses. Foxes were chosen as an analogy for dogs, whose presence is attested on most holocene archaeological sites throughout the northern hemisphere. The patterns of alteration caused by the foxes to the bones of these three species are compared with those recorded by other researchers of carnivore scavenging behaviour, and are found to be both consistent and predictable.

A case study then applies the results of the actualistic survey to an archaeological assemblage of animal bones from a Romano-British site in West Yorkshire, and demonstrates how a knowledge of the effects of scavenging canids can refine an analysis of past human behaviour.

BACKGROUND

Two major influences underlay my decision to attempt this study, and both of them originated in the mid-1970s. One was the publication in 1976 of Schiffer's Behavioral Archaeology, the other was the work of several people involved in studies of early hominids in East Africa (e.g. Hill 1975, Behrensmeier 1975, Crader 1974).

Schiffer's book described agents that can alter an archaeological assemblage by destruction, damage, removal or redistribution, and it drew a distinction between Cultural (C-) and Non-cultural (N-) Transforms.

Some of the specialists working in East Africa had also recognised that humans are not the only agent to affect the distribution and preservation of archaeological materials, and had begun actualistic, experimental or ethnoarchaeological studies to investigate the roles of geological or biological agencies in site formation and transformation processes. A geologist, (Voorhies, 1969), had already demonstrated that fluvial transport of faunal skeletal materials has selective biases regarding the deposition of elements of different sizes and shapes, and an archaeologist (Brain, 1969), had shown that different element types survived better than others, after having been subjected to butchery and consumption by Hottentot villagers and scavenging by their dogs. The actualistic studies by Hill (1975), Crader (1974) and others confirmed these earlier findings i.e.: that element types have varying potentials for survival.

Meanwhile, analysts of faunal assemblages from agricultural holocene sites in Europe tended to concentrate on refining their methods of quantification. There was a general trend for archaeologists to experiment with statistical methods of sampling, (see Mueller, 1977; Cherry et al., 1978), and several papers were published concerning the best ways of quantifying faunal assemblages (e.g. Casteel 1972 & 1977; Grayson 1973 & 1979; Watson 1979). This preoccupation with quantification was aimed, ultimately, at being able to use the data to answer sophisticated questions concerning trading patterns and social hierarchies of archaeological communities. Not

only did analysts wish to quantify the relative (and, if possible the absolute) numbers of bones of different species found on a site, but they also wished to investigate the different frequencies of element types within a single species.

Unfortunately, most of these new methods assumed that archaeological assemblages form unbiased samples of original populations, despite the facts that Guilday (1970) had demonstrated elegantly that archaeological collections need not be random samples, and Payne (1972) had proven that methods of excavation can bias a collection against the recovery of smaller elements and fragments.

Some faunal analysts did recognise the possibility that assemblages may be biased, and began to utilise the ideas publicised by Schiffer. In two important studies of Cultural Transforms, Maltby (1979) and Halstead et al. (1978) highlighted the effects of human activities on the spatial distributions of different types of bones. Maltby (1979) showed that some of the quantitative techniques discussed by other authors were either inappropriate or invalid for his archaeological collection, yet his detailed analyses of spatial and temporal differences tell us much about life in Medieval Exeter that would otherwise have been missed.

However, there has been an unwillingness amongst many analysts to recognise that Non-cultural Transforms may also have been active in biasing faunal assemblages from holocene, agricultural or urban settlements.

The specialists working in East Africa have demonstrated that geological and biological processes, such as soil erosion and scavenging by carnivores, can bias severely the remaining archaeological assemblages. Although it may be true that, in general,

geological processes have had less influence on holocene than on plio-pleistocene sites (due to a shorter time-span), it is certainly not true that they have had no influence at all. Chaplin (1971) pointed out that leaching and degradation of bone by acid groundwater is a common problem on British sites (of all ages), many of which preserve no bone at all, or only the most mineralised elements such as teeth. Chemical and micro-biological destruction of buried bone is an important topic that requires much further work (see Cleminsen, 1979; Hare, 1980; Wilson, 1985) but is beyond the scope of this thesis.

The other major taphonomic factor that the East African researchers investigated is the scavenging of animal bones by carnivores. They found that certain element types were far more likely than others to be destroyed or removed from a carcass, leaving only a depleted and biased assemblage at the original site. Other researchers, working in North America, e.g.: Haynes (1981), Binford (1981), found very similar effects of scavenging behaviour by carnivores, despite the fact that both predator and prey species were different from those in the East African studies. This work suggests that there are some common patterns that obtain under a wide variety of circumstances.

However, the possible effects of scavenging carnivores on the faunal remains recovered from European archaeological sites have been almost totally disregarded by most analysts. Although the work of the East African and North American researchers has obvious implications for plio-pleistocene and later hunter-gatherer sites (particularly cave sites at which scavenging or even bone collecting by carnivores may have taken place, either during or after occupation by humans), few analysts considered applying the studies to sites

occupied by agriculturalists or urban dwellers. Perhaps they considered that 'wild carnivores' were irrelevant to these types of site. Yet not all carnivores are wild: some are commensal with people.

Dogs are a common modern scavenger and were not only the first animal to be domesticated (Clutton-Brock 1981) but also tend to be ubiquitous on holocene sites throughout Britain (Harcourt 1974), Europe (Bokonyi 1974), Asia (Olsen, 1985) and North America (Lawrence 1967). Many 'bone reports' contain references to the percentages of recovered fragments bearing toothmarks of small carnivores, which indicate that some scavenging has occurred (e.g.: Thawley, 1981; IJzereef, 1981).

The author, therefore, feels that it is probable that scavenging by dogs has affected the faunal assemblages from most holocene sites.

Many British faunal analysts use ageing data and the relative frequencies of element types to reconstruct patterns of husbandry, butchery and meat distribution as part of a wider aim to investigate aspects of economic and social behaviour in the past (e.g.: Halstead et al., 1978; Wilson, 1978; Everton, 1982). However, the specialists studying modern scavenging by carnivores have shown that element types do not have equal chances of survival. Since one of the factors affecting bone survival is bone structure, it seems quite probable that fused and unfused examples of bones will also have different potentials for survival.

This thesis, therefore, investigates the damage observed to modern bones by modern canids, in the temperate environment of northern England. The landscape and species concerned in this study are similar to those pertaining to British archaeological sites, but

comparisons with the East African and North American studies suggest that certain processes have similar effects in a wide variety of circumstances.

By establishing the severity and patterns of damage caused by scavenging carnivores (canids in particular), and the principles underlying them, it is hoped that the results can be used in comparison with archaeological assemblages, to assess the degree and nature of alteration caused to the bones by scavengers in the past.

Unless Non-cultural Transforms are investigated and identified (or proven to have had little influence) and taken into consideration, interpretations of past human behaviour will be, at best, presumptive and, at worst, invalid.

#### THE AIMS AND OBJECTIVES OF THIS STUDY

This study aims to investigate the effects of scavenging canids on the bones of ungulate carcasses.

Specific objectives involve answering the following questions:

- (1) Do all element types have equal chances of surviving?
- (2) If not, which element types tend to survive well, and which tend to survive infrequently?
- (3) Within an element type, are some areas of the bone more likely to survive than others?
- (4) Are there distinctive patterns of damage or destruction to each element type that can suggest that the bone

was affected by canids?

- (5) Are unfused bones likely to undergo more severe damage than fused bones?
- (6) What are the underlying causes of the differences noted in (1) - (5)?
- (7) Do dogs redistribute element types selectively?
- (8) If so, which elements tend to be found in what locations?

These eight questions can be investigated in three main groups:

- (A) element frequencies
- (B) fragmentation patterns
- (C) spatial distribution

### THE STUDY

Having established what questions I wanted to ask, I then had to find a suitable set of data. Ideally, I should be able to feed intact carcasses (possibly disarticulated, but not butchered) to dogs within a village community and should be able to monitor exactly what was fed to the dogs and what bones or fragments were recovered where. However, this is not possible in modern Britain where dogs are fed on tinned food and the councils sweep the roads.

Instead, a natural experiment involving foxes has been used, in which the foxes are used as an analogy for dogs. On the moorland areas of Britain, some accidental deaths occur among the hill sheep, and these carcasses are available to scavenging foxes with no, or very

little, interference by humans or other agents of disturbance. Whole carcasses, therefore, are available, and a surface collection of an area should recover the bones and fragments rejected by the foxes. An area of moorland close to Sheffield was chosen where only foxes were known to have free access to sheep carcasses, and where the author could monitor the effects of scavenging over a long period (three years).

A second study area was then chosen to test how typical the results of the Sheffield analysis were. In this second study area (Grizedale Forest in Cumbria), the ungulate species were roe deer and red deer, but the scavengers were more foxes. Chapter 2 describes both of these study areas in more detail, and Figure 1:1 shows the location of the two areas within Britain.

#### THE VALIDITY OF USING FOXES AS AN ANALOGY FOR DOGS

The red fox (Vulpes vulpes L.) is the only wild British species of canid still extant since the wolf was exterminated in the late Mediaeval and post-Mediaeval periods (Lever 1979). It is equivalent in size to a small to medium-sized dog. The average weights of red foxes in Britain range between five and seven kilograms (Lloyd, 1980), which is small when compared to most modern breeds of dog (e.g. beagle: 14 - 18kg.; labrador and mastiff: 29kg. each; Hubbard, 1961). However, the dentition of a fox is slightly larger in proportion to its body weight, due to its more gracile anatomy: the intercanine widths of a fox are 30 millimetres and 26 millimetres for the upper and lower jaws respectively, and these figures are identical

to those for a medium-sized dog (of approximately ten kilogrammes weight) (Swire, 1978).

The fox and dog have very similar dental morphologies and diets, and these two criteria are the most relevant ones for this study. The dental formula for both foxes and dogs is:

$$\begin{array}{cccc} 3 & 1 & 4 & 2 \\ I & C & P & M \\ 3 & 1 & 4 & 3 \end{array}$$

and the skulls and jaws of both species are adapted for siezing, biting and holding prey. The incisors are unspecialised but relatively large, the canines are long and powerful, the premolars are sharp, and two teeth (the upper fourth premolar and the lower first molar) are developed as shearing carnassials, whilst the molars are adapted for crushing (Stains 1975).

All canids are rather generalised carnivores, and will eat a variety of foods including vegetable matter and carrion (Clutton-Brock et al. 1976). Foxes are renowned for being opportunistic feeders (Jensen & Sequeira 1978) and many modern dogs subsist by scavenging, such as the pariah dogs of Asia (Montague 1942) and the dingo of Australia (Gould 1980). Although this study is concerned with the role of scavenging dogs on archaeological sites, it is likely that wolves and foxes may also have been active as scavengers from some human settlements. Harris (1977) has studied scavenging by foxes in urban and suburban areas of England, and Zimen & Boitani (1979) and MacDonald et al. (1980) have studied modern scavenging by wolves and foxes of village rubbish dumps in the Abruzzo mountains of Italy. Grace (1976) recorded similar activities by wolves in the Canadian Arctic.

AN ARCHAEOLOGICAL APPLICATION OF THE PRINCIPLES ESTABLISHED  
BY THIS ACTUALISTIC STUDY

The results of the actualistic study were compared with those published by other researchers (in Chapter 11), and were found to be consistent. They were then applied to an analysis of some archaeological data from a Romano-British site in West Yorkshire (see Chapter 12).

The site, at Castleford, West Yorkshire, was part of the annexe to a Roman fort occupied in the late 1st. Century AD. In my analysis of the faunal material, I wished to investigate whether the army had been self-sufficient in its meat supplies, or whether it had acquired animals (and/or meat) from elsewhere.

To do this, I needed to know:

- (1a) Which element types were present, and
- (1b) if (and, if so, how) the frequencies of element types recovered had been affected by scavenging.
- (2) The age ranges of the animals represented.

Dog bones were found at the site, and several of the bones of other species bear toothmarks, indicating that some scavenging has taken place. Without a consideration of the possible effects of scavenging dogs on the faunal assemblage, considerations of the relative frequencies of element types and fusion states might mistakenly attribute observed variations to past human behaviour patterns.

The frequencies of elements of sheep-goat and cattle bones recovered from Castleford Site 1 were compared with those in the Sheffield sheep collection and in others that are known to have been

scavenged by canids. The similarities indicate that the Castleford material derives from whole carcasses, despite the fact that the element frequencies vary considerably.

In order to avoid the bias against the preservation of younger bones (proven in the actualistic study), an experimental study used the distributions of midshaft diameters in conjunction with fusion and sex data to estimate the demographics of the cattle and sheep-goat death populations. The results indicate that the method has considerable potential and merits further research.

The analyses show that the sheep-goat at Castleford appear to have been raised locally, whereas the cattle (which dominate the assemblage in terms of fragment and element numbers) appear to have been brought in from elsewhere, despite the local availability of suitable cattle pasture on the Coal Measures to the west of the site. This finding supports King's (1978) suggestion that the Roman army in Britain had a sophisticated system for distributing provisions to its bases.

#### SUMMARY

The stimulus for this study was provided by Schiffer's (1976) consideration of Cultural and Non-cultural Transforms, and by the work of researchers in East Africa who were investigating the effects of scavenging carnivores on the carcasses of ungulates, as a means of identifying patterns that might also occur on hominid sites of the Plio-Pleistocene (e.g.: Hill, 1975; Crader, 1974).

Although some faunal analysts in Britain began to

investigate the taphonomic effects of some Cultural Transforms, Non-cultural Transforms tended to be ignored as being irrelevant to agricultural or urban sites, where wild carnivores were unlikely to have had access to the assemblages.

However, nearly all excavated holocene sites in Britain and the rest of Europe have produced the bones of dogs, if not the toothmarked bones of other species. Dogs commonly scavenge bones in modern circumstances, and probably did so in the past.

This study aims to investigate the effects of modern scavenging canids on the bones of entire sheep and deer carcasses, without any interference by humans, so that the effects of canids on element frequencies, fragmentation patterns and spatial distributions can be assessed and defined, and used as reference criteria against which archaeological assemblages can be compared. In this way, some of the effects of past non-cultural agents can be identified and separated from considerations of past human behaviour.

Although the main potential scavenger on most archaeological sites was the dog, foxes have been used as an analogy due to reasons of practicality. The study used natural experimental conditions in two areas of northern England, and involved scavenging foxes with the carcasses of three ungulate species: sheep, roe deer and red deer. The patterns of bone alteration are very similar in both areas and for all three species, and are used as reference data in a case study with material from a Romano-British site in West Yorkshire.

The case study illustrates the relevance of the actualistic results to an analysis of an 'ordinary' holocene archaeological assemblage, and shows how interpretations of the material can be refined or qualified.

**CHAPTER 2. AN INTRODUCTION TO THE ACTUALISTIC STUDY AREAS**INTRODUCTION

This chapter introduces the two areas used in the actualistic study. The main area, part of the open moorland close to Sheffield, South Yorkshire, contained carcasses of several hill sheep that were monitored over a period of three years. The 'supplementary' area, an area of forestry near Grizedale, Cumbria, contained some carcasses of roe deer and red deer.

In both areas, foxes were the major scavengers of the ungulate carcasses, and human interference was minimal or nil.

This chapter describes the field conditions and methods of recording for the two study areas, and Chapter 3 describes the variables and methods of analysis used in the study.

1. THE SHEFFIELD SHEEP SURVEY AREA

## THE LANDSCAPE

The main survey area consists of approximately 2.5 sq. km. of grass moorland in the southern Pennines centred on grid reference SK 2774 (see Figure 2.1). At a height of 240-330 metres above sea level, it has a cool, damp climate: mean minimum temperature = 1.2°C,

mean maximum temperature = 18.7°C, average annual rainfall = 1015-1145 millimetres. The area is used for extensive grazing of hill sheep and receives minimal management.

The area is a gently sloping plateau, crossed north-south by a small stream (Bar Brook), and northwest-southeast by a tributary channel (Sandyford Brook). Figure 2:1 is a map showing the main topographical features of the study area, and the distribution of findspots.

The vegetation consists mainly of coarse grasses (especially purple moor grass, Molinia caerulea), but there is also a small open woodland that flanks the stream on both sides. The trees are mainly birch (Betula, mainly pubescens) and pine (Pinus, mainly sylvestris) with some alder (Alnus glutinosa). Due to heavy grazing by the sheep, who use this wood as their main source of shelter in bad weather, there is no understorey of shrubs or regenerating saplings, and the grass beneath the trees is closely cropped. There are some patches of bracken (Pteridium aquilinum) on the floodplain and on slopes flanking the stream, and there is another, larger patch of bracken (circa 200 X 50 metres) in the western edge of the area beside some abandoned fields.

This large bracken patch is the location of a group of fox dens, some still in use at the time of the study.

Plate 2:1 shows a general view of the area, looking south-east down the valley of Sandyford Brook, with the fox den area in the foreground.

## THE SHEEP

The sheep are a mixture of hill breeds such as Swaledale, Lonk, Whitefaced Woodland and Derbyshire Grit, with some half-breeds sired by lowland breeds such as Leicesters. Nearly all of the sheep are females, but a few wethers are also run with the flocks. The adult females have an average weight of approximately fifty kilogrammes each.

In the severe winter of 1978-9 the area was covered with deep snowdrifts, in which many of the sheep died. There were too many carcasses for the tenant farmers to remove, so many of them remained lying around and were utilised by the local foxes as food sources.

## THE SCAVENGERS

There are six types of vertebrate that are potential agents of carcass destruction in the study area:

1) humans, 2) dogs, 3) foxes, 4) badgers, 5) stoats, and 6) birds.

1) & (2) Humans and dogs

At the time of the study (1979-1982), the area was owned by a water authority who forbade public access. The tenant farmers rarely

visited the land, although it is possible that their sheep dogs may have attacked the carcasses occasionally. Similarly, stray dogs occasionally roamed the moors. Since the foxes were being studied as an analogy for dogs, the rare occurrence of dog-induced damage is probably not a problem.

Only one instance of human-induced disturbance was noted in the three years of the study: this concerned the removal of some sheep skulls and the redistribution of some sheep bones that lay beneath a tree in which a hawk was nesting, and which had probably been visited by ornithologists. There was no associated damage to any of the bones.

### 3). Foxes

The presence of active foxes in the area was evidenced by the large number of occupied dens (identified by the presence of recently disturbed ground, footprints in the snow, and fresh deposits of chewed bones), and by the common presence of fox scats in the area, especially in the vicinity of disturbed sheep carcasses. A fox skeleton was discovered in the mud of the Bar Brook's floodplain, in the middle of the concentration of sheep carcasses.

### 4). Badgers

Badgers are not known to inhabit this part of the moor (M. Hammond, pers. comm.), and there were no signs of their presence (i.e. no setts or latrine pits) in the area throughout the study period.

### 5). Stoats

Stoats have been recorded in the southern Pennines, but not in this particular area (Clinging & Whiteley, 1980). They are usually active predators rather than scavengers (Corbet & Southern 1977), and are unlikely to cause much damage to sheep carcasses, even when present.

### 6). Birds

There are some small birds of prey and carrion-eaters in the southern Pennines: e.g. kestrels and crows, but these are unlikely to damage the bones of an animal as large as a sheep. Buzzards and seagulls have been recorded as being able to carry meat-covered bones of new-born lambs for short distances (Hewson, 1981), but even these small items are probably too heavy for the southern Pennine species of birds to carry.

### Summary of potential scavengers

Attacks to the sheep bones are considered to have been due almost entirely to foxes. Although foxes were never seen actually feeding on a carcass, this is not surprising since my visits were all during the daytime and foxes are crepuscular and nocturnal in habit (Burrows, 1968). Their presence in the area was attested by the fresh use of their dens, and several of the sheep carcasses had been marked

with fox scats, most of which contained chips of bone.

Apart from foxes, damage is likely to have been incurred only by dogs (either dogs belonging to shepherds, or free-roaming strays) and, possibly, by occasional trespassing humans.

#### THE TIMING OF THE STUDY

The survey area was visited from April 1979 until March 1982, at first at monthly intervals, later (after August, 1979) at approximately two monthly intervals. Snow cover sometimes precluded the recording of low-lying skeletal remains, but new carcasses were usually visible.

On each visit, the author walked about within the area, looking for new carcasses and recording the state of previously noted remains. Several carcasses were discovered on the first visit, due to the multiple deaths in the snow drifts, but isolated carcasses continued to accrue throughout the three year period due to individual deaths, usually of old or young sheep. Most of the deaths occurred in the wooded area, where the ailing sheep had taken shelter.

#### METHODS OF RECORDING IN THE FIELD

When a carcass was discovered, its condition was recorded on a printed sheet (see Figure 2:2 for an example). This noted its

location, (eight figure grid reference), the vegetation and slope details, and details of its anatomical position (e.g. 'lying on its left side, head to the north'). Any damage to the carcass was also recorded and a sketch plan drawn, either on the recording sheet, or on graph paper at a scale of 1:10 (see Figure 5:3 for a field plan of the remains of one of the Grizedale red deer carcasses).

Each time a carcass was re-visited, the scattered remains were again planned at 1:10 to show the extent and sequence of disarticulation. An area of approximately 30 metres radius was searched around the original carcass position for dispersed bones. Thirty metres was chosen as it appeared to give a wide margin around the scattered bones. Notes were also made of any damage to individual bones.

When the carcass had decomposed to isolated, disarticulated bones, any evidence of burial was also noted. Sometimes the bones were collected at this stage for study of their fragmentation patterns.

In March 1982, when the grass was at its shortest (due to reduced growth in winter plus overgrazing by the sheep), all bones that were visible within the survey area were collected. Some of these still had small amounts of skin or flesh adhering to them. These bones were cleaned in the laboratory by soaking in cold water and then pushing the flesh off with fingers or soft tooth brushes. The bones were never boiled or treated with chemicals, nor touched with metal blades.

Checklists were made of all of the elements collected from each carcass or group of bones. Bones sharing a number (e.g. 9) all come from one individual. Groups of bones with one number but with alphabetical suffixes (eg 146A, 146B) come from a group of bones that

may derive from various different individuals. This was the case either for animals which died together in a snow drift (e.g. the S146 group) or for animals whose remains had been collected and redeposited (possibly on several different occasions) at the fox dens (e.g. 25A-C, 27A-K etc).

Appendix I lists all of the sheep bones collected during the three year study of the Sheffield area.

#### SUB-DIVISIONS OF THE COLLECTION

The area contained three main types of sheep remains:

- 1) carcasses, which tended to occur in the wooded valley of Bar Brook,
- 2) isolated bones lying on the open grass moorland, and
- 3) bones lying in and around the fox dens.

A fourth type concerns the 146 group. This contains the remains of several sheep that died together in a snow drift in a hollow in the stream bluff of the tributary channel (Sandyford Brook, see Figure 2:1 and Plate 2:2). Their bones were found immediately below the site of death (about 5 metres away), in the Juncus rushes beside the stream. Number 146 was an articulated limb, but numbers 146A-146W were isolated bones. The fox den area is about eighty metres away.

Figure 2:3 shows the distribution of findspots in the Sheffield area, and distinguishes between fresh carcasses, scavenged

carcasses, and isolated bones. Some of the finds disappeared between visits and so could not be collected: see Chapter 4 for a discussion of burial rates, and Chapter 6 for a discussion of the spatial redistribution of elements.

#### RECORDING OF THE COLLECTION IN THE LABORATORY

Back in the laboratory (after the bones had been cleaned, if necessary), elements were recorded for fragmentation patterns, fusion states and completeness categories.

The main aspects to be studied in the collection were:

- (1) element frequencies,
- (2) patterns of redistribution of element types, and
- (3) patterns of damage to each element type.

### 2. THE GRIZEDALE SURVEY AREA AND COLLECTIONS

#### INTRODUCTION

In order to check that the patterns found in the Sheffield sheep remains were not idiosyncratic, a complementary, but briefer, study was undertaken in Grizedale Forest, Cumbria (see Figure 1:1 for a location map), to investigate the effects of foxes on the carcasses of two other ungulate species, i.e.: red deer and roe deer. Again,

there is little human access to the area, and badgers are not known to be active.

Foxes, however, are known to be present, and to scavenge the carcasses (J. Cubbington, per. comm.).

#### FIELD RECORDING METHODS

The area covers approximately 20 square kilometres centred on Grid Reference SD 3394, and is owned by the Forestry Commission, who manage it as commercial mixed and coniferous forest. Land heights vary between 90 and 300 metres above sea level.

Gamekeepers kept notes of any carcasses they had found during the year and on two occasions: May 1978 and June 1979, I visited the area for one week, and recorded all of the carcasses in the same way as I had recorded those in the southern Pennines. The carcasses were scattered very thinly throughout the survey area, and no distribution map is included.

Due to the dense undergrowth in some areas (mainly bilberry (Vaccinium myrtillus) and bramble (Rubus fruticosus)), it was usually only possible to trace relatively complete remains, and no isolated bones were collected. However, disarticulation and removal of body parts from the carcasses could be noted, and collection of the remaining bones enabled studies to be made of element frequencies and of rates of attack to element types. Patterns of damage to element types were also studied, and compared with those observed in the Sheffield collection.

## ANALYSES USING THE GRIZEDALE COLLECTIONS

The Grizedale deer collections were analysed for element frequencies and rates of attack (see Chapters 5 and 7 respectively), and the results support those from the Sheffield sheep study. Patterns of damage were very similar to those observed for the Sheffield sheep bones, and have not been included in the quantified analyses presented in Chapter 8.

Appendix II lists all of the bones collected in the Grizedale study area.

SUMMARY

These two studies investigate the effects of scavenging foxes on the bones of carcasses of three ungulate species, i.e.: sheep, roe deer and red deer, in the temperate conditions of upland and northern England. They are both 'natural experiments', in which the foxes had free access to the carcasses, with minimal or nil interference from humans.

The studies aimed to investigate:

- (1) the frequencies of elements surviving,
- (2) patterns of redistribution of element types, and
- (3) patterns of damage to element types.

The use of three ungulate species and two study areas was designed to test the possibility that observed patterns are consistent and predictable for a variety of circumstances and, hence, probably relevant to situations that may have obtained during the formation of archaeological deposits.

**CHAPTER 3: INTRODUCTION TO THE DATA AND VARIABLES EXAMINED  
IN THE SHEFFIELD SHEEP AND GRIZEDALE DEER STUDIES**

INTRODUCTION

This chapter introduces the variables investigated in the actualistic study. It distinguishes between external variables i.e.: chewing, disarticulation, redistribution, weathering and burial, and internal variables i.e.: element size, structure (i.e.: bulk density), fusion state, meat cover and marrow content.

The chapter describes the collections used, i.e.: the Sheffield sheep and Grizedale roe deer and red deer carcass collections, and the Sheffield sheep non-carcass collection (which is sub-divided according to the contexts of the finds).

A table presents the summary data for bone frequencies, Minimum Numbers of Individuals, and rates of attack in each of these collections and sub-collections, and shows that they have undergone varying degrees of alteration.

The element types used in the calculations are discussed, as are the statistical techniques. Since the data are not normally distributed, statistical analyses have been restricted to non-parametrical techniques, i.e.: chi squared and Spearman's rank order correlation analyses. These have shown both general trends and individual deviations, and have highlighted the relative influences of the various external and internal variables.

AIMS AND OBJECTIVES OF THE ACTUALISTIC STUDY

The aim of this study of modern scavenging by foxes of sheep and deer carcasses was to investigate how scavenging canids can affect the bones of medium-sized ungulates, without any intervention by people. Once these effects have been identified, they can be compared with archaeological assemblages upon which both dogs and humans are known to have acted, in order to distinguish the effects of humans from those of scavenging canids, and to ascertain the taphonomic histories of the archaeological deposits.

In particular, the actualistic study hoped to discover:

- (1) the frequencies of elements recoverable after entire carcasses have been scavenged by canids,
- (2) the percentages of each element type showing signs of carnivore attack,
- (3) diagnostic patterns of damage to elements that have been attacked by canids,
- (4) the degree to which unfused bones may be more susceptible to damage than fused bones, and
- (5) predictable spatial distributions of the scavenged bones.

THE VARIABLES OBSERVED TO BE IMPORTANT IN THE ACTUALISTIC STUDY

Figure 3:1 shows a simplified sequence of factors that I have observed to affect sheep carcasses on the Sheffield moors.

This study aimed, not only to observe the frequencies of elements surviving scavenging, but also to investigate some of the specific variables that influence these frequencies, so that underlying principles might be identified. In this way, it may be possible to make predictions for patterns of element frequencies and damage in other circumstances, not directly observed in this study.

Internal and external variables

The effects of the external factors (i.e. chewing, disarticulation, removal, weathering and burial) on the frequencies and fragmentation patterns of the different element types appear to be partially determined by internal properties of the element types themselves. These inherent factors include size, structure (represented by bulk density), meat cover and marrow content. Structure is also related to the biological age and fusion state of a bone, and Chapter 9 compares the patterns of alteration observed for fused and unfused bones (see Question (4), above). The other internal variables are discussed in Chapter 10, where they are used in statistical analyses in order to assess the degree to which each one is correlated with the observed frequencies of elements and element parts.

Quantification of the variables

The data for the effects of the external factors and of fusion state have all been observed during the course of this study. For the internal variables, detailed measurements of bulk density, meat cover and marrow content for sheep bones have been taken from published sources.

Brain (1969) suggested, and Lyman (1982) confirmed that element density is related to element survival, and Lyman's (1982) figures for bulk density are used in the calculations in Chapter 10. Binford (1981) constructed a Meat Utility Index (MUI) that relates the weight of meat to the (dry) weight of the underlying element. Because of the way in which the sheep were butchered, a few of the elements were left as articulated units and, therefore, have average or combined figures. Because Binford gives both total (i.e.: meat plus bone) and dry bone weights, it has been possible to calculate absolute meatweights for the major elements. Although these have a slight, systematic bias due to the unmeasured differences between wet and dry bone weights, the rank orders of the weights are unlikely to have been affected. Chapter 10 makes use of both the MUI (i.e.: the ratio of meat:bone weights) and the 'absolute' meat weights. Binford (1981) also gives values for marrow content of some of the major elements, but his quantifications do not appear to correlate with his stated method of measurement, and are discussed in more detail in Chapter 10.

### Disarticulation

The variable of disarticulation was observed to be involved in the spatial association of particular element types but had not been a part of the original research design. Reference is made to these observations where relevant, but the precise sequence of disarticulation of the sheep bones is being studied separately (Stallibrass, in preparation) and will provide a body of data comparable to that published by Hill (Hill, 1975 & 1979, Hill & Behrensmeyer, 1984).

### The interaction of the variables

Figure 3:2 presents a flow diagram of how the author believes these internal and external factors may have affected the observed frequencies of elements, patterns of damage, and spatial distributions of element types. It is based on her field and laboratory observations made during the actualistic study.

## THE PRESENTATION OF THE RESULTS

It was clear during the study that the factors affecting the final variables (such as element frequencies) are interrelated. For

clarity of exposition, however, they have sometimes been treated individually in the following group of chapters. Cross-references emphasise the fact that no single factor can totally predict element frequencies, patterns of damage, or spatial distributions.

The data for element frequencies are considered separately for the three main collections: the Sheffield sheep carcass bones (Chapter 4), the Grizedale roe deer and red deer carcass bones (Chapter 5) and the Sheffield non-carcass sheep bones (Chapter 6). The raw data for element frequencies in the Sheffield sheep collections are presented in Appendix I and those for element frequencies in the Grizedale collections are presented in Appendix II. Both of these appendices include all bones collected, although the calculations omit certain element types for practical reasons (see below). Chapter 4 also considers the effects of disarticulation, weathering and burial on the frequencies of elements in the Sheffield sheep carcass collection. Chapter 6 considers the spatial distributions of element types in the carcass collection and the non-carcass sub-collections.

Chapter 7 then considers the rates of attack for bones in all three collections, and relates these to element frequencies and to the degrees of partial bone loss suffered by the element types.

Chapter 8 presents the patterns of alteration to each of the 26 element types used in this study. It defines the types of alteration caused by carnivore damage and weathering processes, and gives a detailed analysis of which types of alteration tend to occur in specified areas of each element type.

Chapter 9 discusses bone breakage and fragmentation, and evaluates the roles of trampling and split lines in the patterns observed in the Sheffield sheep total collection (i.e.: the carcass

and non-carcass collections combined). It also considers the degrees of damage that can be inflicted by canids of varying sizes on the bones of ungulates, and tests whether or not unfused epiphyses are more likely to be destroyed than fused examples.

Chapter 10 then summarises the findings of this study, and tests the correlations of the internal variables with the observed element frequencies and rates of damage in the Sheffield sheep collections using data published by other authors.

Chapter 11 compares the element frequencies in the Sheffield sheep collections with element frequencies recovered by other researchers from environments where carnivores (and sometimes humans as well) have been active, in order to define predictable patterns of element frequencies that can be expected in given circumstances. Chapter 11 closes with a consideration of the implications of all these findings for analysts of archaeological assemblages.

The rest of this introductory chapter describes the materials studied, and discusses some of the methods used in this study in detail.

### THE BONE COLLECTIONS

#### THE SHEFFIELD SHEEP COLLECTIONS

A total of 813 bones was collected from the Sheffield moors, of which 694 are used in this study (see below for why some element types were not used). The bones were allocated to one of two

collections on the basis of whether or not they had come from a monitored carcass. The non-carcass bones were further divided into sub-collections on the basis of the locational context from which they were recovered. Appendix I lists all 813 bones, and allocates them to their relevant collection or sub-collection.

The groupings are defined as follows:

A: Carcass finds: these bones came from 21 carcasses whose decomposition had been monitored. In some instances, some of the elements were still held in articulation by dried tendons: N = 516

B: Non-carcass finds:

- 1) **'Articulated' fox den finds**: some of the bones in the fox den area came from units that had disarticulated in situ. All of these units were of limb bones: N=53
- 2) **Isolated fox den finds**: these were bones found in the fox den area that could not be re-articulated: N=43
- 3) **Isolated finds**: these were individual bones found scattered across the surface of the moor: N=54
- 4) **S146**: these bones were the remains of a group of sheep that had died close to (within circa 100 metres of) the fox dens: N=28

### **The S146 sub-collection**

The S146 sub-collection included bones from one forelimb

that could be re-articulated, and this was reassigned to the 'articulated' fox den group since it resembled the finds in that sub-collection and had, in fact, been dragged or carried some way towards the dens. Most of the bones in the S146 group had been displaced two to five metres downhill from the death site (a snow drift in the stream bank), towards the fox dens, and were found in the Juncus rushes beside the stream. Plate 3:1 shows the death site viewed from the fox den area after the bones had been collected. Some forelimb elements (including the 'articulated' unit) were found 20-30 metres down the valley, but all of the vertebrae remained close to the main death site. The S146 sub-collection formed an intermediate group between known carcasses, and the 'articulated' and isolated fox den finds. The individual carcasses could not be identified at the time of collection, which was three years after the animals' deaths.

#### The total Sheffield sheep collection

For some of the analyses comparing the data recovered in this study with those published by other researchers, the carcass and non-carcass collections have been amalgamated into the 'total Sheffield sheep collection', N=694.

#### Bones that were observed but not collected

During the three years of the Sheffield moorland sheep study several carcasses were recorded that eventually disappeared. None of

these, therefore, could contribute to the collection of carcass remains that was used for the study of element frequencies and patterns of damage. However, they did provide useful evidence of the sequence of joint disarticulation, and of rates of bone weathering and burial.

### THE GRIZEDALE DEER COLLECTIONS

#### The animals

Bones of two species of deer were collected from Grizedale Forest: the remains of sixteen roe deer and four red deer. Because of the vegetation cover and the time available, both species are represented by carcass remains only. In the first year (June, 1979), some of the carcasses may have been over one year old, but in the second year (July 1980) all but one of the carcasses were from deaths that had occurred within the previous twelve months, and some of these had not fully decomposed. The exception was one roe deer carcass that was only partially decomposed in June 1979, and which was recorded then (as 1979 No. 8) and subsequently re-recorded and collected in July 1980 (as 1980 No.11).

Appendix II lists all roe deer and red deer bones collected in the Grizedale survey area.

### Timespan

Because of the shorter time span of exposure to destructive agents (such as scavengers, microfaunas, climatic variables) the Grizedale collections are considerably better preserved than the Sheffield collections. The greater degree of articulation ensured that more of the smaller elements could be recovered from the deer carcasses than was possible for the Sheffield sheep collections.

## METHODS OF ANALYSIS

### Element types

Twenty-six element types are used throughout this study. Element types that were identified but not utilised are the skull and the smallest bones of the body: i.e. loose teeth, sesamoids, carpals, the central-plus-fourth and the second-plus-third tarsals and the lateral malleolus. Roe deer splint metapodials were also excluded from the discussions. Appendices I and II list all finds collected from the Sheffield and Grizedale areas, respectively.

These element types were excluded because the main aim of the study was to find a set of data that could be compared with archaeological material, and these element types are unsuitable because:

(1) Skulls are highly crushable items, and can disintegrate into innumerable little fragments. Counts of these therefore, are difficult to relate to the number of elements represented unless a

single portion, such as the basioccipital, is counted. In archaeological collections, however, even this portion is often broken (or deliberately split) into two or more fragments, and so the skull has been excluded from the list of elements used here for statistical purposes. The skulls found in the survey collections were usually more or less whole, and always at least half complete. Also, they did not follow the usual pattern for burial, and they are discussed in Chapters 4 and 6 regarding their survival and spatial distribution, respectively.

(2) Numbers of loose teeth can vary greatly according to the preservation condition of their enclosing jawbones.

(3) Loose teeth, sesamoids, carpals, and the smaller tarsals are all very small, and isolated examples must have been difficult to see in vegetated areas. Their frequencies may reflect vegetation and collection conditions, therefore, rather than any activity by foxes.

(4) The sesamoids were nearly all found whilst still held to the larger foot bones by dried tissue. This state does not obtain in archaeological conditions and frequency comparisons between the two types of collection would, therefore, be invalid.

(5) Splint metapodials only occur in the deer, and cannot be compared with remains of sheep or cattle.

The 26 element types used throughout this study are: the hyoid, mandible, scapula, humerus, radius, ulna, metacarpal, pelvis (i.e.: innominate), femur, tibia, metatarsal, patella, astragalus, calcaneum, navicular-cuboid, proximal phalanges, medial phalanges, distal phalanges (anterior and posterior phalanges have been combined in each case), the atlas, axis, cervical vertebrae, thoracic vertebrae, lumbar vertebrae, the sacrum, ribs and sternbrae.

Minimum Numbers of IndividualsMethods of calculation

Minimum Numbers of Individuals (MNIs) were known for the carcasses in both the Sheffield sheep and the Grizedale deer collections, but had to be calculated for the non-carcass sheep finds. This was done for each of the sub-collections. In each case, the commonest element was selected and pairs looked for.

There were seven tibiae including one pair in the general isolated group (MNI=6). In the isolated fox den group there were ten tibiae with no pairs (MNI=10). In the 'articulated' fox den group there were six radii with no pairs (MNI=6), and in the S146 group there were seven humeri with three pairs (MNI=4).

N.B. the humerus in the 'articulated' S146 unit (which was re-assigned to the 'articulated' fox den group) could not be paired with any of the humeri retained in the S146 group, and would, therefore, have increased the MNI to 5. However, this does not radically alter the data presented in Table 3:2.

The S146 sub-collection MNI

Unfortunately, the original number of carcasses in the S146 group cannot be compared precisely with the recovered remains. The snow drift contained six fresh carcasses in May 1979, and these certainly contributed the majority of the bones recovered as group S146 in March 1982. But there were also two other fresh carcasses

lying along the minor stream channel within a radius of 30 metres of the group of six. One of these two carcasses was actually in the stream, and no bones were collected directly from this individual. Although some may have been removed by foxes and subsequently collected elsewhere, this seems unlikely as the carcass was totally immersed in a particularly muddy part of the stream, and was probably buried before any disarticulation could be caused by scavengers. In contrast, the eighth carcass was lying in the Juncus beside the stream, and may well have contributed to the S146 collection. The original number of carcasses contributing to the S146 group, therefore, was at least six, probably seven, and improbably eight. The MNI calculated on humeri (including the 'articulated' limb re-assigned to the 'articulated' fox den group) is only five, indicating a total loss of evidence for at least 13%, and probably 14% or 17% of the individuals.

#### The total non-carcass collection MNI

When the non-carcass finds were pooled, the most frequent element was the tibia (N=21). Of these, eleven were left and ten right. No attempt was made to search for pairs and a parsimonious estimate of MNI=11 was used for calculations involving the entire non-carcass sub-collection.

## Element frequencies

### Introduction

Following the work of Brain (1969 & 1984) it was expected that some elements would be better represented in the collection than others. Brain (1969) found that small bones, and elements consisting mainly of trabecular bone tended to be under-represented due to a size bias in the recovery process and to consumption of the less dense elements by humans and scavenging dogs. Chapter 10 investigates the effects of size on the frequencies of elements in the Sheffield sheep total collection

### Measures of element frequencies

Two measures have been used in this study to compare the frequencies of the 26 element types in the various collections.

#### **Raw frequencies**

The first measure is raw frequency, which is simply a count of the number of fragments of an element type. Although some bones had been reduced to a fraction of their former size, there was never more than one fragment from any one bone. Raw counts of fragments, therefore, are the same as raw counts of elements.

**Brain's Index**

However, some bones occur more often than others in an entire carcass and, therefore, would be expected to be more frequent in the collections. To counteract this bias, raw frequencies have been adjusted (following Brain, 1969) by dividing the raw frequency of an element type by (a) the number of times that element would occur in an intact carcass, and (b) the number of individuals represented in that collection. This adjusted frequency is referred to as 'Brain's Index' and has not been converted into a 'survival percentage' (sensu Brain, 1969). The reason for leaving the ratio as it stands is because a percentage would give the false impression that a known proportion of the number of bones originally present had survived. This is only true for the carcass collections, for which the exact MNIs are known. It may not be true for the non-carcass sub-collections, for which MNIs have had to be estimated. Indeed, it is unlikely to be true, since a high degree of bone loss was observed during the three year study period, including the complete disappearance of whole carcasses.

MNIs for archaeological assemblages are also estimates rather than exact values (Grayson, 1984), and the use of Brain's Index permits direct comparisons of observed rank orders of relative frequencies, without presuming that these frequencies reflect absolute values. The ratios, therefore, are a form of relative and not absolute quantification, and should not be mistaken for such. Binford (1981), in his consideration of elements surviving from wolf kills, transformed his data so that his results suggest that some element types survived at rates of one hundred percent, although he clearly states that this was not the case (Binford 1981; compare page 210 with Table 5.01). The fact that a loss has taken place is important, and

should not be obscured by statistical manipulation.

### Spatial distributions of elements

A further factor that might affect an element's frequency in the collection is its removal for consumption elsewhere. Carnivores that tend to hunt or scavenge individually rather than co-operatively tend to be wary of competitors whilst eating. They tend to take portions of carcasses away to a sheltered location where they are unlikely to be disturbed. Such behaviour has been observed for many species, including spotted hyaenas (Kruuk, 1972), lions (Schaller, 1972) and foxes (Murie, 1944). The author has personally observed domestic dogs behaving in a similar manner, as have Kent (1981) and Binford & Bertram (1977).

In the Sheffield sheep study, an area of circa 30 metres radius was searched around each carcass, although most elements were found within a five to ten metre radius. Items found beyond the 30 metre limit were included in the general isolated collection, unless they formed part of the fox den or S146 assemblages.

### Percentages of attacked bones of each element type

It was thought by the author (following Brain, 1969) that some elements might be attacked more often than others, and that a high rate of attack might sometimes indicate a high rate of bone loss due to consumption. Rates of attack were calculated as percentages of

each element type showing signs of having been attacked by a carnivore. The possible relationship of an element type's attack rate and its frequency was tested using Spearman's rank correlation coefficient, and the results are presented in Chapter 7.

#### Visual patterns of damage

Each damaged fragment was recorded on a printed sheet that had been drawn by the author to show three to six views of that element type. The stimulus for this method was provided by Wilson's (1978) diagrams for the recording of butchery marks, although the diagrams used in this study were originals compiled by the author herself. The edges of each fragment were drawn onto all relevant views on the sheet, and all marks such as punctures, flake scars, etc. were also drawn on. Any colour or texture changes were also noted. Figure 3:3 shows an example of a recording sheet used for a humerus.

Each fragment was also recorded in tables compiling the locations and types of any damage incurred, together with the location of any evidence of weathering. See Chapter 8 for detailed descriptions of these records of damage and weathering.

Fusion state

The fusion state of each collected bone was recorded as:

- (1) fused
- (2) unfused
- (3) in the process of fusing, or
- (4) fused, but with the fusion line still visible.

Completeness categories

Fragments were assigned to one of five categories of completeness based on the length of an intact bone, i.e.:

- (1) 0-25% of the original length of the element still present
- (2) 26-50% of original length
- (3) 51-75% of original length
- (4) 76-99% of original length
- (5) 'complete' i.e. at least parts of both ends present.

(N.B. 'end' can be either a fused epiphysis or an unfused diaphysis).

SUMMARY DATA FOR THE BONE COLLECTIONS

Table 3:1 lists the summary data for the carcasses from both Sheffield and Grizedale, and Table 3:2 subdivides the Sheffield sheep

collection.

A comparison of the rates of attack and the average numbers of bones per individual in the different collections and sub-collections

Tables 3:1 and 3:2 illustrate a continuum of degree of disturbance/destruction of the dead animals, with low numbers of elements per individual and high percentages of attacked elements indicating higher rates of alteration. The most severely affected are three of the four Sheffield sheep non-carcass sub-collections, whilst the best preserved collections are those of the Grizedale roe deer and red deer carcass bones.

The carcass collections

In the Grizedale collections red deer and roe deer bones were kept separate, in case the size of the carcass or bone in relation to that of the scavenger affected the degree of destruction. However, Table 3:1 shows that the rates of destruction were very similar: i.e. there were averages of 60 and 66 bones per carcass and 40% and 38% of the bones had been attacked for roe deer and red deer respectively. These two groups: the red deer and roe deer carcass collections, are both markedly different from the Sheffield sheep carcass collection, in which only 25 bones were recovered per carcass, and 52% of the bones had been attacked. Almost certainly, the higher degree of destruction observed in the Sheffield moorland collection is

due either to: (1) a longer period of exposure of carcasses prior to collection, and/or (2) a higher intensity of scavenging by foxes due to greater competition for food. The fox population in Grizedale Forest is subjected to some culling by the gamekeepers (J. Cubbington, pers. comm.), and so it is quite probable that competition for food was less in the Grizedale area. The similar size and anatomy of roe deer and sheep suggest that it is unlikely that species differences could have led to such marked differences in intensity of alteration.

#### The non-carcass sub-collections of sheep bones

As expected, the non-carcass finds show an even higher degree of attack and dispersal than either of the carcass collections: there were only 16 bones per individual (taking the most conservative estimate of 11 for the MNI of the entire non-carcass collection), and 83% of the bones had been attacked.

Three of the non-carcass groups have attack rates of circa 90%, contrasting with the fourth group, the 'articulated' fox den finds, of which only 63% were attacked. These 'articulated' groups consisted of limb units whose extremities (i.e. the phalanges) often remained relatively intact. However, the rate was still noticeably higher than that for the sheep carcasses.

Detailed descriptions of the types of attack suffered by the 26 element types are given in Chapter 8.

STATISTICAL TECHNIQUES USED IN THIS STUDYAn introduction to the statistical limitations of the data

The aim of this actualistic study was to discover general patterns that are consistent and predictable for a range of circumstances in which scavenging canids might affect an assemblage of animal bones. Because the study was a natural experiment concerning what actually happens, rather than a laboratory experiment investigating the hypothetical effects of single, non-interacting variables, there are certain factors that could not be controlled for individually.

For instance, there is, inevitably, a bias against the recovery of the smallest elements due to the problems of visibility in a vegetated environment. The effect of this bias is proven and defined in Chapter 10. Similarly, it was not possible to excavate the areas in order to ascertain what elements were missing from the collections due to burial, because of two factors:

(1) the extensive nature of the areas studied, and

(2) the fact that both areas are privately owned and permission could not have been granted due to the nature of the landuse in both areas.

The bias against the recovery of small bones is probably balanced by a similar bias operated by excavation techniques on some archaeological sites. The site utilised as a case study in Chapter 12 was excavated mainly using pickaxes and shovels, and none of the material was sieved. A more careful excavation, however, would be

expected to recover a higher proportion of any small bones present in the ground (Payne, 1972) and this must be allowed for if element frequencies are compared with those reported here for both the actualistic and the case studies.

The problem of bones that might have become buried during the actualistic study is one that cannot be fully controlled for, but it is discussed in more detail in Chapter 4. It is thought not to be a major bias to the results, although it may reduce their precise comparability with archaeological assemblages which consist, by definition, of buried bones.

#### The choice of statistical techniques

Because of the limitations imposed by the nature of the natural experiment, and because of the aim to discover basic rather than specific patterns, the statistical procedures utilised throughout this study have been kept to the simplest, strongest forms of non-parametrical techniques. Two techniques have been chosen, both of which utilise ordinal rather than interval data. Analyses have proven that the data are not normally distributed, and more sophisticated techniques, therefore, would be inappropriate and their results invalid.

The techniques used are chi squared and Spearman's rank order correlation analyses. Although the study aimed to define basic patterns, it was also hoped that exceptions would highlight the influences of different variables. The deviations of observed figures from those expected by a null hypothesis (in a chi squared analysis)

or by a perfect correlation (in a Spearman's rank order correlation analysis) have helped the author to refine her hypotheses and to investigate the relative influences of different variables.

### The statistical significances of the results

The results of both the chi squared and the Spearman's rank order correlation analyses were compared with figures in a standard set of statistical tables (White et al., 1974) for their levels of statistical significance.

For chi squared analyses, White et al. give fourteen percentage points for the level of 'p', ranging from  $p < 0.995$  to  $p < 0.001$ . In each analysis presented here, the nearest statistically significant level for 'p' has been given.

In contrast, White et al. give only two significance levels for Spearman's rank order coefficients (one-tailed test), i.e.:  $p < 0.05$  and  $p < 0.01$ .

Considering the nature of the data, correlation coefficients that are statistically significant at the  $p < 0.01$  level are thought by the author to provide good support for the hypotheses, and coefficients that are significant at the  $p < 0.05$  level are also accepted as indicating that the correlation is not caused by random variation, although the statistical chance of such an event is one in twenty, and readers may wish, therefore, to put different interpretations on these results.

SUMMARY

The actualistic study aims to investigate element frequencies, their rates of damage, their spatial distributions, diagnostic patterns of alteration (caused by carnivore damage and weathering processes) and the relative rates of survival for fused and unfused epiphyses.

Several variables are considered to have affected these aspects of the collections, based on observations made during the study. The variables are (1) external: chewing, disarticulation, redistribution, weathering and burial, and (2) internal: element size, structure (i.e.: density), fusion state, meat cover and marrow content. Data for the external variables and fusion state have been observed directly during the study. Measurements for the other internal variables have been taken from published sources.

The collections comprise:

(1) **Carcasses:** Sheffield sheep

Grizedale roe deer

Grizedale red deer

(2) **Non-carcasses:** Sheffield sheep: 'articulated' fox den finds

isolated fox den finds

general isolated finds

the S146 group

Twenty-six element types are used in this study. Skulls and very small elements are not included in the calculations, for reasons given in the text.

Minimum Numbers of Individuals are known for the carcass collections, and have been calculated for the non-carcass sub-collections (see text for methodology).

Summary data show that the Grizedale roe deer carcass, Sheffield sheep carcass and Sheffield sheep non-carcass collections have undergone varying degrees of alteration, reflected by their different rates of attack, and by their different ratios of numbers of bones to numbers of individuals.

The statistics used in this study are non-parametric techniques, i.e.: chi squared and Spearman's rank order correlation analyses. More sophisticated techniques would be invalid since the data are not normally distributed. The results of the analyses show general trends and individual exceptions to these trends, and help to point out the relative degrees of influence of the different (internal and external) variables on the observed results.

CHAPTER 4. ELEMENT FREQUENCIES IN THE SHEFFIELD SHEEP CARCASS  
COLLECTION

INTRODUCTION

This chapter investigates the frequencies of the 26 element types recovered in the Sheffield sheep carcass collection. It shows that there has been a considerable loss of elements from the ground surface (over 50% of each element type is missing), and that the degree of loss varies greatly between element types. Some of the internal and external variables described in Chapter 3 are tested for their degrees of correlation with the observed element frequencies.

Intact element size is found to have a strong correlation with the frequencies of recovered elements, i.e.: the collection favours larger elements. However, there are some exceptions to this general trend, most of which can be explained by disarticulation patterns or by destructive carnivore damage (i.e.: consumption).

The bulk density (Lyman, 1982) and the Meat Utility Index (Binford, 1981) values of the elements are also compared with element frequencies. The results of Spearman's rank order correlation analyses show that neither variable has a significant statistical (or behavioural) correlation with the observed element frequencies.

Observations show that there is an anatomical pattern to the elements remaining at the death sites of carcasses, i.e.: axial elements (e.g.: vertebrae, the mandible and the pelvis) tend to remain in situ, forelimbs tend to be removed as articulated units, (with or

without the scapula), whilst lower hindlimbs tend to be removed in small units or as individual elements, leaving the femora with the pelves.

The relevance of 'natural' (i.e.: non-cultural) patterns of carcass disarticulation to archaeological assemblages is discussed, with regard to both non-butchered and butchered animals.

The research had aimed to include a study of weathering patterns of element types (similar to that of Behrensmeyer (1978)), but it was found that most bones became obscured or buried by vegetation or soil within 18 - 24 months of the animal's death, before any serious degree of weathering could occur. However, there are observable differences in the three main collections (i.e.: Sheffield sheep carcasses, Grizedale roe deer carcasses, and Sheffield sheep non-carcasses), and these are discussed and related to differences in timespans of exposure prior to burial.

The anomalous burial pattern of skulls is also described.

Chapter 5 discusses the element frequencies recovered in the Grizedale roe deer collection, and compares them with those described here for the Sheffield sheep carcasses. Chapter 6 discusses the element frequencies in the Sheffield sheep non-carcass collection, and uses the various sub-collections in comparisons with the carcass collection to show how element types tend to be differentially distributed between different types of context.

THE ARCHAEOLOGICAL RELEVANCE OF THIS STUDY

The sheep carcass collection has been considered separately from the non-carcass collection in this chapter because it provides a very interesting parallel for archaeological sites where whole carcasses may have been deposited. In the absence of any taphonomic biases, if the inhabitants of a settlement slaughtered animals, ate the meat and discarded the bones, the element types should be recovered subsequently from the archaeological deposits in anatomical frequencies. However, this is rarely, if ever, the case. Usually, the observed discrepancies are interpreted as being the results of hypothesised patterns of past human behaviour. Apart from assuming (or confirming by experiment) that small bones have been missed during non-sieved excavations, analysts working on assemblages from agricultural or urban sites have tended to ignore the possibility that non-human taphonomic agents may have biased the assemblages. Some, e.g. Bourdillon & Coy (1980), do refer to such possibilities, but have not had the data with which to test their material.

This study, therefore, is able to provide valuable data concerning the element frequencies recoverable from whole carcasses when there are no cultural biases save size selection (which is known to operate also on most archaeological sites (Payne, 1972)). The pattern of these observed frequencies can then be compared with that of an archaeological assemblage, where similar non-cultural taphonomic agents (i.e.: scavengers, and weathering and burial processes) are known to have been present. Any residual variability should be due to the effects of other variables, possibly cultural, that have not been

investigated in the actualistic study. A case study using such an archaeological assemblage is presented in Chapter 12.

THE OBSERVED FREQUENCIES OF ELEMENT TYPES  
IN THE SHEFFIELD SHEEP CARCASS COLLECTION

Table 3:1 showed that an average of only 25 bones was found per collected sheep carcass. Using the 26 element types considered throughout this study, each carcass should have released 113 elements onto the ground surface. The total collection of 516 bones from 21 carcasses represents the recovery of only 22% of those expected, indicating that there has been a considerable overall loss of bones. However, this loss is selectively far greater for some element types than for others: although every element type has lost at least 50% of its expected numbers, the exact percentages of lost bones range from 52% for the pelvis to 98% for the hyoid.

(N.B. Since the exact MNI is known for the carcasses, Brain's Index values can be converted into survival percentages. See Chapter 3 for a discussion of this point.) The raw frequencies and Brain's Index values are presented in Table 4:1 and Figure 4:1.

HYPOTHESES REGARDING FACTORS THAT MAY HAVE INFLUENCED  
THE OBSERVED ELEMENT FREQUENCIES

Introduction

Chapter 3 introduced several internal and external variables that appeared, during the course of the actualistic study, to have had some influence on the frequencies of elements and/or on their patterns of damage and weathering.

This chapter investigates some of these variables with regard to the frequencies of element types in the Sheffield sheep carcass collection. In particular, it looks at the internal variables of intact element size, structure (i.e.: bulk density; Lyman, 1982), and meat cover (Binford's (1981) Meat Utility Index), and at the external variables of disarticulation, and consumption by carnivores.

The next part of this chapter describes the relative frequencies of element types in detail, and discusses the predictive powers of the different internal factors.

Hypothesis 4:1 There is a cultural bias against  
the recovery of small bones

Correlation of element size and frequency

One possible cause for both the poor overall recovery rate, and the selective nature of the recovery, is a bias against the

recovery of the smaller elements. Full data for the average sizes of intact Sheffield sheep elements are given in Chapter 10, where the total collection is analysed. Table 4:2 compares the rank orders of these average element sizes with the element frequencies recovered from the Sheffield carcasses using a Spearman's rank order correlation analysis, and Brain's Index (BI) values for the frequencies. The results show that there is a statistically significant correlation between element size and element frequency in the carcass collection:  $p < 0.05$  (very nearly  $p = 0.01$ ). However, although there is quite a good general correlation between the two sets of data, certain elements have very large differences in ranking positions, i.e.:

cervical vertebrae: BI ranks 12.5 places higher than size

thoracic vertebrae: BI ranks 13.5 places higher than size

lumbar vertebrae: BI ranks 19.5 places higher than size

astragalus: BI ranks 10 places higher than size

ribs: size ranks 13 places higher than BI

hyoid: size ranks 10 places higher than BI

N.B. the total number of ranked places = 26

The next section discusses possible causes for these anomalies.

The influence of other factors, i.e. structure, meat cover, marrow content, articulations and consumption, on the recovered element frequencies

Correlation analyses using two of the other internal factors discussed in Chapter 3, i.e.: structure (Lyman's 1982 figures) and meat cover (Binford's (1981) Meat Utility Index figures), show almost nil correlation with element frequencies in both cases:

structure & BI:  $Rho = -0.09$ ,  $n=26$ ,  $p>0.05$

meat cover & BI:  $Rho = 0.07$ ,  $n=26$ ,  $p>0.05$ .

Neither of these factors, therefore, can explain the observed patterns of element frequencies.

An analysis has not been conducted using the marrow frequencies given by Binford (1979) since they do not include values for any of the anomalous elements noted above.

However, the six anomalies can all be explained by one of two other factors noted in this study, i.e.:

- (1) disarticulation, and
- (2) consumption of small, attractive, fragile elements by carnivores (Hypothesis 4:2).

These two factors are discussed below.

1) Disarticulation

The three types of vertebrae and the astragalus were all

found more frequently than would be expected from their sizes. These 'anomalies' may be explicable in terms of the natural disarticulation sequence of ungulate carcasses.

#### **Cervical, thoracic and lumbar vertebrae**

The individual bones of the spine are held together by very strong ligaments during life, and these joints were observed to remain articulated until very late in the sequence of disarticulation (Stallibrass, In Preparation). Similar observations have been made for other ungulate carcasses studied by Hill (1975), Binford (1981) and Haynes (1981).

This 'longterm' articulation of the spine has two important consequences:

(1) the spine remains as a unit that is too big for a fox to carry, and is, therefore, likely to remain in situ at the site of death,

(2) its large size renders it highly visible in the landscape and, therefore, all of the articulated vertebrae have a high chance of being recovered, whereas individual bones might be overlooked in the vegetation.

Plate 4:1 shows a typical scavenged carcass two months after death. Although it remains fully articulated from the skull and jaws to the pelvis and femur, both forelimbs and the lower half of one hindlimb have been removed. The forelimbs were never located, but the lower hindlimb unit was found 12 metres from the carcass (see Plate 4:2). The spine of this individual remained articulated for a further three months, by which time all other elements had been removed or disarticulated.

**The astragalus**

Similarly, the astragalus is held very firmly to the distal tibia until late in the sequence of disarticulation (observations made during this study and by Hill (1975) et al.). This association with a larger bone was noticed by the author to enhance the visibility of astragali during collection: of the ten astragali recovered from the carcasses, nine were found with their matching tibia (N.B. some of them were still attached by ligaments although all traces of flesh had disappeared, see Plate 4:2 for an example).

2) Hypothesis 4:2. Small, attractive, fragile elements are consumed by scavenging carnivores

The ribs and the hyoid are both less frequent in the carcass collection than would be expected from their sizes.

**The hyoid**

The hyoid, in fact, is the least frequent element type in all of the Sheffield sheep collections and sub-collections (only one example was recovered), although it only ranks 16th out of 26 for size. Unlike the astragalus, which is smaller than the hyoid but which was recovered more frequently (N=10), the hyoid does not benefit from being articulated with a larger bone. In fact, it is the only element in an ungulate skeleton that is not articulated with any other bone. Instead, it is connected to cartilage and to the tongue. The tongue is a good source of meat and Binford (1981) and Kuyt (1972) have both observed that wolves tend to attack the tongue first when eating from

a carcass. Plate 4:3 shows a scavenged carcass from the Sheffield sheep study. Note that the tongue has been removed through the throat. This removal must have affected the hyoid, but appears to have inflicted little damage on the mandible (see Chapter 8 for detailed descriptions of damage observed on the recovered mandibles). Chapter 7 shows that an element's meat cover (using Binford's (1978) MUI values) is positively correlated with its rate of attack, and so the hyoid is expected to have suffered from a high frequency of attack.

However, a high rate of attack does not necessarily imply a high rate of destruction. An element can only be destroyed if the agent of destruction is sufficiently large or strong in relation to the element itself. The hyoid is, in fact, a very weak structured bone. Although it is quite long compared to some other element types, such as the astragalus, it is composed of trabecular rather than compact bone, and is very thin and flat. The evidence described in Chapter 8 concerning the damage inflicted by foxes on larger bones, such as the pelvis, demonstrate that a fox is perfectly capable of consuming such a lightly-constructed element as the hyoid. (N.B. Chapter 9 discusses the abilities of various canid species to consume bones, using published data from other sources).

The hyoid, therefore, is likely to be under-represented in this collection because: (a) it is attractive to carnivores due to its association with the tongue, and (b) it is sufficiently small and fragile to be destroyed entirely by a fox.

### **The ribs**

The ribs are one of the three largest element types in this

collection (average intact length = 0.21 m), and yet their Brain's Index value ranks 15th out of 26. Intact bones, therefore, should not have been biased against by recovery methods, but observations show that damaged ribs tend to suffer a considerable degree of destruction by foxes: 21% of the recovered damaged ribs retain less than one half of their original lengths, and 15% retain less than one quarter (full data regarding completeness categories are given in Chapter 7). Fifty percent of an average intact rib's length is roughly equal to that of an intact sacrum, which ranks 11th out of 26 for size, and 25% of an average rib's length is approximately equal to that of the hyoid, which ranks 16th for size. The rib's BI rank of 15th, therefore, becomes less anomalous when its fragmentation pattern is taken into account.

This high degree of destruction is not surprising considering the nature of a rib: it has a large meat cover and medium marrow content. Besides being attractive to carnivores for these reasons, the structure of a rib is very weak: most of its length consists of a very narrow strip of thin trabecular bone, similar to the hyoid, and Chapter 8 shows that it is this distal area of the element that tends to be destroyed. Unlike the hyoid, however, which is totally composed of this type of bone, a rib does have a denser section at the proximal end, which is more likely to survive, and which is the part of the element that tends to be recovered. Its chances of recovery are also enhanced because it tends to remain articulated with the thoracic vertebrae for some time (although not for as long as the vertebrae remain together). Once disarticulated, a partially destroyed rib may well be overlooked due to its small size. It is notable that no ribs were found in any of the non-carcass

collections; they were recovered only from the scavenged carcasses, where they lay close to other, more conspicuous elements.

3) Hypothesis 4:3. The removal of easily disarticulated elements or units

**Anatomical groups of elements**

Table 4:1 presents the Brain's Index values of the 26 element types, and shows that there are some interesting clusters of similar values for element types that are linked anatomically. Apart from the mandible, which tended to remain with the spinal column, the highest BI values are all for elements from the hindlimb, i.e.: pelvis, femur and tibia, or from the spine itself, i.e.: atlas, axis, cervical vertebrae, thoracic vertebrae and lumbar vertebrae. The 'high' relative frequencies for the main types of vertebrae have already been commented upon, above, and are thought to be due to their strong articulations with each other.

The three hindlimb elements show rather varied frequencies, but Table 4:2 shows that this may be explained in terms of their size differences: their ranks for BI and size values are almost identical.

In contrast, the relative frequencies of the forelimb elements are all extremely similar to each other, but all rank considerably lower than their sizes would suggest.

What could account for the different relative frequencies observed for the forelimbs and hindlimb elements?

It was shown, above, that structure and meat cover are not correlated with element frequencies, and that the general correlation

of size with element frequency cannot explain the different patterns of frequencies shown by elements within the forelimb, hindlimb and axial skeleton. Other factors that need to be investigated in more detail are marrow content and disarticulation sequences.

#### **Marrow content**

Although marrow content values were not available for all 26 element types and could not be used to investigate the anomalous frequencies of vertebrae and ribs, etc., Binford (1979) does give figures for the eight major limb bones (i.e.: the scapula, humerus, radius and metacarpal; and the pelvis, femur, tibia and metatarsal). However, a Spearman's rank order correlation analysis shows that these values are not significantly correlated with the observed frequencies:

marrow content & limb element BI:  $Rho=0.40$ ,  $n=8$ ,  $p>0.05$ .

This lack of statistical correlation is caused mainly by the rank positions of the pelvis, which has very little marrow content but is the most frequent element.

#### **Disarticulation patterns of limb bones**

The relevance of disarticulation to the frequencies of the spinal elements has been discussed above. This section discusses its relevance to the relative frequencies of forelimb and hindlimb elements.

During the study, it was observed that forelimbs were often

detached from a carcass at an early stage of disarticulation. Sometimes the limb remained quite close to the carcass (i.e. within a 30 metre radius) and could, therefore, have been recovered with the other elements during collection. Plate 4:4 shows a forelimb that is still fully articulated from the scapula to the hooves, but which has been detached from the carcass. Noticeably, all flesh has been removed, but ligaments still hold the joints in articulation, and skin is still present from the midshaft of the metacarpal down to the hooves. This is a typical example of a removed forelimb, although sometimes the scapula was not present. Hill (1975) also noted that the forelimb tended to detach from the carcass very soon after death, due to the weak connections of the scapula to the rest of the body. Other authors have noted that carnivores tend to remove whole forelimbs (e.g.: Mills & Mills, 1977; Binford, 1978; Haynes, 1981).

Plate 4:5 shows another typical forelimb group in the Sheffield sheep collection, which is at a later stage of disarticulation when even the ligaments have decomposed. Units such as these are typical for the 'articulated' fox den sub-collection (see Chapter 6).

The different patterns of relative frequencies observed for forelimb and hindlimb elements in the carcass collection, therefore, can be explained by the pattern of disarticulation and removal of units, i.e.:

**The forelimb:** the entire forelimb, from the scapula or the humerus right down to the distal phalanges is often removed as an articulated unit, leading to:

- (1) reduced frequencies for all forelimb elements, and

- (2) equal frequencies for all forelimb elements.

**The hindlimb:** the strong articulation of the pelvis and the femur leads to:

- (1) hindlimb elements tending to remain with the carcass, and
- (2) the removal of single elements, or of lower limb units (from the tibia down to the distal phalanges).

THE RELEVANCE OF NON-CULTURAL DISARTICULATION PATTERNS  
OF SHEEP CARCASSES TO ARCHAEOLOGICAL ASSEMBLAGES

It might be thought that the sequence of disarticulation observed in this study (and that observed by Hill, 1975) might not be relevant to patterns of disarticulation on archaeological sites.

However, I hope to show that this is not the case, for two reasons:

- (1) not all animals on archaeological sites need have been disarticulated by people, and
- (2) ethnographic studies show that people do not totally ignore the anatomy of a carcass when butchering it, but tend to make use of it to aid disarticulation. Similar practices may have occurred in the past.

1) Natural disarticulation of animals on archaeological sites

It is quite feasible that some animals that die on archaeological sites have not been slaughtered by people, but have been allowed to disarticulate naturally. This may be the case for either:

- (a) all individuals of a species, e.g. for taboo reasons, or
- (b) certain individuals of species that were normally butchered, because of disease, putrefaction, etc..

**(a) All individuals of a species**

Some species of animals are regarded as taboo sources of meat by various modern communities, e.g. Hindus do not slaughter cattle, Muslims and Jews do not slaughter pigs. In the Romano-British period, it appears that people tended not to eat the flesh of either horses or dogs (Davies, 1971). However, dead animals may not have been deliberately buried and may have been accessible to scavengers. The relative frequencies of their elements might be expected to be similar to those observed for the scavenged sheep carcasses.

**(b) Certain individuals of species**

Certain individuals of 'food' species such as cattle, pigs and sheep might not be eaten due to, for example, a fear of the disease that killed the animal, or a dislike of still births, or the putrefaction of the carcass before it could be eaten. Such individuals might be discarded, e.g. into a ditch or onto a midden, where their carcasses could be scavenged in a way similar to that observed for the Sheffield sheep.

## 2) The influence of anatomical considerations on butchery practices

Binford (1979) describes how Nunamiut Eskimos disjoint caribou carcasses rather than chop through the bones during primary butchery. Yellen (1977) describes similar processing patterns amongst the !Kung Bushmen. Butchery marks on bones from archaeological assemblages (e.g. Wilson, 1978) that resemble those noted by Binford (1981) suggest that disjointing was also common in the past at some sites.

When butchering a carcass, various factors may be taken into consideration and influence the methods used, e.g.:

- (1) size of carcass
- (2) meat distribution on carcass
- (3) the number of parcels of meat required
- (4) the average size of meat parcel required
- (5) the weights of the resulting joints
- (6) the butchery tools available
- (7) the relative strengths of the joints and the bones.

### **Butchering versus disjointing**

Some of the larger bones, e.g. the femur, are of robust construction and require a considerable blow with a sharp or blunt instrument to break them, especially if they are still covered by a large amount of meat. For these elements, it is probably easier to detach them by severing the joints, rather than by breaking through the bones. Yellen (1977) describes exactly how the !Kung cut the head of the femur out of the acetabulum, to detach the hindlimb from the

carcass, and Binford (1982:127) describes similar techniques used by Nunamiut Eskimos.

More fragile elements are more likely to be chopped through, especially if the joints are either very numerous (as are the joints of the ribs with the thoracic vertebrae) or very strong (as in the spinal column). Although modern cuts of meat vary culturally, most manuals e.g. Gerrard (1977) describe basic units which remain articulated for most animals. In particular, these include units from the spine and from the lower limb.

#### Lower limbs

The carpus and tarsus joints are known in Britain as the 'break joints' because they are easy to snap apart by hand. The lower limbs from the carpals or tarsals down to the distal phalanges may then be discarded, or sent elsewhere (e.g. to bone workers, glue manufacturers, etc.). This pattern of disposal was observed in Grizedale where culled red deer and roe deer were butchered by the gamekeepers before being sold for consumption elsewhere. A sheltered spot beside a stream in the forest had been chosen as a dump area for the butchery waste, which consisted of skulls (excepting those with good sets of antlers), mandibles, and articulated lower limb units from the carpals or tarsals down to the hooves. Plate 4:6 shows a general view of the dump which contains only butchery waste (the plastic sacks in the photograph contain wet waste, such as entrails). Plate 4:7 shows a close up of the remains (mainly of red deer in this view) disarticulating in situ.

In contrast to these butchery units, the corresponding units

seen in the actualistic study tended to include the tibia with the rest of the lower hindlimb, and the forelimb tended to be complete (from the scapula or the humerus down). This was observed both for disarticulated units during the monitoring of the carcasses (see Plates 4:2;, 4:4 and 4:5), and for the remains recovered at the fox dens (see Chapter 6).

#### OBSERVED PATTERNS OF WEATHERING AND BURIAL OF ELEMENTS

This study hoped to observe and record weathering patterns for elements, and to relate them to known timespans of exposure to weathering processes prior to burial. This would have provided a valuable body of data that could have been compared with that described by Behrensmeyer (1978), who defined five stages of weathering effects that she observed on surface material in the Amboseli Basin, southern Kenya.

However, it was very noticeable that most elements in the Sheffield sheep study disappeared before reaching any pronounced stage of weathering, apparently due either to removal or to burial (or, in a few cases, to consumption, see above).

BURIALThe effects of removal on the burial of elements

The removal of elements or of articulated units from carcass sites was observed to have two major effects on the patterns of burial observed for the element concerned. One effect is obvious, the other more subtle:

- (1) Removed items are deposited, and possibly subsequently buried, some distance from their original location and are spatially separated from other elements deriving from the same individual.
- (2) Removed items tend to have reduced chances of becoming buried for a variety of reasons (see below).

1) Spatial separation

Even items recovered from an individual sheep carcass may have been collected from locations up to 60 metres apart. Although, in practice, elements tended to remain within five to ten metres of a carcass, this still implies an area of approximately 20 metres diameter that would need to be searched for residual remains.

Removed items might be carried some distance: the nearest carcasses to the fox dens were the S146 group, some 80-100 metres away. Precise distances are unknown since the carcass bones were not tagged, but Andrews has monitored the dispersal of elements from horse

and sheep skeletons on open ground in Wales and has found that elements may be moved up to 40 metres within three years, whilst bones carried off by scavengers may be taken up to two kilometres (Andrews & Cook, 1985).

Chapter 6 investigates the different patterns of element frequencies found spatially separated in the non-carcass sub-collections, and compares these between themselves and with the carcass collection to look for predictable patterns for different types of location, (e.g. carcass sites, general scatters, fox dens).

## 2).The relative chances of removed and non-removed items becoming buried

During the three year study period, it was noticed that some elements were becoming buried within a short space of time. Of the 42 carcasses recorded in the area, only 21 retained some bones long enough to be collected as 'carcass' remains. Bones were often left at the carcass site after a recording visit because they were not fully disarticulated. Since one of the original aims of the study had been to observe patterns of damage to the elements, the author did not wish to remove items before the foxes had finished attacking them. However, items that had been recorded on these earlier visits were often missing on subsequent visits. Although some of the 'missing items' were undoubtedly removed, others were observed actually in the process of becoming buried.

The effects of the presence of non-bone carcass remains

It was noticed that elements that remained immediately in situ at the carcass site tended to become buried particularly quickly.

This was because:

- (1) if a carcass was not fully scavenged, the fleece remained covering some bones and protected them  
(a) from removal and (b) from weathering.
- (2) The presence of the fleece also acted as a wind trap for any transported dust particles, although the ground surface in this area tended to be fully vegetated and so windblown dust was not prolific. In a more trampled area, with reduced vegetation cover, windblown particles might be more important.
- (3) The original vegetation, buried beneath the carcass, was killed due to lack of air, sunlight and space, but algae quickly colonised the fleece.

The combination of algae, windblown dust and leaf litter then formed a substrate that was colonised by higher plants such as sheeps' sorrel (Rumex acetosella) and grasses.

Plate 4:8 shows a typical old carcass group remaining in situ. The underlying vegetation has been destroyed, and intact or lightly damaged elements remain, some of them partially buried by fleece and leaf litter.

A second example, Plate 4:9, shows part of another carcass group partially covered by algae.

The effects of element type

It was also noticeable that certain elements tended to become buried more easily than others. Elements that were particularly susceptible to quick burial (or obscuration by vegetation) were the flat bones such as the scapula (see Plate 4:8, bottom right) and the mandible (see Plate 4:9, upper centre). Other element types that probably became buried rather quickly are the smallest bones, although none of these were observed in the process of being buried. Gifford and Behrensmeyer (1977) and Gifford-Gonzalez et al. (1985) have observed that small bones do tend to get buried more quickly than larger elements, partly due to trampling. Trampling is probably less important in the Sheffield sheep study than in Gifford-Gonzalez et al.'s experimental conditions, but could be important on an archaeological site where the movements of people and livestock were concentrated. Trampling would also contribute to the erosion of surface vegetation, adding to the amount of windblown dust in a defined area.

One element type in the Sheffield sheep study was never observed in the process of being buried. This was the skull. On the contrary, it was notable for being a highly mobile element and had nearly always moved from its last recorded position in between my visits. Almost invariably, skulls had moved downslope (the exceptions were along slope, never upslope). Some skulls, in fact, rolled more than 30 metres and fell into the course of the stream. Possibly, these movements were sometimes aided by kicks from passing livestock. Skulls also tended to be removed: either by humans (as in the one incidence of cultural disturbance) or by foxes: several skulls were found at the

fox dens.

The effects of vegetation conditions

Items that had been removed from the exact carcass site, and which had been divested of any covering fleece, were observed to have a reduced chance of being buried even if they remained within 30 metres of the carcass site. This was mainly because of the fact that the bones rested on top of existing vegetation. Whereas the carcass remains had destroyed any underlying ground cover, isolated bones were not able to do this, and tended to balance on top of the vegetation, from which they might be dislodged. Obviously, the season of the year and the precise details of the local vegetation affected the degree to which these bones were held off the ground. In areas of tussocky grass with sheep tracks, bones often lay between tussocks where they may have rested undisturbed. The removed lower hindlimb unit illustrated in Plate 4:2 is clearly lying on top of the grass, and was observed to have moved at least 2.5 metres when it was next recorded one month later. The completely articulated, but detached forelimb in Plate 4:4 was never seen again by the author, presumably having been removed by scavengers before the next visit was made, two months later.

If they are deposited in a 'quiet' environment, however, removed items may survive to become buried. The forelimb elements in Plate 4:5 had been taken along an animal track into a secluded patch of bracken. Although they lay on top of bracken litter at the time that the photograph was taken, they were probably buried by the following autumn's dead bracken leaves and thus protected from further

disturbance. Similarly, vegetation can be seen beginning to grow up around elements from a forelimb unit shown in Plate 4:10, and these bones were probably buried by vegetation before the end of that year.

#### RATES OF BURIAL

A full study of the time taken for elements to become buried is beyond the scope of this study, as it requires very detailed analyses of vegetation conditions and would benefit from selective excavation of areas around monitored carcasses (for reasons why excavations were not carried out see Chapter 2).

However, it was clear that several elements did become buried within three years and that many, in fact, became buried before 18-24 months had elapsed. Andrews and Cook (1985) describe how several of the bones from a dead cow that they monitored in southwestern England disappeared from the ground surface before their next visit eight months after the cow's death (which was in January, 1977). In 1984 a small excavation produced 23 bones, plus eight skull fragments. By this time there were no bones visible on the ground surface. Amongst the small assemblage recovered from the excavation were four bones that had not been visible on the ground in August 1977, i.e.: one mandible, one maxilla, one pelvis and one metapodial (Andrews & Cook, 1985, Table 1). It is probable that these bones were obscured by vegetation or buried by soil within the eight month period.

Timing of burial clearly varies greatly with local conditions of vegetation and soil erosion or deposition. Working in an

arid environment, Behrensmeyer (1978) found that some elements remained on the ground surface for up to 10-15 years, whilst Gifford and Behrensmeyer (1977) found that the debris from a recent hunters' campsite in a lake basin (also in an arid environment) became totally buried by some flood deposits within a few months.

Appendix III gives an example of the patterns of disarticulation, dispersal, weathering and burial noted by myself in the Sheffield sheep survey, using the data recorded on seven visits to one of the monitored carcasses over a period of two years. By the end of the two year period, only four vertebrae remained on the ground surface within 30 metres of the original carcass site. Photographs of parts of this carcass at an early stage of disarticulation (two months after death) are shown in Plates 3:2, 4:1 and 4:2).

## WEATHERING

### Types of weathering

None of the elements shown in any of these plates show any serious signs of weathering prior to burial.

During the study, three main types of weathering effects were noticed:

(1) isolated skulls found at the fox dens often had a grainy appearance, similar to Behrensmeyer's (1978) Stage 3. However, the lengths of time for which these skulls had been exposed to weathering processes are unknown. In contrast, none of the skulls of the

carcasses, which were known to have been exposed for a maximum of two or three years, showed any similar degree of weathering.

(2) Mandibles and longbones were sometimes observed to have longitudinal cracks through the outer layers of bone, similar to Behrensmeyer's (1978) Stage 1. These cracks (i.e.: split lines) are recorded in Chapter 8 for collected examples of individual element types.

(3) Some areas of certain bones appeared 'weathered', i.e.: the surface had become slightly eroded, exposing the underlying trabecular bone. These areas of 'weathering' (some of which may be due to carnivore activity rather than, or as well as, to genuine processes of weathering), are described in Chapter 8 for individual element types. In no instance did the presence of such areas appear to threaten the survival of the element. As with the skulls, however, there appears to be a difference between the weathering states of the carcass and non-carcass bones: the bones recovered from the non-carcass locations tend to show more areas of weathering than do those from the carcass collection (see below).

A further form of weathering was observed on one collected scapula. The size of the bone indicates that it was from a young individual, but the bicipital tuberosity has been removed, and so its fusion state cannot be assessed. This scapula has reached a stage of weathering similar to Behrensmeyer's Stage 3. Plate 4:11 shows that the thin blade of the scapula has been warped and there are several cracks running (mainly longitudinally) through the blade. If trodden on, this scapula would probably fragment *considerably*, but its glenoid and neck portion may be strong enough to survive intact.

The relationship of timespan and the degree of weathering observed

Very few of the collected bones show any serious signs of alteration by weathering processes, but there do appear to be differences in the average degrees of alteration shown by the three major collections. The Sheffield sheep carcass and the Grizedale roe deer carcass collections both have data for 15 element types, but this is reduced to 14 for the Sheffield sheep non-carcass collection, which contains no ribs. Summary data for these three collections are:

	ROE DEER CARCASSES (15 els)	SHEFFIELD SHEEP CARCASSES (15 els) (14 els)		SHEFFIELD SHEEP NON-CARCASSES (14 els)
Exposed trabec. bone areas	45	87	82	122
Total number of areas	2960	1771	1405	816
% of areas exposed	1.50%	4.91%	5.84%	14.95%

It is clear from the figures given above that exposed areas of trabecular bone are much more common in the non-carcass sheep collection (average= 15%) than in the carcass sheep collection (average= 5 - 6%) which, in turn, is more affected than the roe deer collection (average= 1.5%).

Chi squared analyses show that these differences are statistically highly significant:

sheep non-carcass cf. carcass: chi squared = 51.28, 3<sup>0</sup> freedom, p<0.001

sheep cf. roe deer carcasses: chi squared = 48.20, 3<sup>0</sup> freedom, p<0.001

The roe deer collection is known to consist almost entirely of bones that were collected within one year of the animals' deaths,

whereas several of the Sheffield sheep carcasses were monitored for up to three years before their remains were collected. The differences in relative frequencies of areas of exposed trabecular bone, therefore, may be due to the greater timespan of exposure to weathering processes undergone by the Sheffield carcasses. The non-carcass bones were exposed for an unknown period of time but, if the difference shown between the Sheffield sheep and Grizedale roe deer carcasses is due to the difference in timespan, then the same factor may also explain the greater relative frequency of areas of exposed trabecular bone in the non-carcass collection, i.e.: the non-carcass bones may have been exposed for a longer timespan than the carcasses. N.B. The presence of some areas of trabecular bone exposed by carnivore damage may have emphasised the differences shown between the collections, but is not considered to have altered rank orders of frequencies.

#### SUMMARY

This chapter has looked at data concerning relative frequencies of elements collected from scavenged sheep carcasses as a control sample for the patterns that might be looked for on archaeological sites. It is important for analysts of archaeological assemblages to be able to identify the remains of animals that have been allowed to disarticulate and become buried naturally, and to be able to recognise when such a non-cultural sequence has been interfered with by human behaviour.

The Sheffield study shows that elements are not recoverable

in anatomical frequencies even when there has been no interference by humans.

The main points concerning element frequencies are:

(1) There is a considerable loss of bones involving at least 50% of each element type, and probably the total loss of some individuals.

(2) The losses are far greater for some element types than for others.

(3) There is a general correlation between intact element size and element frequency, i.e.: the larger an intact element, the greater its chances of recovery.

(4) There is no correlation between element structure (i.e. bulk density) or meat cover with element frequency.

(5) Vertebrae tend to be more frequent than expected from their sizes due to their tendency to remain in articulated units for a long time.

(6) Mandibles tend to stay with the spine.

(7) Forelimbs tend to be removed in toto by scavengers.

(8) Hindlimbs tend to be removed as individual elements by scavengers, or as articulated lower limbs (from the tibia through to the distal phalanges).

(9) Astragali tend to remain articulated with the distal tibiae for a

long time.

(10) Hyoids may be consumed completely.

(11) Ribs are likely to suffer severe damage by partial consumption and may then be selected against by a size bias in recovery methods.

(12) This natural sequence of disarticulation, also studied by Hill (1975) and Toots (1965) is likely to affect cultural patterns of disarticulation or butchery, i.e.:

(a) stronger joints will be left articulated (e.g. as spinal units), and associated bones will be preferentially chopped through (e.g.: the femur shaft), and

(b) weaker joints will be disarticulated and the associated bones left intact (e.g. the scapula and the metapodials).

(13) Modern practices of butchery in Britain tend to remove lower limbs from the carpals or tarsals to the distal phalanges, whereas scavengers tend to remove whole forelimbs or lower hindlimbs from the tibia to the distal phalanges. Similar patterns could be looked for in archaeological assemblages.

(14) In a temperate grassland such as that studied in upland northern England, bones tend to become buried by vegetation and/or soil before they suffer much weathering damage, and are often buried within one to two years of the animal's death.

(15) Removal of elements from a carcass tends to reduce their chances

of becoming buried due to:

- (a) removal of protective fleece and flesh
- (b) redeposition on top of vegetation rather than directly onto the soil
- (c) greater chance of being damaged.

(16) Some element types may become buried more quickly than others,

e.g.:

- (a) smallbones or flat bones probably become buried particularly quickly
- (b) skulls tend to resist burial and tend to suffer greatest spatial disturbance.

(17) Because of their tendency to remain unburied, skulls may show greater evidence of weathering damage than other elements.

(18) Longbones and mandibles may show longitudinal cracks (split lines) due to weathering stresses (see Chapter 8).

(19) All element types may show areas of exposed trabecular bone where the thin outer layer of compact bone has been eroded (see Chapter 8).

(20) The degree of weathering (i.e.: the frequency of areas of exposed trabecular bone) increases with time of exposure prior to burial.

The next chapter describes the element frequencies recorded in the Grizedale survey, in which roe deer and red deer carcasses were

examined in a study comparable to that conducted on the Sheffield sheep. It looks for consistent patterns of alteration caused by non-cultural agents such as scavenging foxes, and weathering and burial processes.

CHAPTER 5. ELEMENT FREQUENCIES IN THE GRIZEDALE ROE DEER  
AND RED DEER CARCASS COLLECTIONS

INTRODUCTION

This chapter describes the frequencies of elements from carcasses of roe deer (MNI=16) and red deer (MNI=4) in Grizedale Forest, Cumbria, and compares them with those described in Chapter 4 for the Sheffield sheep carcass collection. Figure 1:1 shows the location of the survey area and Chapter 2 describes the techniques used in the study.

The roe deer and red deer carcasses were studied as a comparison to the Sheffield sheep carcasses in order to look for consistent patterns of alteration to ungulate carcasses caused by scavenging foxes.

The data show that patterns of element frequencies are consistent, and that differences in absolute frequencies can be related to differences in the levels of intensity of attack which, in turn, are considered to be related to factors of timespan and population densities of 'predators' and prey.

The patterns of disarticulation are very similar for all three ungulate species, and it appears that foxes are well able to remove whole limbs from adult red deer carcasses, typically moving them for short distances (e.g.: 5 - 10 metres), and probably dragging them rather than carrying them. By analogy, dogs should also be capable of removing limbs or elements from carcasses of adult cattle.

SIMILARITIES AND DIFFERENCES BETWEEN THE SHEFFIELD AND GRIZEDALE  
SURVEY CONDITIONS

Similarities

The conditions prevailing for the two survey areas are very similar, i.e.: the carcasses at Grizedale are not disturbed by people (except for the removal by gamekeepers of skulls that have good sets of antlers), the deer carcasses are accessible to scavenging foxes, all three species are ungulates and the bones of roe deer and sheep are quite similar in size.

Differences

The main differences between the two areas are:

(1) **Vegetation:** the Grizedale area is forested (mainly firs, with some areas of hardwoods) and some areas have a dense ground cover of bilberry (Vaccinium myrtillus) and heather (Calluna vulgaris), which hampered searches for isolated items. Scavenged carcass remains were collected within a 30 metre radius that was searched intensively, as in the Sheffield study. Occasional isolated bones were found, but have not been included in this study due to the small sample size (N <20).

(2) **Timespan:** all of the Grizedale carcasses had been noted

as fresh deaths during the two years. Only one individual had been exposed to scavengers for more than 12 months before I collected the bones, whereas most of the Sheffield carcasses were monitored for two to three years. Several of the deer carcasses had not finished decomposing, which meant that more bones were still held together by soft tissues than had been the case in the Sheffield study. For this reason, more of the smaller elements (such as sesamoids, carpals and tarsals) were recovered. Appendices I and II list all bones recovered in the Sheffield and Grizedale areas, respectively. The longer timespan is thought to have affected rates of attack and weathering, as well as element frequencies (see Chapters 7 and 4).

(3) **Intensity of predation:** the Forestry Commission gamekeepers control the fox population numbers (J. Cubbington, pers. comm.), and it is probable that there was a lower density of foxes in the Grizedale area than in the Sheffield area. The deer carcasses were also widely dispersed, and did not form a predictable food location, unlike the Sheffield sheep carcasses which tended to cluster in certain areas (see Figure 2:1). This factor may also have led to a lower intensity of attack in the Grizedale area.

A fourth, but less important, factor concerns the **relative sizes of the three ungulate species**. Roe deer bones are similar in length to those of sheep, although they tend to be more gracile. Red deer bones, however, are considerably larger than those of sheep or roe deer and might be expected to suffer less damage, especially through consumption and removal. However, this does not appear to be the case (see below).

Expected differences in element frequencies between the Grizedale  
and Sheffield carcass collections

The element frequencies in the Grizedale deer collections, therefore, are expected to be basically similar to those in the Sheffield sheep collection due to the general similarities between the two study areas, but they are expected to differ slightly in the following ways:

(A) The Grizedale collections are expected to have suffered a lesser degree of bone loss due to:

- (i) the shorter timespan involved, leading to a lesser degree of disarticulation prior to collection, and
- (ii) the suggested lower level of scavenging due to control of foxes by gamekeepers.

(B) The red deer collection is expected to show a smaller loss of bones than that shown by the roe deer collection due to the larger sizes of red deer bones.

(Unfortunately, the sample size of red deer carcasses is extremely small (MNI=4) due to the tendency for animals to be culled before they can die a natural death. The more solitary and elusive behaviour of the roe deer enables more of them to avoid being culled).

Differences (A) and (B), above, are expected to be reflected specifically by:

- (1) The recovery of more bones per individual, and higher Brain's index values for all element types, in each of the Grizedale collections than in the Sheffield sheep carcass collection.

- (2) more pronounced differences between the frequencies of elements in the different anatomical units (i.e.: the forelimb, hindlimb and axial skeleton).
- (3) The recovery of more bones per individual in the red deer than in the roe deer collection.

The next part of this chapter investigates these three expectations.

### OBSERVED ELEMENT FREQUENCIES

#### ROE DEER

Table 5:1 presents the raw frequencies and Brain's Index values of the 26 element types used in the Grizedale roe deer collection (Appendix II gives the full data for recovered elements, including sesamoids etc.). Figure 5:1 presents the raw frequencies for both roe deer and red deer, and Figure 5:2 presents the Brain's Index (BI) values for both roe deer and red deer.

Expectation 1: There will be more bones per individual in the roe deer than in the sheep carcass collection

It is clear from Table 5:1 that the first expectation (above) is met, i.e.: the roe deer collection contains more bones per individual than does the Sheffield sheep carcass collection: roe deer:

60 bones per individual; Sheffield sheep: 25 bones per individual. This indicates a recovery of 53% of the expected number of bones (i.e.: 16 X 113) compared with only 22% in the Sheffield sheep carcass collection. The Brain's Index values for the roe deer all tend to be much higher than those for the Sheffield sheep, ranging from 0.20-0.80 (mean=0.65) compared with 0.02-0.48 (mean=0.32) for the sheep.

Expectation 2: There will be a greater range of relative frequencies of elements in the roe deer collection than in the sheep carcass collection, which will emphasise the differences between anatomical units

#### Anatomical units

The roe deer bones were collected when the carcasses were in a less advanced stage of decomposition than that reached by most of the Sheffield sheep carcasses, and so the sequence of disarticulation was expected to show more clearly in the frequencies of elements. This expectation is supported by the data. Figure 5:2 shows a very clear block of high frequencies for all of the elements from the axial skeleton and thoracic region (including the sacrum, ribs and sternbrae) for the roe deer.

The pelvis is also particularly well represented, as are the femur and tibia.

As in the Sheffield sheep carcass collection, the elements of the hindlimb not only tend to have higher BI values than do those of the forelimb (BIs = 0.47-0.78, compared with 0.38-0.50), but they

also have more variable values. The lowest values for the hindlimb elements are for the metatarsal (BI=0.47) and the tibia (BI=0.59), suggesting that some lower hindlimb units have been removed. In the forelimb group, the elements have very consistent BI values (0.38, 0.38, 0.41 and 0.41) except for the humerus which is slightly more frequent (BI=0.50).

These values show a very similar pattern to that exhibited by the Sheffield sheep carcass collection (see Chapter 4), i.e.: (1) forelimb elements tend to be preferentially removed in toto by scavengers; (2) hindlimb elements tend to be removed less often, and as individual elements or lower limb units rather than as whole limbs; and (3) the axial skeleton tends to remain at the carcass site longer than any other unit.

Plate 5:1 shows an almost complete axial and thoracic unit that is mostly disarticulated but which retains bones more or less in anatomical positions. There is almost no damage to any of these bones, although all four limbs have been removed. Plate 5:2 shows a removed forelimb unit that is disarticulating in situ. Although all of the flesh has been removed from the scapula, humerus, and radio-ulna, the carpals, metacarpals and phalanges are almost all still held together by ligaments, aiding the recovery of the smaller elements.

### Individual element types

Table 5:2 presents a chi squared analysis that compares the raw frequencies of the 26 element types in the Sheffield sheep and Grizedale roe deer carcass collections. The null hypothesis predicts

that the elements are equally distributed between the two collections, in proportion to their total numbers. The results show that there are almost no grounds for discounting the null hypothesis ( $p > 0.95$ ).

The most notable deviation between observed and expected frequencies occurs for the sternebrae, which have a chi squared quotient of 7.98. This is caused by the extremely low value for sternebrae in the Sheffield sheep carcass collection, which in turn is considered to be due to the total consumption by foxes of many of the bones, compounded by the proven bias against the recovery of small bones (see Chapters 9 and 10).

The better survival of sternebrae in the Grizedale roe deer collection is interpreted by the author as an indication of a lower level of attack, which is also indicated by the lower percentage of attacked bones in this collection (see Table 3:1 for summary data for all of the collections, and Chapter 7 for statistical analyses of the rates of attack).

#### RED DEER

**Expectation 3: There will be more bones per red deer individual than per roe deer individual**

The red deer carcass collection was very small (MNI=4) due to the rarity of natural deaths of this species in the forest. Table 3:1 shows the summary data for the species, and Figures 5:1 and 5:2 and Table 5:3 give the raw and relative frequencies of the 26 element types (Appendix II lists the full data for element frequencies,

including sesamoids etc.).

It was expected that foxes would find it more difficult to consume or remove red deer bones because of their comparatively large sizes, and so higher frequencies of elements were expected for the red deer collection in comparison with the roe deer collection. In fact, although there is a slight difference in the expected direction, the difference is very small, i.e.: there are 60 bones per individual roe deer, and 66 bones per red deer. Compared to the Sheffield sheep carcass collection (with only 25 bones per individual) both deer collections are very similar. The following section demonstrates that foxes certainly are capable of removing elements (and articulated units) from red deer carcasses.

#### Relative frequencies of the 26 element types

The small sample size of the red deer collection precludes the use of a chi squared analysis to compare the raw frequencies of the 26 element types in the red deer collection with those of either the Sheffield sheep or the roe deer collections. However, a Spearman's rank order correlation analysis of the Brain's Index values shows that the relative frequencies of elements are very similar in the red deer and roe deer collections:  $Rho=0.89$ ,  $n=26$ ,  $p<0.01$ . This suggests that there are no major differences between the two deer collections, despite the differences in intact bone sizes.

Anatomical units

Figure 5:2 shows the Brain's Index (BI) values of the 26 element types in both the roe deer and red deer collections. The patterns of BI values are very similar in the two collections, i.e.: not only are the rank orders very similar (see above), but both collections highlight the same clusterings of BI values for elements from anatomical units. The red deer collection is dominated by elements from the axial/thoracic unit, and has relatively more ribs and sternebrae than either of the other two collections. The relative frequencies of these two element types may support the suggestion, made above, that the larger red deer bones are less likely to be totally consumed or drastically reduced in size than are their smaller counterparts in the roe deer and sheep skeletons.

The pattern of relative frequencies shown by the hindlimb elements is extremely similar to that shown by the roe deer collection.

The forelimb element frequencies are less consistent than in the other collections, but are still more consistent than those of the hindlimb. As in the roe deer collection, the radius, ulna and metacarpal have very similar Brain's Index values (all three have BI=0.25) whilst the humerus is slightly more frequent (BI=0.38). The anomaly is caused by the relatively high frequency of the scapula (BI=0.63) which cannot be explained by the factors considered in this study, and which may be due to random fluctuations in such a small sample.

It is interesting to note that, despite the general trend for the Brain's Index values to be slightly higher in the red deer

than in the roe deer collection, this is not the case for the forelimb elements. It was expected (see above) that red deer bones would be too large for foxes to remove, but the field plans demonstrate that this is not the case.

Figure 5:3 is a field plan of the remains of one of the red deer carcasses collected during the Grizedale study. It shows that the remains of an articulated forelimb, from the humerus down to the hooves, had been moved four metres from the main carcass site onto an animal track; an articulated hindlimb, from the femur down to the hooves, had been moved 3.5 to 4.5 metres (in a different direction from the forelimb, but partly onto the same animal track), and that isolated bones (i.e.: the two scapulae), had been moved for distances of 16 and 25 metres.

Whole limb units or lower hindlimb units of red deer were often found 5 - 10 metres away from the main portion of a carcass. It was noticeable that, as in the Sheffield sheep survey, limbs were always moved alongslope or downslope, never upslope, and that items were often found along animal tracks. It is extremely improbable that any of these parts of decomposing carcasses were moved by people (D. Morgan, pers. comm.) and, therefore, it appears that they were removed by scavenging carnivores. Since the only potential species in the Grizedale survey area is the fox (see Chapter 2), the author considers the observed distributions of red deer elements to be due to the activities of foxes.

There is no need for a scavenger to carry a desirable item of food, provided that it can drag it over the ground. The tendency for items to move along or downslope rather than upslope probably indicates that most of them were dragged, rather than carried.

Since foxes, which are comparable in size to a small dog (see Chapter 1), are capable of removing whole limbs from red deer carcasses, it is very probable that a medium- or large-sized dog would have no difficulty in removing articulated units or individual elements from carcasses the size of red deer or cattle.

On archaeological sites, therefore, not only bones of sheep-sized and smaller animals, but also those of cattle-sized species, may have been redistributed by dogs prior to burial.

#### SUMMARY

This chapter has studied the element frequencies of bones collected from roe deer and red deer carcasses in Grizedale Forest, Cumbria, and compared them with those described in Chapter 4 for the Sheffield sheep carcass collection.

It has shown that the patterns of relative frequencies are very similar in all three collections, supporting the hypothesis that foxes alter carcasses of medium-sized ungulates in predictable ways. Since foxes are comparable in body size to small-sized dogs (and their dentition is comparable to that of medium-sized dogs (Swire, 1978)), it may be expected that these observed patterns of element frequencies should also occur on archaeological sites where whole carcasses have been scavenged by dogs. Deviations from these patterns may be attributable to other agents, including human behaviour.

The slight differences observed between the element frequencies in the Grizedale and Sheffield collections were expected

due to slight differences in timespan and intensity of scavenging (which were shorter and lower, respectively, for the Grizedale study).

The Grizedale deer collections, therefore, were expected to have suffered less intense damage, and this was reflected by both deer collections having:

- (1) more bones per individual
- (2) higher Brain's Index values for all element types
- (3) relatively higher Brain's Index values for particularly susceptible elements (i.e. sternbrae, ribs and the hyoid)
- (4) more frequent articulations of elements
- (5) a greater clustering of element frequencies from anatomical units (i.e.: the forelimb, hindlimb, and axial/thoracic skeleton).

One expectation that was proven false by the Grizedale study concerned the ability of foxes to move bones the size of those of red deer, i.e.: foxes are capable of moving, not only individual, defleshed, bones of the size of those of red deer, but also whole limbs retaining flesh. Remains of articulated limbs were often found 5 - 10 metres from their carcasses. They had nearly always been moved along or downslope, seldom upslope, which suggests that the items may have been dragged rather than carried.

Since foxes are capable of moving limbs and elements from carcasses the size of red deer, it is extremely probable that dogs are capable of moving similar items from carcasses the sizes of red deer or cattle. On archaeological sites, therefore, not only bones of

sheep-sized and smaller species may have been redistributed by dogs, but also the bones of cattle (and even, perhaps, of small horses).

The next chapter, Chapter 6, describes the frequencies of element types in the Sheffield sheep non-carcass collection, and discusses where removed items may be redeposited.

CHAPTER 6: ELEMENT FREQUENCIES IN THE SHEFFIELD SHEEP  
NON-CARCASS COLLECTIONS

INTRODUCTION

This chapter considers the element frequencies in the non-carcass collection of sheep bones from the Sheffield moors, and compares them with those of the sheep carcass collection. This is to test whether or not different patterns of element frequencies characterise different types of depositional environment, i.e.: carcass sites, carnivore den sites, and general scatters.

It finds that there is a recognisable difference between residual and transported assemblages. Residual assemblages (such as the carcass collection and the S146 group), are composed of a wide range of element types, with elements from the axial/thoracic and upper limb units well represented. In contrast, transported assemblages (such as the two fox den sub-collections and the general scatter), are dominated by elements from the limbs, and may lack some of the thoracic elements (such as ribs and sternbrae).

Because of the lack of absolute values for Minimum Numbers of Individuals, raw frequencies have been used, unless otherwise stated. This also makes comparisons with archaeological materials more direct, as Minimum Numbers of Individuals have to be calculated for these, too, and can vary according to how assemblages are grouped together (Grayson, 1979).

The non-carcass finds were divided up into four sub-collections:

- a) "articulated" fox den finds,
- b) isolated fox den finds,
- c) general isolated finds
- d) bones from group S146

(see Chapter 3 for descriptions and locations of these sub-collections).

The total number of elements in the non-carcass collection (using the 26 main elements used throughout this study) is very small: only 178 elements. Table 6:1 presents the raw frequencies and rank orders of elements in the non-carcass sub-collections.

The main characteristics of the Sheffield sheep collections are:

- 1) **Sheffield carcasses:** elements from known individual carcasses
  
- 2a) **"articulated" fox den finds:** elements disarticulated in situ in and around a group of fox dens
  
- 2b) **isolated fox den finds:** individual elements found in and around the same group of fox dens
  
- 2c) **general isolated finds:** individual elements found scattered over the surface of the moor
  
- 2d) **S146:** elements remaining from a cluster of scavenged carcasses located close to the fox dens

N.B. None of the carcasses were located within the fox den area. The nearest carcasses to the dens were those in group S146, located approximately 80 metres away from the nearest den entrance.

#### THE HYPOTHESES

The main hypotheses to be tested regarding element frequencies in these sub-collections are:

**Hypothesis 1:** the "articulated" and isolated fox den finds are similar, the isolated finds simply being older, more disturbed examples of previously articulated units.

**Hypothesis 2:** the combined fox den finds are complementary to those in the carcass collection, since they represent items removed from carcasses.

**Hypothesis 3:** the combined fox den finds are complementary to those of the S146 group, which are the remains of a group of carcasses situated closest to the dens.

**Hypothesis 4:** the general isolated finds could resemble either the S146 sub-collection (i.e. residual items), or the fox den sub-collection (i.e. removed items), or a combination of the two.

THE STATISTICS

Two statistical techniques are used in this chapter: Spearman's rank order correlation analysis and the chi squared analysis. The sample sizes of the non-carcass sub-collections are all very small (Ns = 28, 43, 53 and 54, see Table 6:1), and the number of element types is comparatively large, i.e.: 26. Because of this, the Spearman's rank order correlation tends to emphasise elements that are scarce in both sub-collections. These are mainly the small elements that are likely to have been overlooked due to collector bias (see Chapter 10 for statistical support for this proposition). Differences between the rank orders of the larger elements (which are thought to be due mainly to fox scavenging behaviour) are likely to be masked by the uniformly low frequencies of these smaller items. Several of the Spearman's rank order correlation analyses do not show any statistically significant results, despite the fact that some elements do show disparate distributions.

To overcome this problem of small sample sizes, the elements have been grouped into naturally occurring anatomical units that were observed to remain articulated for several months during the three year study.

These units are:

- 1) the forelimb: scapula, humerus, radius, ulna
- 2) the hindlimb: femur, tibia, patella
- 3) lower limbs: astragalus, calcaneum, navicular-cuboid,  
metacarpal, metatarsal, proximal phalange,  
medial phalange, distal phalange
- 4) the axial/thoracic skeleton: mandible, hyoid, atlas,

axis, cervical vertebrae, thoracic  
vertebrae, lumbar vertebrae,  
sacrum, pelvis, ribs, sternebrae.

For most of the statistical comparisons, the results of a chi squared analysis and a Spearman's rank order correlation analysis are given. The chi squared analyses show statistically significant results using the grouped elements, whilst the Spearman's rank order correlation analyses highlight the specific elements within each anatomical unit that show the greatest differences in frequencies between the sub-collections.

#### FOX DEN FINDS

Forty-three bones were found in and around the fox dens in tightly clustered groups of elements that had disarticulated in situ. The elements most commonly represented are from the limbs, especially the forelimb. A further 53 bones were found in the same area, but as isolated elements. These consist of a much greater variety of elements and include some vertebrae, including one atlas.

#### **Skulls**

An unusually high number of sheep skulls were found at the fox dens, (i.e.: 10, in a collection of 96 bones from 10 individuals). Table 6:2 presents the frequencies of skulls in all of the Sheffield collections and sub-collections. It is possible that the skulls had

been taken back to the dens as playthings for the fox cubs (cf. Eadie, 1949). The collection also included a well-chewed golf-ball and a butchered calf bone, both probably scavenged from habitations in the valley one to two kilometres away.

### THE QUESTIONS

The hypotheses stated at the beginning of this chapter require answers to the following questions:

- 1) Do the "articulated" and isolated fox den groups contain similar distributions of elements?
- 2) Do the combined fox den sub-collections complement the carcass collection?
- 3) Do the combined fox den sub-collections complement the S146 sub-collection, which was a group of scavenged carcasses located close to the foxes' dens?

Question 1: Do the "articulated" and isolated fox den groups contain similar distributions of elements?

### Results

Table 6:3 presents a chi squared analysis of the raw

frequencies of elements, grouped into anatomical units, in the "articulated" and isolated fox den finds. The results show that the elements are not equally distributed between the two sub-collections, but the result is only just statistically significant ( $p=0.05$ , rather than  $p<0.01$ ), indicating that the differences are not particularly great: chi squared=9.50, with 7 degrees of freedom,  $p=0.05$ . It is clear from Table 6:3 that the differences are evenly spread between all four anatomical groups, and the author interprets these as being of minor behavioural significance.

Figure 6:1 presents the Brain's Index values of elements in the two sub-collections. The "articulated" fox den sub-collection is dominated by elements from the forelimb. There are also a few bones from the upper hindlimb (pelvis, femur and tibia) and some foot bones. The only element from the axial/thoracic skeleton that is represented at all is the sacrum (the one example was associated with the pelvis).

The isolated fox den sub-collection also has some forelimb elements, which may have derived from disarticulated units, but the two commonest elements are the tibia and metatarsal, i.e.: the lower hindlimb bones. There are also a few vertebrae and foot bones and some (i.e. 2) mandibles.

### Conclusions

The distributions of elements in the two sub-collections are neither identical nor complementary. They both emphasise limb units rather than elements from the axial/thoracic skeleton, and both have few of the very small bones (that mainly derive from the feet). The

clustering of relative frequencies of elements suggest that most of them were originally taken to the fox dens as articulated units, although not all of them preserved their spatial associations. The two fox den sub-collections, therefore, have been combined for further comparisons since they appear to contain similar groups of elements, but in different stages of disarticulation and disturbance.

The units represented, i.e.: whole forelimbs and lower hindlimbs, were commonly observed to be missing from the carcasses (see Chapter 4), although some of them remained within the collection radius of 30 metres.

Question 2: Do the combined fox den sub-collections  
complement the sheep carcass collection?

Results

Table 6:4 presents a chi squared analysis comparing the raw frequencies of elements, grouped into anatomical units, in the combined fox den sub-collection (N=96) and the Sheffield sheep carcass collection (N=516). The results are statistically very highly significant: chi squared=108.22, with 7 degrees of freedom,  $p < 0.001$ , showing that there are major differences between the two groups. It is clear that the forelimb elements are much more frequent in the fox den sub-collection than expected by the null hypothesis (i.e. that elements are equally distributed between the two collections in proportion to their total sizes) and that the elements of the axial/thoracic skeleton are less frequent than expected.

Figure 6:2 presents histograms of the Brain's Index values of elements in the two collections, and shows clearly that the forelimb and lower hindlimb elements predominate in the combined fox den sub-collection, whereas the carcass collection has a much more even distribution of elements including many from the axial/thoracic skeleton. The greater range of Brain's Index values for the elements in the fox den sub-collection is only partially explained by the different methods of calculating Minimum Numbers of Individuals (MNIs). (N.B. the more conservative the estimate of MNI, the higher the Brain's Index value of the most frequent element). If the figures are standardised so that the highest Brain's Index value in both collections is the same, the different patterns remain equally clear. However, the practice of standardising the figures removes some of the information concerning bone loss, and so has been avoided throughout this thesis.

Although a Spearman's rank order correlation analysis of the raw frequencies in the two collections fails to give a statistically significant result, ( $Rho=0.21$ ,  $N=26$ ,  $p>0.05$ ), this is probably due to the comparatively small sample size of the fox den sub-collection, together with the paucity of small bones (e.g. those from the feet) in both collections. Table 6:5 presents the elements in descending order of rank differences. It shows not only that some groups of elements are unevenly distributed between the two collections, but that some element types (within anatomical groups) are also ranked very unevenly, e.g.: ribs and thoracic and lumbar vertebrae, all rank far more highly in the carcass collection than at the fox dens.

### Conclusions

It is clear from the statistical analyses and histograms that, although the two collections are not complementary in their relative frequencies of elements, they are significantly different, i.e.:

- 1) The residual material recovered in the sheep carcass collection contains comparatively higher numbers of ribs and thoracic and lumbar vertebrae
  
- 2) The accumulated material taken back to the fox dens contains comparatively higher numbers of limb bones, especially elements from the forelimb (humerus, radius, ulna and metacarpal), and the lower hindlimb (tibia and metatarsal).

**Question 3** Do the combined fox den sub-collections  
complement the S146 sub-collection ?

### Limitations of the data

The S146 group was located approximately 80-100 metres from the fox dens, and showed distinctive signs of scavenging such as removal of limbs and the chewing of elements. It may well have been scavenged by some of the foxes living in the dens and, therefore, some of the elements recovered at the fox dens may have derived from the

S146 group. However, the fox den sub-collection contains remains from more individuals than were originally present at the S146 site, and so the two collections need not be statistically complementary (due to overprinting by elements from other individuals). Also, it was clear during the study period that some elements and articulated units were only removed a short distance from the S146 carcasses and were, therefore, recovered within a 30 metre radius and not at the dens themselves. This applies in particular to the humeri, most of which were found together with other forelimb elements in the shelter of the Juncus rushes just below the death site (see Plate 3:1).

### Results

Table 6:6 presents a chi squared analysis comparing the raw frequencies of elements, grouped into anatomical parts, in the combined fox den and S146 sub-collections. The results show that there are significant differences between the two groups: chi squared = 19.85, with 7 degrees of freedom,  $p < 0.01$ . These differences mainly concern the distributions of elements from (a) the lower limbs (which are less frequent than expected by the null hypothesis in the S146 group), and (b) the axial skeleton (these elements are more frequent than expected in the S146 group).

Figure 6:3 presents the Brain's Index values of elements in the two sub-collections and shows that, whilst both groups emphasise forelimb elements, the S146 group has no lower forelimb elements (i.e.: metacarpal down to distal phalanges). Nor does it have any lower hindlimb elements, excepting tibiae. Rather, it emphasises upper

parts of both fore- and hindlimbs, and also retains a few vertebrae.

### Conclusions

Although the element frequencies in the two sub-collections are different, they are not complementary except in the proportions of upper to lower limbs. The ambiguous circumstances and the very small sample size of the S146 group (N=28) may preclude any conclusive statistical analyses.

### GENERAL ISOLATED FINDS

The origin of the general isolated finds is uncertain. The carcass collection and S146 group are known to have derived from monitored carcasses, whilst the fox den collections are known to consist of transported items that have been removed from carcasses (there were no carcasses in the fox den area itself; the S146 group was the nearest source, 80-100 metres away).

The general isolated finds sub-collection may contain residual material from carcasses, and/or transported items. The following analyses investigate Hypothesis 4, i.e.: they compare the element frequencies in the general isolated sub-collection with those in the carcass and fox den collections, to see which pattern of frequencies (residual or transported) they most resemble.

Question 4: Does the general isolated finds sub-collection resemble the residual material of the carcass collection, or the transported material of the fox den sub-collections, or a mixture of the two?

### Results

Table 6:7 presents a chi squared analysis of the raw frequencies of elements, grouped into anatomical units, in the general isolated sub-collection and the carcass collection. The results show that there are very significant differences in element distribution: chi squared=54.41, with 7 degrees of freedom,  $p < 0.001$ .

The biggest difference is in the frequencies of forelimb elements, which are relatively more frequent in the general isolated sub-collection than in the carcass collection.

Figure 6:4 presents the Brain's Index values for the general isolated and carcass collections, and shows that the general isolated sub-collection is very heavily biased towards limb bones, whereas the carcass collection has a far more even distribution. The general isolated sub-collection does have a few axial items, which may be residual.

The almost total lack of foot bones in the general isolated sub-collection may well be due to problems of visibility in the vegetation. The areas around the carcasses (including the S146 group) and around the fox dens were searched intensively, but the general isolated remains were collected whilst I walked slowly across the general area. This sub-collection, therefore, may be preferentially biased against by the problem of the recovery of small bones.

Table 6:8 presents a chi squared analysis of the raw frequencies of elements, grouped into anatomical units, in the general isolated and combined fox den sub-collections. The differences between these two sub-collections is significant at the  $p < 0.05$  level, rather than at the  $p < 0.001$  level (i.e.: chi squared=14.22, with 7 degrees of freedom,  $p < 0.05$ ), indicating that the differences between the raw frequencies of elements in these two sub-collections are less marked than those observed above between the general isolated sub-collection and the carcass collection. The chi squared results do not emphasise differences for any particular anatomical unit.

Figure 6:4 also presents histograms for the Brain's Index values of the combined fox den sub-collection (together with those for the general isolated and carcass collections). It shows that the relative element frequencies are quite similar for the general isolated and combined fox den sub-collections: both emphasise limb bones almost to the exclusion of other elements. Visually, the general isolated frequencies tend to resemble those of the isolated fox den sub-collection, rather than those of the "articulated" fox den sub-collection (see Figure 6:1).

### Conclusions

The element frequencies in the general isolated sub-collection are very different from those of the carcass collection, but only slightly different from those in the combined fox den sub-collection. The group, therefore, probably consists mainly of removed items, together with a few residual bones (mainly from the axial

skeleton) from carcasses.

It is interesting that, in three years of collecting, isolated remains from scavenged carcasses should be so poorly represented. Typically, elements from the axial skeleton of monitored carcasses remained at the original sites of death, yet almost no vertebrae were found in the general isolated finds collection. It is possible that this is due to preferential burial of items remaining with the carcasses (see the section on Burial in Chapter 4). Although individual vertebrae tend to be shorter than most of the limb bones, groups of vertebrae that had disarticulated in situ should have been equally visible, if they had remained on the ground surface.

#### RESIDUAL VERSUS TRANSPORTED ASSEMBLAGES

This chapter has investigated the differences in relative frequencies of elements in collections of bones that accrued in different types of environment, i.e.: carcass sites, carnivore (fox) dens, and general scatters. The collections can be characterised as containing mainly either residual or transported elements according to their environmental context. The next part of this chapter compares these two types of assemblage (i.e.: residual versus transported elements) by combining the collections in the following way:

**1: residual material:** carcass collection, S146

sub-collection N=544

**2: transported material:** combined fox den and general

isolated finds sub-collections N=150.

The following analyses test the degrees to which the element

frequencies in these two types of assemblage are similar or complementary.

### Results

Table 6:9 presents a chi squared analysis of the raw frequencies of elements, grouped into anatomical units, of the residual and transported assemblages. The chi squared value is statistically extremely significant: chi squared=104.61, with 7 degrees of freedom,  $p < 0.001$ . The main differences in element frequencies concern the forelimb and axial/thoracic units. As noted for individual sub-collections, the forelimb elements are comparatively more frequent in the transported assemblage, whilst the axial/thoracic elements are comparatively more frequent in the residual assemblage.

Figure 6:5 presents the Brain's Index values for elements in the two assemblages in histogram form. The transported assemblage is dominated by limb elements (both forelimb and hindlimb) and has comparatively very few bones from the feet or axial skeleton (it has no examples of bones from the thoracic skeleton, i.e.: no ribs nor sternebrae). Within the limb units, two elements are particularly frequent: the radius and the tibia, both of which are the major element in a lower limb unit.

In the residual assemblage, although the foot bones are still comparatively rare, element frequencies in the axial/thoracic unit are comparable to those in the forelimb unit, whilst the dominant group combines the pelvis with the femur and tibia, i.e.: there is

more of an emphasis on the upper hindlimb remaining with the axial skeleton, although the tibia is particularly common in both assemblages.

The chi squared analysis and the histograms, therefore, emphasise the differences between the two assemblages. However, a Spearman's rank order correlation analysis of the raw frequencies of elements in the two assemblages tends to emphasise the similarity between them:  $Rho=0.60$ ,  $N=26$ ,  $p<0.01$ . Table 6:10 presents the rank differences in element frequencies in descending order, indicating which elements rank higher in which assemblage. It is clear that the statistically significant similarity is partially caused by the fact that smaller and/or more fragile elements are rare in both assemblages, i.e.: the phalanges, ankle bones, and hyoid and sternbrae. Table 6:10 again emphasises the relatively greater frequencies of the axial/thoracic elements in the residual assemblage (i.e.: lumbar, thoracic and cervical vertebrae, the pelvis, ribs and the axis), and the relatively greater frequencies of the limb bones (especially forelimb bones) in the transported assemblage (i.e.: metacarpal, radius, ulna), but it also highlights the fact that some of the larger elements are common in both assemblages, i.e.: the tibia, humerus, scapula, femur and mandible. The good 'survival' properties of these elements are discussed in Chapter 7, with regard to attack rates and completeness categories; in Chapter 8, with regard to specific forms of damage; and in Chapters 10 and 11, with regard to internal factors of bulk density, meat cover etc., and in comparison with other collections of carnivore-scavenged ungulate bones.

Conclusions

The comparison of residual and transported assemblages highlights the emphasis on limb bones in transported collections (especially forelimbs and lower hindlimbs), and the much more even distribution of elements in residual assemblages which include elements from the axial/thoracic skeleton and the upper hindlimb. Some of the larger elements, however, are common in both types of assemblage.

SUMMARY

This chapter has compared the element frequencies in different collections and sub-collections of the Sheffield sheep bones. It has shown that relative frequencies of element types are related to the types of environmental context in which an assemblage is found. That is:

**Residual assemblages** are characterised by high relative frequencies of elements from the upper hindlimb, the forelimb, and the axial/thoracic skeleton. (The paucity of foot bones may be due to collector bias against small bones).

**Transported assemblages** are characterised by being dominated by elements from the whole forelimb and the lower hindlimb. Precisely these units were observed as articulated units being removed from carcasses during the three year study of the Sheffield sheep and, again, in the studies of the roe deer and red deer in Grizedale Forest (see Plates 4:2, 4:4, 4:5, 4:10, 5:2).

However, some of the larger element types (i.e. some of the limb bones, and the mandible) are relatively common in both types of assemblage. Possible reasons for the preferential recovery of these elements are discussed in subsequent chapters.

The general scatter of isolated bones was shown to resemble collections of known transported items far more than collections of residual items. Whether or not this is due to preferential burial of residual items at carcass sites is unknown, and requires further investigation through selective excavation, which was not possible within the scope of this thesis.

The following chapter, Chapter 7, investigates the rates of attack shown by the different collections and sub-collections, and relates them to element frequencies and patterns of bone loss.

CHAPTER 7. RATES OF ATTACK IN THE CARCASS AND NON-CARCASS  
COLLECTIONS OF SHEEP AND DEER BONES

INTRODUCTION

This chapter investigates the significance of the percentages of bones in an assemblage that show signs of having been attacked by carnivores. It discusses average rates of attack for both whole assemblages and individual element types.

It finds that the average percentage of bones in an assemblage that show signs of attack is correlated with the overall rate of bone loss (i.e. with the average number of bones per individual). Both factors are considered to represent bone preservation conditions.

It shows that individual element types tend to be attacked in proportion to their Meat Utility Index (MUI, Binford, 1978), and that two of the smallest, most fragile and meaty element types may be consumed or destroyed entirely when attacked by carnivores.

The last part of the chapter considers partial bone loss for the twelve medium or large-sized element types, and shows that the percentage of an element type that is attacked tends to be correlated positively with its degree of partial bone loss. However, some element types (e.g. the radius and metacarpal) may show signs of damage that, whilst frequent, are superficial and lead to little bone loss. The details and implications of such partial bone loss are given in the following chapters (Chapters 8 and 9).

CHEWED BONES IN ARCHAEOLOGICAL ASSEMBLAGES

It was noted in Chapter 1 that several authors of archaeological bone reports (e.g. Wilson, 1978; Thawley, 1981; Grant, 1984) have commented that some of the bones studied show tooth marks similar to those made by modern dogs. Some authors (e.g. Knol, 1986) have quantified the number of chewed bones as a percentage of the total recovered.

Knol also makes the important observation that some element types are chewed more often than the others, i.e.:

skulls & lumbar vertebrae: no chewing marks  
ribs: chewing marks very rare  
mandibles: chewing marks quite common  
metapodials & prox. phalanges: tend to be chewed  
longbones: chewed quite often  
humerus: particularly frequently chewed  
(taken from Knol, 1986:157-8)

Morgan (1985) also comments that longbone fragments and ribs were the commonest elements to show tooth marks in a Romano-British assemblage, although Morgan attributes the marks to either humans or dogs.

Clearly, the presence of carnivore tooth marks on some of the bones demonstrates that carnivores, probably canids, have had access to at least some of the faunal material before it became buried. Differences in average rates of attack for different element types may be due to differing methods of disposal (e.g.: immediate burial versus surface litter) and/or to differences pertaining to the

elements themselves.

It would be useful to establish whether or not the average percentage of bones chewed in an assemblage is related to the overall loss of bones, and whether or not there tends to be a selective loss for certain element types.

### QUESTIONS

This chapter investigates the types of correlations exhibited by the degrees of attack and frequencies of elements in the modern collections of deer and sheep bones.

The specific questions are:

- (1) Is the percentage of attacked bones in an assemblage correlated with the average number of bones per individual (i.e. with overall bone loss)?
- (2A) Are some element types more likely to be attacked than others?
- (2B) If so, is the rate of attack linked to the attractiveness of the element, as measured by its meat cover?
- (3) Is the percentage of an element type that is attacked correlated with the relative frequency of that element type (i.e. with selective element loss)?
- (4) Is the attack rate of an element type correlated with its average degree of completeness (i.e. with selective partial destruction)?

Question 1: Is the percentage of bones attacked correlated  
with the number of bones per individual?

Results

Figure 7:1 graphically presents the percentages of attacked bones and the numbers of bones per individual in the three carcass collections and four non-carcass sub-collections of sheep and deer bones. The figures for these values are also given in Table 3:1.

Figure 7:1 clearly shows that there is an inverse correlation between the two variables. This is supported statistically by a linear regression analysis:  $y = -0.99x + 91.03$ ,  $r = -0.88$ . A low number of bones per individual is interpreted as representing poor preservation, and this is associated with a high percentage of attacked bones.

It is very noticeable that the two deer carcass collections are much better preserved than is the sheep carcass collection, which, in turn, is better preserved than any of the sheep non-carcass sub-collections. It was noted in Chapter 5 that there were far more articulated bones in the two deer collections than in the Sheffield sheep collection (due to a shorter timespan between the death of an animal and the collection of its bones). This greater degree of articulation is reflected both by the higher numbers of bones per individual and by the lower incidences of attack (the two factors are interrelated, since the more bones are attacked, the more likely they are to become disarticulated).

There is a similar marked difference between the carcass and non-carcass collections of sheep bones. This is not caused by the

different methods of assessing Minimum Numbers of Individuals for the two types of collection; on the contrary, the conservative estimates of MNIs for the non-carcass sub-collections may have reduced the differences by boosting their average numbers of bones per individual. Yet all four of the non-carcass sub-collections have very small numbers of bones per individual (less than ten in each case, see Figure 7:1). Nor are the rates of attack correlated with the type of collection, i.e.: the S146 group is known to be the remains of a group of carcasses, and yet their rates of attack and numbers of bones per individual are similar to those of the transported collections of isolated fox den and general isolated finds, rather than to the other collections of residual carcass remains. The main factors affecting these two variables appear to be timespan and intensity of scavenging, rather than type of depositional context.

The 'articulated' fox den group has an intermediate rate of attack between those of the carcass and non-carcass collections: 63%. This is due to the fact that many of the foot bones in the units have not been attacked. This pattern of damage is discussed with regard to the association of rates of attack with element types (see below, Question 3).

### Conclusions

The percentage of bones showing signs of attack in an assemblage is inversely correlated with the numbers of bones per individual. Both traits are interpreted as representing the degree of preservation of an assemblage, i.e.: the higher the number of bones

per individual and the lower the percentage of attacked bones, the better the degree of preservation.

Question 2A: Are some element types more likely to be attacked than others?

2A:Results

Table 7:1 presents the percentages of each element type that show signs of having been attacked by carnivores in the red deer, roe deer and sheep carcass collections, and in the sheep non-carcass collection. Clearly, in each collection, there is a great variety in the degree of attack suffered by different element types (0-100%, 0-84%, 0-100% and 0-100% respectively). Rank differences are shown most clearly by the two larger collections: the roe deer and sheep carcass collections, which also have intermediate average rates of attack. The rank differences are less clear for the red deer collection, because of the small samples sizes for many of the element types (most of the paired elements are only represented by two or three examples), and for the sheep non-carcass collection, in which ten of the 22 element types present have identical attack rates of 100%.

However, all four collections tend to emphasise the same element types as being preferentially attacked. Spearman's rank order correlation analyses show that the ranking of element attack rates are well correlated between the collections, despite the problems of the red deer and sheep non-carcass collections:

red deer & roe deer:  $Rho=0.38$   $N=26$   $p<0.05$   
 roe deer & sheep carcasses:  $Rho=0.57$   $N=26$   $p<0.01$   
 sheep carcasses & non-carcasses:  $Rho=0.77$   $N=22$   $p<0.01$   
 red deer & sheep non-carcasses:  $Rho=0.50$   $N=22$   $p<0.05$

Chi squared analyses highlight which element types are preferentially attacked and which are preferentially left intact by scavenging canids. Only the roe deer and sheep carcass collections have statistically significant results, probably because of the sample problems mentioned above:

N	%	ATTACKED	
263	38%		red deer: chi squared= 44.71, 51 <sup>o</sup> freedom, p<0.750
961	40%		roe deer: chi squared=198.03, 51 <sup>o</sup> freedom, p<0.001
516	53%		sheep carcasses: chi squared=195.82, 51 <sup>o</sup> freedom, p<0.001
178	84%		sheep non-carcasses: chi squared= 32.78, 51 <sup>o</sup> freedom, p<0.900

Table 7:2 presents the chi squared values in descending order for the Sheffield sheep carcass collection, and Table 7:3 presents similar data for the roe deer collection. Note how similar are the main deviations from the null hypothesis (i.e.: that all element types have equal chances of being attacked) in the two collections:

- i) proximal, medial & distal phalanges are far more intact than expected
- ii) ribs, pelvis, lumbar vertebrae are far more attacked than expected.

These two groups of element types rank very low and very

high, respectively, on the variable of meat cover. Question 2, below, tests the correlation of an element's attack rate with its meat cover (using Binford's (1978) MUI values).

### 2A: Conclusions

The rates of attack vary considerably between the 26 element types (i.e.: from 0-100%), yet the rank orders of rates of attack are very consistent between the four major collections, i.e.: some element types are more likely to be attacked than others, and these types tend to be consistent regardless of overall rates of attack, and regardless of whether the collection is of residual or transported items. The reasons for these differences, therefore, may be internal rather than external (see Chapter 3 for a discussion of internal and external factors).

In particular, ribs, the pelvis, and lumbar vertebrae tend to be preferentially attacked by canids, whilst the collected examples of proximal, medial and distal phalanges all tend to be preferentially left intact.

### Question 2B: Is an element's rate of attack linked to its attractiveness (as measured by its meat cover?)

This hypothesis is tested using Binford's (1978) Meat Utility Index (MUI), which is a measure of the ratio of the weight of meat to that of the underlying bone.

## 2B: Results

A series of Spearman's rank order correlation analyses shows that the percentage of an element type that is attacked is positively correlated with that element's meat cover (measured by its MUI). Again, the most statistically significant results come from the two larger collections.

Correlation coefficients for elements' MUIs and percentages attacked are:

red deer:	Rho=0.42	N=17	p~0.05
roe deer:	Rho=0.59	N=17	p~0.01
sheep carcasses:	Rho=0.71	N=17	p<0.01
sheep non-carcasses:	Rho=0.44	N=15	p~0.05

Table 7:4 lists the data used in the Sheffield sheep carcass analysis, and Figure 7:2 presents the data as a scattergram. Although there is an overall correlation of the two variables, certain element types show large differences in rank (in Table 7:4), and these are peripherally located on the scattergram of Figure 7:2, i.e.: cervical vertebrae, ribs, sternbrae and thoracic vertebrae are all 'under-attacked', whilst the tibia and humerus are 'over-attacked'. Details of forms of attack are given and discussed in Chapter 8.

## 2B: Conclusions

Generally, there is a positive correlation between the

attack rate and the attractiveness of an element type (as measured by Binford's (1978) Meat Utility Index (MUI)). However, some element types are attacked considerably more frequently or less frequently than would be expected from their MUI values. Chapter 10 discusses the relative influences of other factors that might affect the variable of attack rate.

**Question 3: Is the percentage of an element type that is attacked correlated with the relative frequency of that element type?**

It was suggested in Chapter 3 that some small, fragile, attractive elements might tend to be consumed entirely if they suffered severe attack. If this is the case, then an element's attack rate might be inversely correlated with its frequency.

### Results

Table 7:5 presents a Spearman's rank order correlation analysis of the rates of attack and Brain's Index values for the 26 element types in the Sheffield sheep carcass collection. The results disprove the expectation by showing that there is, in fact, a statistically significant positive correlation between the ranks of the two variables, i.e.: the more frequently recovered elements also tend to be more frequently attacked:  $Rho=0.35$ ,  $N=26$ ,  $p<0.05$ .

Figure 7:3 is a scattergram of the same data, and shows that, although the rank orders are correlated relatively well, the

actual values are not. The Brain's Index values are known to be well correlated with average intact element sizes (see Chapter 10), whilst the attack rates are known to be well correlated with meat cover (see above, Question 2B). The apparent correlation between the rank values of rates of attack and Brain's Index may be an artefact due to the coincidence that the more meaty bones also tend to be the larger bones.

However, it can be seen from Table 7:5 that there are a few notable exceptions to the general trend for the more frequent elements to be more frequently attacked, and these exceptions support the original prediction. The three element types that have the most disparate rankings in the two variables (i.e.: that show an inverse correlation, as predicted) are: the patella, the sacrum and sternebrae. All three of these element types rank much higher on the variable of percentage attacked than on Brain's Index, i.e.: there are very few of any of them, but what there are tend to be attacked.

The patella and sternebrae are very small elements (see Table 10:2) and consist of trabecular bone covered with meat (sternebrae) or muscle attachments (patella). It is quite possible that these elements do tend to be consumed entirely by canids. Chapter 8 describes the severe damage observed on some examples of larger elements, which implies that foxes are certainly capable of completely consuming or destroying these smaller bones. However, it is impossible to prove that this has occurred without direct observations of the foxes feeding. Such observations would require a further study using infra-red surveillance techniques (as also suggested by MacDonald, 1977), since the foxes' behaviour is nocturnal or crepuscular. It may be circumstantially relevant that no examples were found of either of

these two element types in the non-carcass collection, despite intensive searching in the fox den and S146 areas. The non-carcass collection is thought to have undergone more severe alteration, reflected by both its higher average rate of attack and lower average number of bones per individual. The lack of element types that are thought to be most susceptible to consumption may be another indicator of severe alteration. Chapter 9 discusses the ability of canids to consume bones, using data published by other authors.

The third element type whose rate of attack ranks much higher than its Brain's Index value is the sacrum, which also consists of trabecular bone covered in meat. However, the sacrum is probably too large to be totally consumed by foxes: its average intact length is 11 centimetres, compared with 3 cms. for the patella and 4 cms. for the sternbrae. Its relatively low Brain's Index value (BI=0.19) in the Sheffield sheep carcass collection may be due partially to its tendency to be transported by foxes away from carcasses (see Chapter 6), rather than to consumption or destruction.

Spearman's rank order correlation analyses of the Brain's Index values and percentages attacked in the four collections do not show very consistent patterns. Three of them show that there are overall correlations of frequencies with rates of attack, but the red deer collection shows an almost total lack of correlation.

Brain's Index values & percentages attacked for the 26 element types are:

red deer: Rho=0.09 N=26 p>0.05  
roe deer: Rho=0.66 N=26 p<0.01  
sheep carcasses: Rho=0.35 N=26 p<0.05  
sheep non-carcasses: Rho=0.40 N=22 p<0.05

### Conclusions

The rank orders of Brain's Index values and rates of attack of elements in all four collections show either an overall positive correlation or no correlation at all, whilst the absolute values have a very low correlation coefficient. Neither the rank orders nor the absolute values show a statistically significant negative correlation, (as expected by Question 3), but the rank orders of certain element types do show such a trend within the various collections. In the Sheffield sheep carcass collection, the patella and sternbrae are both very rare, but frequently attacked, and it is possible (although unproven) that these elements are underrepresented due to total consumption by the foxes.

Generally, the more frequent elements are also the more frequently attacked elements. They also tend to be the larger and more meaty elements, and this fact may explain the unexpectedly positive correlation of their rank orders. The rates of attack are correlated far more closely with meat cover (i.e.: MUI, see above), than they are with element frequencies, and the Brain's Index values are far better correlated with intact size, (see Chapter 10), than with rates of attack.

Question 4: Is the attack rate of an element type correlated with its degree of completeness? (i.e.: if an element is more frequently attacked, is it more likely to be partially destroyed?)

### Methods

Each bone recovered was recorded for its relative completeness (see 'Completeness Categories' in Chapter 3). Table 7:6 presents the distributions of Completeness Categories for all 26 element types in the total Sheffield sheep collection. Of the small elements (i.e.: those of 20-70 mm. average intact length), only one example, a proximal phalange, did not retain its full length. N.B. All vertebrae retained their full lengths (i.e.: measured between epiphyses or fusion surfaces), but some of the thoracic and lumbar vertebrae had lost parts of their lateral projections. Table 7:6 shows the Completeness Categories for the widths rather than the lengths of these two element types. Small elements are not considered in the following analyses.

Figure 7:4 presents the data for the twelve medium or large element types (i.e. those of 110 - 210 mm average intact length) in the total Sheffield sheep collection. It is very clear from these histograms that the severity of damage varies considerably between element types.

Precise patterns of damage are discussed in detail for each of the 26 element types in Chapter 8, and the significance of the partial loss of bones is discussed in Chapter 10 with regard to the relative frequencies of different ends of longbones. Partial destruction is particularly relevant to the survival of epiphyseal

fusion data (see Chapter 9).

Table 7:7 presents the data for whole bone equivalents for the twelve medium or large element types in the Sheffield sheep carcass, non-carcass and total collections, and in the roe deer carcass collection.

For the twelve medium and large element types whole bone equivalents (WBEs) have been calculated by using the midpoints of the completeness categories (e.g.: fragments in Category 3 (51-75% of original length present) have been assumed to be 62.5% complete; and Category 4 fragments (76-99% complete) are assumed to be 87.5% complete). The ratio of whole bone equivalents to total numbers of bones (WBE/N) indicates the degree of partial bone loss due to destruction by carnivores.

The following analyses investigate the hypothesis that:

The more frequently an element type is attacked, the more likely it is to suffer partial bone loss.

#### Results. A: A comparison of element types within a collection

Figure 7:5 presents a scattergram showing the relationship of the ratio of whole bone equivalents to numbers of bones (WBE/N) with the percentages attacked of these twelve element types in the total Sheffield sheep collection. It shows clearly that there are two main 'clusters' of element types in the total Sheffield sheep collection. The hypothesis predicted that the percentage of an element

type attacked will be inversely correlated with the ratio of WBE/N (i.e.: more frequently attacked bones will show greater partial bone loss). This appears to be the case for four of the twelve elements, i.e.: for the metacarpal, mandible, ribs and sacrum. The metatarsal and radius are slight outliers from this group, both element types having suffered slightly less bone loss than would be expected from their rates of attack.

The second group of elements in Figure 7:5 comprises the tibia, femur, humerus, ulna, scapula and pelvis. All six of these element types have extremely high rates of attack (95-97%). Four of these have identical attack rates of 95%, yet their WBE/N ratios range from 0.82 (the ulna) to 0.95 (the tibia), indicating that the severity of partial bone loss varies quite considerably between element types. Chapter 8 describes how the proximal tibia tends to be partially damaged (leading to a high attack rate) but seldom removed (leading to a high WBE/N ratio). In contrast, the pelvis (which has an almost identical attack rate: 97%) tends to suffer considerable bone loss (WBE/N = 0.78). To some extent, the degree of bone loss can be explained by the structure of the element, i.e.: the flatter and/or more trabecular bones, such as the ribs, pelvis and sacrum, suffer greater partial bone loss than the denser and more cylindrical elements such as the tibia and femur.

#### Results. B: A comparison of elements between collections

Table 3:1 showed that the Sheffield sheep non-carcass collection has the highest attack rate (83%), whilst the Grizedale roe

deer collection has one of the lowest (40%). Figures 7:6 and 7:7 present scattergrams of the WBE/N ratios and percentages attacked for these two collections, respectively.

Figure 7:7 shows that eleven of the twelve roe deer element types (i.e.: excluding ribs) have WBE/N ratios of 0.89 - 1.00 (average=0.96). This shows that partial bone loss is quite slight, regardless of attack rate (range = 7 - 84%; average = 40%). In contrast, the WBE/N ratios for the same element types in the Sheffield sheep non-carcass collection range from 0.67 - 0.99 (average = 0.86), showing a substantially greater degree of bone loss, associated with the greater rates of attack (range = 60 - 100%; average = 91%). The twelfth element type found in the roe deer collection, the ribs, has an attack rate of 65% and a WBE/N ratio of only 0.68, indicating a considerable partial loss of bone. This element type is missing altogether from the non-carcass collection.

The correspondance of the average degree of alteration suffered by a collection with the degree of partial bone loss suffered by elements is illustrated by the data presented below:

	AVERAGE WBE/N	AVERAGE % ATTACKED
ROE DEER CARCASSES*	0.93	40
SHEEP CARCASSES*	0.89	67
SHEEP NON-CARCASSES*	0.86	91

\* using only the twelve medium or large element types

However, it is noticeable from the Figures and Table 7:7 that, whilst some element types illustrate this trend very well, others tend to suffer little partial bone loss regardless of their own attack rates and those of the collection as a whole. WBE/N ratios and attack rates for a selection of element types illustrating these two patterns are presented below:

(AVE.):	ROE DEER (40% ATTACKED)	SHEEP CARCASSES (53% ATTACKED)	SHEEP NON-CARCASSES (83% ATTACKED)
Tibia	1.00 21%	0.99 95%	0.92 83%
Humerus	0.98 31%	0.86 90%	0.80 100%
Metacarpal	0.98 25%	1.00 0%	0.99 60%
Radius	0.99 31%	1.00 20%	0.96 79%
Metatarsal	1.00 7%	1.00 18%	0.99 100%

### Conclusions

The attack rates of element types tend to be correlated with their degrees of partial bone loss.

However, some element types may suffer high rates of attack but little bone loss, reflecting the superficial nature of the damage. This is particularly true for the metapodials and the radius. Chapter 8 describes patterns of damage observed to all 26 element types in the total Sheffield sheep collection.

The average percentage attacked in an assemblage is also related to bone loss, and may be an important indicator of bone preservation in an assemblage. Chapter 9 discusses the implications of levels of intensity of attack in more detail, particularly with regard to frequencies of epiphyses.

#### SUMMARY

This chapter has looked at rates of attack in bone assemblages, using percentages of element types showing signs of damage, average numbers of bones per individual, Binford's (1978) Meat Utility Index, Brain's Index and partial bone loss (measured by the ratio of Whole Bone Equivalents to total Numbers of bones: WBE/Ns).

The main findings are:

1) The greater the percentage of bones attacked in an assemblage, the lower the average number of bones per individual, i.e.: a high rate of attack is correlated with a high degree of overall bone loss. Both factors are considered to reflect the degree of bone preservation in an assemblage.

2a) Some element types tend to be attacked more often than others.

2b) Generally, the more frequently attacked element types are those with the highest Meat Utility values.

3) There is not an inverse correlation between the percentage attacked and the Brain's Index value of an element type, except for two elements that are so small, fragile and meaty (the sternebrae and the patella) that they may tend to be consumed or destroyed when attacked. Generally, there is a weak positive correlation between the percentage attacked and the Brain's Index value of an element type, but this may be a statistical artefact due to the fact that the elements showing the best correlation between these two variables are also the largest and meatiest element types.

4) Partial bone loss tends to increase with the percentage attacked for the twelve medium or large-sized element types. Average partial bone loss also increases with average percentage attacked for whole assemblages. A high degree of partial bone loss is defined as representing poor bone preservation.

5) Some element types show a strong positive correlation between their percentage attacked and their degree of partial bone loss, but others may have a high percentage attacked and yet suffer little bone loss, due to the superficial nature of the damage.

The percentage of an assemblage that has been attacked is easy to measure for both past and present assemblages. Some analysts of archaeological faunas have commented on the rates of attack shown by an assemblage, but have been unable to interpret its significance.

This chapter has shown that the higher the rate of attack in an assemblage, the higher the degree of overall and partial bone loss.

It has also shown that partial bone loss is not evenly distributed amongst the element types. These facts have important implications for faunal analyses.

Partial bone loss (even less than 25% of original bone length) can lead to the under-representation of the ends of major elements. In particular, it leads to the under-representation of fusion surfaces.

Chapter 8 describes typical patterns of damage for all 26 element types. Chapter 9 discusses the implications of bone loss for calculations of minimum numbers of elements, and for the use of epiphyseal fusion data in demographic analyses.

CHAPTER 8: PATTERNS OF ALTERATION TO THE 26 ELEMENT TYPES  
IN THE TOTAL SHEFFIELD SHEEP COLLECTION  
CAUSED BY CARNIVORE DAMAGE AND WEATHERING PROCESSES

INTRODUCTION

This chapter describes the damage and weathering observed on the bones in the total Sheffield sheep collection (N = 694). It defines the types of alteration observed, and describes typical patterns for each of the 26 element types.

All incidences of these types of alteration have been recorded for each of the element types, and these data are presented in tabular form for the medium- and large-sized element types (Tables 8:1 to 8:30). Many examples are presented in photographic plates for the ten major element types (i.e.: the seven longbones plus the mandible, scapula and pelvis).

Comparisons show that the damage inflicted by foxes on the Sheffield sheep bones is extremely similar to that observed by Haynes (1980, 1981, 1982, 1985) and Binford (1981) on bones of ungulates (especially deer, caribou and sheep) scavenged by wolves or dogs. The closeness of the similarities suggests that there are consistent patterns of damage that tend to be inflicted by scavenging canids on the bones of ungulates, and it is considered that similar patterns should be observable on sub-fossil (or fossil) bones of ungulates that have been scavenged by canids in the past, and which are subsequently recovered in archaeological (or geological) assemblages.

The damage to the Sheffield sheep bones appears to have been inflicted under three main sets of circumstances, i.e.: incidental consumption, deliberate consumption, and incidental damage.

Patterns of bone breakage are described and discussed in Chapter 9, and the correlations of damage to bones with potential underlying factors such as meat cover, marrow content and bone density are investigated in Chapter 10.

### QUESTIONS

The previous chapter discussed which element types are most likely to show signs of attack by carnivores, and how likely they are to suffer partial bone loss. This chapter studies the material in greater detail by investigating:

- 1) What forms of alteration are typical of carnivore damage?
- 2) What forms of alteration are typical of weathering processes?
- 3) Which areas of each element type are most likely to be altered, and in what ways?

QUESTION 1: WHAT FORMS OF ALTERATION ARE TYPICAL OF CARNIVORE DAMAGE?

## METHODS

Throughout this study, the bones have been examined by eye. The aim was to provide a set of readily identifiable types of damage that could be used by recorders of archaeological faunal assemblages. For this reason, microscopical details have not been examined. Some of the surface marks (types 2a and 2b, see below) can be quite subtle, and a X10 lens was used in a few cases to confirm diagnoses made by eye.

The author would like to stress the importance of using a good light source when examining bones by eye: all topographical anomalies, whether caused by carnivores, humans, pathology or butchering equipment show up more clearly in a strong directional light. General room cover by fluorescent lights is usually not satisfactory, particularly if the problem is compounded by soil staining or surface erosion of the bones.

## DEFINITIONS OF THE SIX TYPES OF DAMAGE RECORDED

The following types of alteration were defined by the author, and are based on her observations of the Sheffield sheep bones. Similar types were observed on the deer bones. Since the definitions were made, other authors have published their own definitions, and there is currently a working party aiming to

establish a standard set of definitions for international use. To aid comparisons with Binford's (1981) definitions, these have been referred to where appropriate.

Figure 8:1 illustrates my types in diagrammatic form, and photographic examples are referred to in the text.

1) **Punctures:** these are small holes in the bone, usually approximately 3mm in diameter, that often define a circle of crushed bone. They are thought to be caused by pressure from tooth cusps, particularly those of the canines and carnassials. Punctures are often found with corresponding damage on the opposite side of the bone, indicating where upper and lower teeth have pressed into the bone simultaneously during a biting or holding procedure. See Plate 8:1 for clear examples of punctures on the blade of an ilium (pelvis).

N.B. the diameter of the puncture should vary with the size of the tooth and with the depth of penetration into the bone. A large dog could be expected to create larger punctures than those produced by foxes.

Binford equivalent = punctures.

2) **Surface marks:** these are superficial marks, usually consisting of one of two types: (a) tooth grooves and (b) pitting marks. Both of these are thought to be caused by teeth being dragged over the surface of the bone; probably whilst a carnivore tries to detach some covering flesh or ligaments.

**2a) Tooth grooves:** these are short linear furrows in the surface of a bone (less than 1mm deep), probably caused by teeth 'grazing' the surface. They are often found running approximately perpendicular to the long axis of the bone on the shaft, or parallel to it at the epiphysis. Although they may curve slightly, they are very different to the wiggly lines characteristic of etching by rootlet acids (see Binford, 1981, Figs. 3.07 and 3.08 for examples of rootlet etching).

Binford equivalent=scoring.

**2b) Pitting:** again, these are superficial marks (probably less than 1mm deep). They consist of irregular deformities of a bone's surface, often giving a shallow pitted appearance. They occur at or near broken edges of bones, some of which are rounded as though the bone has been partially dissolved by saliva.

Binford equivalent=pitting.

The two forms of mouthing marks often occur together. Plate 8:2 shows an unfused distal radius with both types of mark present close to the fusion surface.

N.B. In the tables, these two types of shallow, surface damage are combined in the category: 'MOUTHED'.

**3) Flake scars:** these occur on some of the broken edges of bones that have been partially destroyed. Sometimes they are obviously the remains of a puncture mark, where the bone has broken away through

the point of pressure. Some flake scars of this nature can be seen on the ilium illustrated in Plate 8:1.

Binford equivalent = punctures.

Other flake scars are larger: approximately 5 to 8 mm in diameter. Although these are probably due to intense pressure at a localised point, the impact of a tooth cusp (or any other agent of pressure) cannot be seen. These marks are particularly common on areas of thin compact bone, such as the proximal humerus shaft. Plate 8:3 shows an example of this type of flake scar at the broken proximal end of a humerus.

Binford equivalent = chipping back.

4) **Shredding:** some thin bones show a reaction to pressure by cracking longitudinally in several places, giving a shredded appearance to the depressed and jagged edge of the bone. Usually, some adjacent bone has been destroyed. Shredding is often associated with puncture marks and is common on flat bones such as ribs, mandibles and scapula blades. Plate 8:4 shows the shredded symphysis of a mandible, which also exhibits mouthing marks and longitudinal split lines.

5) **Partial or total destruction of epiphyses and tuberosities:** some bones have lost the whole or part of an epiphysis or tuberosity. If only part of the epiphysis or tuberosity is missing, this is recorded as a 'BROKEN EDGE'. If it, or its fusion surface, is completely missing, this is recorded as: 'BROKEN OFF'. Plate 8:5 shows a proximal radius that has a broken edge. Only a part of the proximal

epiphysis remains, and much of the bone has been removed or destroyed. The surface of the bone has mouthing marks and there is a longitudinal crack running into the shaft from the broken edge. This edge also has some flake scars where punctures have broken through, leaving small, depressed arcs of bone. A broken edge is usually associated with at least one other type of damage, indicating that it has been caused by carnivore activities rather than by, for example, trampling.

6) **Spiral or longitudinal cracks:** some elements that have been partially or totally destroyed at one end have a spiral or a longitudinal fracture running into the shaft from the broken edge of the bone. See Plate 8:6 for an example in a proximal femur shaft, and Plate 8:5 for a less obvious example in a proximal radius.

QUESTION 2: WHAT FORMS OF ALTERATION ARE TYPICAL OF WEATHERING PROCESSES?

DEFINITIONS OF THE TWO TYPES OF WEATHERING EFFECTS RECORDED

1) **Exposure of trabecular bone:** in some places, on some elements, the external layer of compact bone is only a thin covering of underlying trabecular bone. This is commonly the case at muscle attachments such as the lateral vastus muscle on the femur, and at epiphyses such as the proximal humerus. Sometimes the underlying trabecular bone is exposed at these areas on the Sheffield sheep

bones. Often, such exposure appears to be independent of damage by scavengers, and it is probably caused by weathering processes such as etching by soil, vegetable and rain water acids; bacterial, fungal and algal activity; and wet/dry, warm/cold fluctuations in ambient conditions. The surrounding bone surface often appears to have degraded slightly, feeling powdery rather than smooth.

On some occasions, however, the exposure of trabecular bone is clearly associated with the presence of puncture marks, or with a partial destruction of the bone. In these cases it is impossible to judge whether the exposure is due purely to carnivore activity, or to the effects of weathering processes, or to a combination of the two.

Because of these cases of uncertain aetiology, the exposure of trabecular bone has been recorded as a separate variable. In the tables it has always been counted as an example of weathering, since this appears to be involved in the majority of instances, whether or not it was the primary cause. Plate 8:7 shows an example of exposed trabecular bone at the attachment of the lateral vastus muscle on the proximal femur. However, at least some of this exposure is due to carnivore activity: note the shallow punctures defining depressed areas of bone at the edges of the exposure.

2) **Split lines:** some bones show cracks in their shafts (running parallel to the long axis of the bone), that start and finish in intact bone and are not associated with any marks of carnivore activity. They are thought to be caused by weathering processes acting on the alignment of the apatite crystals and collagen fibres (Tappen, 1969; Tappen and Peske, 1970). Plate 8:8 shows an example of a

mandible with split lines. The lower border of the horizontal ramus may split off completely along such a line due either to weathering, or to a combination of weathering and pressure from carnivore teeth (as described by Hill (1976:335-6), and Binford (1981:63-64)). This fission might resemble deliberate butchery for the extraction of marrow, and archaeological examples would have to be examined for any evidence of damage by percussion or cleavage.

QUESTION 3: WHICH AREAS OF EACH ELEMENT TYPE ARE MOST LIKELY  
TO BE ALTERED, AND IN WHAT WAYS?

METHODS

For the long bones, a distinction is made between the proximal and distal epiphyses, and between proximal, mid and distal areas of the shaft. Similar details are provided for the mandible, scapula and pelvis.

For each element type, a table presents a breakdown of the areas affected by carnivore damage and/or weathering processes on each bone that has been altered. These data are then summarised to highlight the areas most commonly affected for each type of element. The Completeness Category of each bone is also recorded, as a measure of how severely it has been damaged, and its fusion state is also given (if known), so that any correlation between degree of damage and fusion state can be assessed. The effects of partial bone loss on the preservation of fusion data are discussed in Chapter 9. Completeness

Categories are presented in histogram form in Figure 7:4, which highlights the varying patterns exhibited by different element types.

In the second parts of the tables, the degrees of damage and weathering are compared between the carcass and non-carcass finds to test whether or not there are consistent differences in degrees of alteration between the two collections. These data are utilised in Chapter 4, with regard to weathering, and in Chapter 9 with regard to carnivore damage.

For each element type, a second table then gives details of the precise nature of alteration incurred in each area of the bones, using the eight types of damage and weathering effects described above. Summaries of incidences highlight the typical forms of damage in each area of each element (e.g. for the humerus, the proximal epiphysis is typically broken off, and has flake scars along the broken edge, whilst the distal epiphysis is usually intact or only superficially damaged by mouthing marks).

The tables, therefore, together with Figure 8:1 and the plates, document all forms of damage and weathering noted on the Sheffield sheep bones, and illustrate and highlight the commonest forms of alteration. These data should enable an analyst of archaeological faunal assemblages to identify the effects of some non-human agents of bone modification, prior to any consideration or discussion of human influences.

The following descriptions summarise the commonest forms of alteration to the 26 element types, and should be used in conjunction with the primary data in Tables 8:1 to 8:30, and the illustrations in Plates 8:1 to 8:26.

PATTERNS OF ALTERATION TO THE 26 ELEMENT TYPES  
IN THE TOTAL SHEFFIELD SHEEP COLLCECTION

Comparisons with observations made by Haynes  
(1980, 1981, 1982, 1985) and Binford (1981)

In the following summaries of patterns of alteration observed on the Sheffield sheep bones, reference is also made to observations made by Haynes and Binford. Both of these authors have studied the effects of canids on the bones of ungulates in North America. Haynes studied the bones of bison, white-tailed deer, wapiti and moose. Binford studied the bones of caribou and sheep, some of which (both species) had been altered by dogs rather than by wolves.

The patterns of damage described and illustrated by both authors are extremely similar to those observed in this study of sheep and deer bones, which suggests that patterns of damage caused by scavenging canids to ungulates of a variety of sizes have some consistent forms of patterning that may also have obtained in the past. If this is so, then these patterns of damage should be observable and recognisable in archaeological assemblages that have been scavenged by canids. In the case of British, European and North American assemblages, and possibly in Asian ones as well, the most common canid scavenger likely to have been active on archaeological sites is the dog.

There is one major difference between the observations of Haynes and Binford and those of myself, and this concerns the degree of damage inflicted by the larger carnivores (i.e.: wolves and large

dogs, compared to foxes). The studies of these two authors, and those of others concerning large carnivores (e.g.: Hill, 1975; Kruuk, 1972; Mills & Mills, 1979; Brain, 1981) have shown that some carnivores are strong enough to splinter longbones of sheep or larger ungulates, whereas no such splinters were recovered in the Sheffield or Grizedale collections. It has been observed elsewhere (Payne & Munson, 1985; Binford & Bertram, 1977; Binford, 1981) that dogs are capable of splintering adult goat, sheep or caribou bones, particularly if the bones have already been butchered (as in Brain (1969), Binford & Bertram, (1977) and Binford (1981)). Chapter 9 discusses the data published by these authors in more detail, with particular regard to the observations made in the Sheffield and Grizedale studies, and to the implications for archaeological assemblages.

It should be noted, therefore, that the forms and patterns of damage recorded here for the Sheffield sheep bones scavenged by foxes may well be less well marked than would be the case if the carcasses had been scavenged by larger canids, such as domestic dogs. Since the patterns of damage, even in this study, are usually very obvious, there are good grounds for considering that similar, but more intensive, damage should be clearly identifiable on archaeological material, even if it has suffered slight erosion subsequent to deposition.

Observations of the Sheffield sheep bones

MANDIBLE: N=21, 51% attacked. See Tables 8:1 & 8:2.

The main areas of damage are the angle of the jaw and the symphysis, and the mandible is likely to be reduced to 75 - 99% of its original length. Plate 8:9 shows a range of damage to the angle and symphysis areas of mandibles, and Plate 8:4 shows typical damage to a symphysis in close-up. The angle usually has a broken edge, and flake scars and punctures are quite common. The symphysis tends to be broken off and shredded, and to have lost the incisors.

The main part of the horizontal ramus, however, tends to remain intact with no damage to the cheek tooth row, although split lines due to weathering processes are quite common and may facilitate the fission of the lower border of the ramus when attacked by carnivores (as described by Haynes (1981:154) and Binford (1981:63-64 and Fig. 3.28). Plate 8:8 illustrates split lines in a mandible in the Sheffield sheep collection.

Haynes (1982) and Binford (1981) describe very similar patterns of attack to mandibles, with damage concentrated in the snout (symphysis) and masseter muscle (angle) areas.

SCAPULA: N=20, 95% attacked. See Tables 8:3 & 8:4.

The proximal articulation and tuberosity are likely to have irregularly broken edges (sometimes with punctures present), but the

neck width usually remains intact.

The spine is very likely to be broken and may well have a shredded edge and/or punctures.

The distal border of the blade is almost always damaged by breakage and punctures, and is often shredded and cracked as well. Plate 8:10 shows the typical patterns of damage to scapulae, with irregular edges to the distal borders of the blades. Plate 8:11 shows a less common form of damage, in which the head of the bone is removed. The scapula on the far right is an unusually well-weathered example, which is shown in close-up in Plate 4:11.

Binford (1981) comments that the three most severely altered areas on scapulae are the acromion (tip of the spine), the proximal tubercle and the vertebral borders of the blade. His Fig. 3.40 shows crenellated edges to the breaks, very similar to those illustrated here in Plate 8:10.

Haynes also describes splintered, punctured and broken edges to the blade, but comments that the degree of damage does not appear to correlate with the size of the scapula. He suggests that this is because the meat is easy to detach from the blade, which need not be damaged unless the scavenger deliberately consumes it.

HUMERUS: N=30, 97% attacked. See Tables 8:5 & 8:6.

The proximal epiphysis and tuberosities often suffer very heavy damage and are usually missing completely. Plate 8:12 shows a range of de-capitated humeri.

The proximal shaft tends to be broken off with a scalloped

edge and wide flake scars. Plate 8:13 and Figure 8:1 show typical examples, and Plate 8:3 shows a close-up of a flake scar.

All areas of the shaft are likely to be mouthed (tooth grooves are particularly common), but punctures are rare on humeri.

Humeri with unfused distal epiphyses are likely to be reduced to shaft tubes with no fusion surfaces remaining (see Chapter 9). Fused distal epiphyses, however, are unlikely to show any serious damage. See Plate 8:12 for illustrations of a range of damaged humeri.

Humeri are likely to be severely reduced in completeness: only about one third of the Sheffield sheep humeri retain their complete length.

None of the Sheffield sheep humeri show any split lines.

Both Haynes (1980, 1982) and Binford (1981) emphasise the early destruction of the proximal humerus, often accompanied by gouging of the cancellous bone (when removal is only partial). Binford shows some de-capitated humeri in his Fig. 3.42 that are extremely similar to those shown here in Plates 8:12 and 8:13, with flake scars and pitting at the broken edges.

RADIUS: N=29, 59% attacked. See Tables 8:7 & 8:8.

Typically, the radius shows little serious damage. Plate 8:2 shows mouthing marks on the unfused distal end of a radius.

The main area of damage is the distal epiphysis which is occasionally punctured or broken off. Plate 8:14 shows the most severely damaged bones, all of which have lost their distal epiphyses or fusion surfaces. Two of them have also lost their proximal ends and

have been reduced to tubes. Plate 8:5 shows a close-up of a partially destroyed proximal radius.

Split lines are quite common in the shafts of radii.

Haynes (1980, 1982) comments that radii may hardly be touched, even on heavily scavenged carcasses, despite the removal of the covering flesh from the proximal half of the bone. Binford (1981) shows a more severe pattern of damage, in which the distal end has often been broken off, but the proximal end still tends to be relatively intact.

ULNA: N=22, 95% attacked. See Tables 8:9 & 8:10.

Nearly all of the ulnae have suffered damage to the olecranon process which is usually broken off and punctured. Plate 8:15 shows a range of damage to ulnae, most of which are still fused to intact, or almost intact, radii. Plate 8:16 shows a close-up of a proximal ulna, showing how the olecranon process has been destroyed. The remaining bone is covered with mouthing marks. Another example is illustrated in Figure 8:1.

There is little damage to the articulation or the shaft of the ulna.

Split lines are rare.

Both Haynes (1980, 1982) and Binford (1981) describe the frequent removal of the olecranon as the typical form of damage for the ulna (see Binford, 1981: Fig. 3.45).

METACARPAL: N=19, 32% attacked. See Tables 8:11 & 8:12.

The metacarpal resembles the radius in having, typically, very little and very light damage.

The most distinctive form of damage is the presence of puncture marks (which may occur in any of the areas), but tooth grooves are more common. An example with tooth grooves is illustrated in Figure 8:1.

Trabecular bone may be exposed particularly around the distal fusion surface. Plates 8:16 and 8:17 show the most severely damaged metacarpi and metatarsi in dorsal and ventral views.

None of the Sheffield sheep metacarpi show any split lines.

Binford (1981) comments that, when eating, the dogs tended to work their ways up from the toes to the metapodials, which suffered only slightly from gnawing. He also notes that damage tends to be more severe at den sites than at kill sites. Haynes (1980) notes that metapodials are seldom gnawed.

PELVIS: N=30, 97% attacked. See Tables 8:13 & 8:14.

The ilium and the ischium suffer frequent and heavy damage, both showing jagged broken edges with many punctures. Sometimes they also have flake scars or shredded edges. Plates 8:1 and 8:18 show punctures and flake scars (i.e.: remains of punctures) on the blades of an ilium and an ischium, respectively. Figure 8:1 illustrates typical light damage to an ischium blade. The pubis is affected in similar ways, but less severely.

The acetabulum is very rarely damaged at all.

Most of the pelves have been reduced to 50 - 99% of their original lengths. Plate 8:19 shows a ventral view of pelves with light damage, and the same bones are shown in Plate 8:20 from a lateral view. The edges of the blades are partially destroyed. Plate 8:21 shows more severe damage. On these bones, the whole of the ilium has usually been removed, and the obturator foramen tends to be broken into by the removal of the pubis.

None of the Sheffield sheep pelves show any split lines.

Haynes (1980, 1982) and Binford (1981) both describe a very similar pattern of damage, i.e.: the canids (wolves and dogs) work their ways in towards the acetabulum, destroying the edges and tuberosities of the ilium, ischium and pubis as they eat. Binford gives illustrations of examples that are very similar to those given here (for instance, compare Binford's Figs. 3.34 and 3.35 with my Plates 8:19 and 8:20, and Binford's Fig. 3.39 with my Plate 8:21).

FEMUR: N=25, 88% attacked. See Tables 8:15 & 8:16.

The proximal tuberosity is usually broken and has punctures. The proximal epiphysis has similar, but less frequent, damage. Plate 8:22 shows relatively lightly damaged femora that retain their proximal epiphyses and tuberosities, which have been affected only by occasional punctures. However, some of these bones have exposed trabecular bone on their distal epiphyses, which is probably due to a combination of carnivore and weathering effects.

The proximal shaft may be heavily damaged, with loss of

bone, punctures and mouthing marks. Sometimes a spiral or longitudinal fracture emanates from the broken edge. Figure 8:1 illustrates a spiral fracture in a proximal femur shaft.

Four bones have an area that is crushed where the lateral vastus muscle inserts. Plate 8:7 shows a close-up of one of them, where it is clear that carnivore damage has been involved in the exposure of trabecular bone in this area. See the General Comments section below for a discussion of this pattern of alteration.

The distal shaft is often broken and tends to have mouthing marks. Plate 8:23 shows a range of moderately or severely damaged femora. The proximal trochanter has been removed and the fusion line of the proximal epiphysis has been attacked on two of the bones. The other five have all been reduced to tubes. Plate 8:6 shows a close-up of the spiral fracture at the proximal end of one of these tubes.

The distal epiphysis is often broken and tends to have punctures and areas of exposed trabecular bone.

The femur is the element most commonly reduced to a shaft tube (28%) in the Sheffield sheep collection (see Chapter 9).

Split lines are very rare.

Both Haynes (1980) and Binford (1981) emphasise the early nature of attack to the greater trochanter, and the subsequent attack to the distal condyles, which may have gouges into the cancellous tissue, especially along the medial ridge of the trochlea (compare Binford's Fig. 3.47 with my Plate 8:22).

TIBIA: N=40, 95% attacked. See Tables 8:17 & 8:18.

The proximal epiphysis and tuberosity are often damaged, but fused proximal epiphyses are usually only partially destroyed. Plate 8:24 shows a typical range of lightly damaged tibiae, and Plate 8:25 shows a close-up of a partially destroyed fused proximal epiphysis.

The proximal shaft often has a broken edge with mouthing marks and punctures, and sometimes also has flake scars or a shredded edge. Plate 8:26 shows a range of more seriously damaged tibiae, most of which have unfused distal epiphyses. Three other tibiae in the photograph have been reduced to tubes and may have had unfused distal epiphyses. The distal shaft is rarely seriously damaged. Fused distal epiphyses of tibiae are very rarely damaged.

Several bones show split lines.

Binford (1981) comments that the first area of the tibia to be damaged is the proximal crest (as in the Sheffield sheep collection, see Plates 8:24 and 8:25, and Figure 8:1). Haynes (1980) describes more severe damage, in which the proximal ends have been removed completely (as in Plate 8:26), although the distal ends have not even been cleaned of flesh.

METATARSAL: N=20, 50% attacked. See Tables 8:19 & 8:20.

Metatarsi show very similar patterns of damage to those shown by the metacarpi, except that split lines are common in the metatarsi. That is, damage is not very common, and usually consists only of superficial mouthing marks.

If damaged at all, the distal shaft and epiphysis tend to be punctured.

Trabecular bone is sometimes exposed around the distal fusion line. Plates 8:16 and 8:17 show the most severely damaged examples.

Haynes (1985) comments that the distal metapodials are only gnawed in extreme cases of scavenging. He also comments (1980) that metapodials sometimes split longitudinally into anterior and posterior (sic) halves due to weathering.

HYOID: N=1, 0% attacked.

There is only one hyoid in the total Sheffield sheep collection, and this bone has not been altered.

The author considers that the rarity of hyoids in the collection may be due to the total consumption of the bone in conjunction with the tongue, which was consumed early on in the sequence of scavenging (as also noted by Hill, 1975; Haynes, 1981 and Binford, 1981) (see Chapter 9 for a discussion of the total consumption of bones by canids). Haynes (1985) notes that, at the wolf homesites that he studied, all elements of bison were present except hyoids, caudal vertebrae and sternebrae. Binford (1981) does not describe damage to the hyoid, nor does he give frequencies.

ASTRAGALUS: N=13, 8% attacked.

Only one out of the thirteen astragali has been damaged, and this is covered in superficial mouthing marks.

When it is still articulated, the astragalus is protected by surrounding elements (such as the distal tibia and the calcaneum). It was noted in this study (and by Haynes, 1981) that lower legs tended to stay intact, with skin covering from the lower tibia, radius, or metapodial, down to the hooves.

CALCANEUM: N=7, 57% attacked.

The tuber calcis tends to have some exposed trabecular bone caused by carnivore damage, or punctures. The rest of the bone is undamaged.

Binford (1981:76) comments that the commonest form of damage to any of the tarsals is the partial destruction of the tuber calcis.

NAVICULAR-CUBOID: N=10, 0% attacked.

None of the ten navicular-cuboids have been altered.

Haynes (1981) and Binford (1981) both note that tarsals are seldom damaged.

PATELLA: N=4, 100% attacked.

All four of the (rare) patellae have exposed trabecular bone thought to be caused by carnivore damage, and three of them also have punctures.

Binford (1981:74) comments that joints that bend tend to be the foci for damage to bones, and this may explain the paucity of patellae and their high rate of damage. Haynes (1981), Binford (1981) and I (this study) have all noticed the early attack to the knee joint, causing damage to the distal femur and the proximal tibia (see Plate 4:3). The typical damage to the distal femur, noted both in this study and by Binford (1981), is to the ridges against which the patella articulates. It is almost impossible for damage to this area to occur without the removal or destruction of the overlying patella. Payne & Munson (1985) have proven that dogs can (and do) consume the patellae of goats. Of the four goat patellae that they fed to the dogs (as parts of larger joints of meat), only three were recovered: two from faeces and one from vomit.

It is clear, therefore, that the patella is not only a focus for attack, but that it is also small enough to be consumed totally by dogs. It may even be small enough to be consumed by foxes, which would explain its rare recovery in the Sheffield sheep carcass collection, and its total absence from the non-carcass collection.

PROXIMAL PHALANGE: N=36, 28% attacked. See Tables 8:21 and 8:22.

The commonest form of damage is punctures, and these are

found most commonly on or near the distal articulation.

It is possible that some phalanges were eaten. Haynes (1981:97, and 1985) notes that deer phalanges may be redeposited in wolf scats several miles from the killsite. Payne & Munson (1985) also note that goat phalanges tend to be eaten by dogs, and that some of them may be recoverable from faeces, often in a partially digested and eroded state (see Payne & Munson, 1985: Plate 3).

MEDIAL PHALANGE: N=17, 6% attacked.

Only one out of the seventeen bones has been damaged, and this simply has a few punctures.

DISTAL PHALANGE: N=22, 5% attacked.

Only one out of the twenty-two bones has been damaged, and this simply has a few punctures.

ATLAS: N=9, 78% attacked.

Most of the atlases have been damaged. The commonest form of damage is punctures, but some bones have suffered partial loss of their wings, leaving jagged edges and exposed trabecular bone.

A similar form of damage is illustrated as being typical by Binford (1981: Fig. 3.30).

AXIS: N=7, 43% attacked.

Less than half of the axes have been damaged, usually by punctures. Two of the seven bones have each lost their dorsal spine and a transverse process, leaving jagged, crushed edges.

CERVICAL VERTEBRAE: N=43, 37% attacked. See Tables 8:23 & 8:24.

Less than half of the cervical vertebrae have been damaged, and all of them retain both of their epiphyses.

The transverse processes tend to be punctured or broken off, and trabecular bone is exposed quite often, either by carnivore damage or by weathering processes.

Binford (1981) describes similar damage to processes, which appears to have been relatively more common in his collection than it is in the Sheffield sheep collection.

THORACIC VERTEBRAE: N=79, 46% attacked. See Table 8:25 & 8:26.

Nearly half of the thoracic vertebrae have been damaged, and all of these have lost part of their dorsal spine. Punctures here are common and quite a lot of the broken edges are shredded.

In contrast, the body of the vertebra is almost always intact, and none of the thoracic vertebrae has lost any epiphyses or fusion surfaces.

Binford describes very similar damage to thoracic vertebrae (see

Binford, 1981: Fig. 3.32).

LUMBAR VERTEBRAE: N=52, 79% attacked. See Tables 8:27 & 8:28.

Most of the lumbar vertebrae have been damaged, nearly always in the area of the transverse spines. These tend to be broken off and punctured.

The dorsal spine is quite often also broken off, and is susceptible to weathering which exposes trabecular bone along its tip.

Like the atlas, axis, cervical vertebrae and thoracic vertebrae, the lumbar vertebrae all retain the full length of the body between epiphyses (or fusion surfaces).

Again, Binford (1981: Fig. 3.31) shows a very similar pattern of damage. Haynes (1982) also found very similar patterns of damage to vertebrae, with spinous and lateral processes having the most damage (i.e.: breakage and punctures), with isolated punctures on the bodies of the vertebrae.

SACRUM: N=7, 100% attacked.

All of the sacra have suffered damage, often of a severe nature. The wings are usually punctured, and half of them have been partially broken off.

The distal part of the bone is also often broken off, leaving flake scars, punctures and exposed trabecular bone, but all seven retain their proximal fusion surface.

Binford (1981:66) comments that the dorsal spines of the sacra are prime targets for chewing by dogs. This study finds that, although this is also the case for the Sheffield sheep bones, the damage tends to be more extensive.

RIBS: N=122, 66% attacked. See Tables 8:29 and 8:30.

Most of the ribs have been damaged, and all of these have lost a distal portion of the shaft. The broken end is often shredded (see Figure 8:1). In contrast, very few of the ribs have lost the proximal head of the bone. Several are reduced to less than one quarter of their original length, and the broken edges are usually associated with flake scars and/or punctures.

Haynes (1981:137) found that some deer ribs were consumed entirely by wolves, and that their articular ends could sometimes be recovered from wolf scats. Binford (1981:66) comments that the ribs are usually attacked from the distal end, as in the Sheffield study (see Binford, 1981: Fig. 3.33). He also describes how carnivores pull ribs off the vertebrae, which sometimes results in the bones breaking 'an inch or two' (i.e.: 2.5 - 5 centimetres) from their proximal ends. He points out that this breaking point coincides with the point of maximum curvature.

Davies (1984:22-23) found that ribs tended to break at this point when subjected to trampling, and comments that this area is where the structure of the rib changes from a curved, roughly square in cross-section bone (proximal end) to a thin, flat and roughly straight bone (distal two-thirds).

Breakage in this area, therefore, should not be assumed to be due

to carnivore activity unless there are other signs of their complicity, such as punctures or shredded edges. It appears that the bone has a natural area of weakness at this point, which may be exploited by a variety of destructive agencies.

STERNEBRAE: N=9, 78% attacked.

The rare examples of sternebrae recovered in the Sheffield sheep collection tended to be punctured.

Haynes (1981:154) notes that sternebrae are usually splintered and consumed. In a later study (Haynes, 1985) notes that sternal and caudal elements were never found at killsites. Since the sternal ends of ribs in this study, and in Haynes' (1981, 1985) and Binford's (1981) all tend to show damage compatible with partial consumption, the author considers it likely that sternebrae also tended to be consumed by the foxes in the Sheffield study (see Chapter 9).

#### GENERAL COMMENTS

Typically, the damage incurred by the foxes begins at the epiphyses or outer edges of the bones. The animals tend to work their way in towards the centre of an element, removing or destroying the bone as they procede. All of the bones recovered retained their full circumferences for at least part of their length, i.e.: no bone splinters were recovered. See Chapter 9 for a discussion of breakage patterns.

There are no examples of any bones that have been broken across

their midshafts by trampling: all of the breaks observed are accompanied by definite signs of carnivore damage, and tend to occur close to an epiphysis rather than in midshaft. Chapter 9 discusses the possible effects of trampling on bone breakage patterns.

The damage to the Sheffield sheep bones appears to have been incurred under three main sets of circumstances:

(1) **During the consumption of flesh that covers thin areas of bone.** The ends or edges of flat bones appear to be consumed together with their covering flesh. Their edges are partially or totally broken off, and have areas of crushed or shredded bone, often accompanied by punctures. Elements exhibiting such damage include: ribs, sternbrae, the mandible, scapula and pelvis, and the dorsal spine of thoracic vertebrae and the lateral spines of lumbar vertebrae. It is considered that this form of damage may have contributed to the very low frequency of the hyoid in this collection. Haynes (1981) notes that sternbrae and caudal vertebrae were never found at killsites, and that patellae were also extremely rare. He considers that these elements tend to be consumed.

(2) **During the deliberate consumption of trabecular bone.** Some elements or element parts are composed of trabecular bone containing marrow. Often, these areas are epiphyses of longbones, and their removal permits access to larger volumes of marrow contained in the shafts of the bones. The total removal of these areas by foxes is considered by the author to be, at least in part, deliberate rather than incidental, and to be linked to the attractiveness of the marrow. Although these areas are

often covered by relatively large amounts of flesh, they may be too large to be removed in conjunction with the meat unless additional pressure is deliberately exerted by the fox.

Typically, the whole epiphysis is removed (or destroyed), leaving the end of the shaft broken off. The broken edge usually has flake scars and may be pitted by mouthing marks where pressure has been applied repeatedly.

Elements exhibiting this form of damage tend to be the long bones (especially the proximal humerus, distal femur and proximal tibia), and the scapula and pelvis.

**(3) Incidental damage incurred during the removal of covering flesh, tendons or ligaments.** Many of the elements bear tooth grooves where the foxes' teeth have scored into the surface of the bone. These marks do not alter the chances of the fragment's survival (i.e.: they are not linked with any significant bone loss), and they may be the only indication of any association with carnivores. Kent (1981), Binford (1981) and Haynes (1985) have all observed that scavenging dogs sometimes remove flesh from bones without leaving any marks on the bones concerned. These superficial grooves are sometimes the only marks caused by foxes that were observed on radii in the Sheffield sheep collection.

Sometimes, however, the incidental damage to bones can be more serious. Typically, this form of damage is located specifically at attachments of tendons or ligaments, rather than beneath a general cover of meat. Haynes (1980) also notes that the degree of damage inflicted by carnivores is partly related to the ease with which meat can be removed from the bone.

Two element types that are attacked more often than expected from

their meat values in the Sheffield sheep collection (see Chapter 7 and Table 7:4) are the ulna and the calcaneum. Both of these elements have major tendon insertions that link to the large muscle masses of the upper limbs. It is these insertions rather than any other areas of these elements that are attacked (i.e.: the olecranon process of the ulna, and the tuber calcis of the calcaneum). These attachments are both very strong, and require considerable effort to detach, leading to damage to the underlying bone. Typically, part or all of the olecranon is removed, and the edge has flake scars and associated punctures. The less flat epiphysis of the calcaneum is more difficult to remove totally, but also tends to have a broken edge and punctures.

The patella is similar in structure to the tuber calcis and also has the insertions of major tendons. Very few patellae were found, and all four showed clear evidence of attack by carnivores (i.e.: partial destruction and/or punctures). The author considers that many of the patellae may have been consumed by the foxes. Binford notes (1981:74) that carpals (which have a very similar structure to the patella, but which tend to be even smaller) are either completely consumed, or are not damaged at all, suggesting that even minor damage can destroy these elements.

Some tendons attach to the surface of an element rather than to an edge or epiphysis. One such tendon is that of the lateral vastus muscle, which inserts into the ventral surface of the proximal femur shaft (see Bradley, 1959, Figure 54). Four of the 22 femora in the Sheffield sheep collection exhibit damage in this area, thought to be due to the detachment of this tendon by foxes. The damage leaves an area of exposed trabecular bone, with depressions caused by shallow punctures around the edge of the exposed area. Plate 8:7 illustrates an example.

Shipman et al. (1981) recorded a similar location for damage on

fossil bones of giant gelada baboons at the Acheulian site of Olorgesailie. A debate ensued concerning the agent of destruction (Binford & Todd, 1982; Shipman et al., 1982) but considerations of carnivore attack were restricted by the assumption that carnivores always place the entire circumference of a bone within their mouths, which in turn presumes that the carnivore concerned has a sufficiently large gape to do this. In contrast to this assumption, the author has often observed domestic dogs detaching flesh from bones in a different manner. Typically, the dog holds the bone more or less upright between its forepaws, and chews the meat or tendon beside the bone, gradually working its way towards the point of insertion. At this point, the shearing action of the carnassials is used to detach the tendon at its insertion. The pressure from the carnassials may push into the surface of the bone, leaving a small area of exposed trabecular bone with depressed edges, exactly like those seen on the Sheffield sheep femora. This method of detachment may explain the damage observed by Shipman et al. (1981). A similar observation of 'chipping back' is described by Binford (1981:51) who also describes butchery marks made by Nunamiut Eskimos in exactly the same location (Binford, 1981:Fig. 4.37, marks Fp-7).

Other element parts that exhibit similar incidental damage considered to be due to the detachment of tendons and ligaments include the distal and proximal epiphyses of the femur, the proximal humerus, and the tuberosities of the scapula, humerus, femur and tibia. These are all areas of trabecular bone and tend to be partially destroyed, often exhibiting punctures and areas of crushing.

## SUMMARY

This chapter has defined six types of damage thought to have been inflicted by foxes on the Sheffield sheep bones, i.e.:

- (1) punctures
- (2a) tooth grooves (mouthing marks)
- (2b) pitting marks (mouthing marks)
- (3) flake scars
- (4) shredding
- (5) partial or total destruction, and
- (6) spiral or longitudinal cracking.

It also described two types of alteration caused by weathering processes, i.e.:

- (1) exposed trabecular bone, and
- (2) split lines.

The exposure of trabecular bone sometimes appears to be initiated by, if not entirely caused by, carnivore activity rather than by weathering. However, weathering appears to be involved in the majority of cases, even if it was not the primary cause of the exposure.

The patterns of damage for each of the 26 element types have been summarised in the text, and the detailed data have been presented in tabular and photographic form. The patterns observed in this study are very similar to those described by Haynes (1980, 1981, 1982, 1985) and Binford (1981) for the bones of deer, caribou and sheep that had been scavenged by wolves or dogs. The closeness of the similarities suggests that there are typical patterns of damage caused by canids to bones of ungulates, which should be observable on bones that have been scavenged in the past, and which are recovered in archaeological assemblages.

**CHAPTER 9: CHARACTERISTICS OF BONE BREAKAGE AND BONE LOSS  
OBSERVED IN THE SHEFFIELD SHEEP TOTAL COLLECTION**

INTRODUCTION

This chapter continues with the analysis of patterns of damage to sheep bones. Chapter 7 considered the rates of damage and of bone loss observed in different collections and for different element types, and Chapter 8 described the types of alteration observed in the Sheffield sheep collection. This chapter investigates the patterns of bone breakage and bone loss exhibited by different element types under different degrees of intensity of damage.

It begins by considering the potential relevance of trampling and weathering processes to patterns of bone breakage and concludes that, in the Sheffield study, these factors are of little or no importance with regard to the observed patterns. However, in other, specified circumstances, these factors may affect breakage patterns, and they may have influenced some archaeological assemblages.

The chapter then investigates: (1) the intensity of damage, and (2) the fusion states of epiphyses, and finds that both of these factors have influenced the nature and degree of bone loss in the Sheffield sheep study.

The study shows that (1a): the more intense the level of damage, the more epiphyses will be lost or destroyed, and (1b): as the intensity of damage varies, so does the rank order of the relative frequencies of epiphyseal ends. It also shows that (1c): the degree of damage observed in the Sheffield study of fox scavenging is probably

of a low level compared to that which dogs are capable of inflicting on the bones of unimproved breeds of sheep. The range of damage observed may be more comparable to that inflicted by large dogs on the bones of cattle found on archaeological sites.

With regard to fusion data, the study concludes that (2a): unfused epiphyses are more likely to be destroyed than are fused epiphyses, and (2b): the most commonly surviving (or recovered) part of a longbone is the midshaft area, which will, therefore, give more reliable information concerning element frequencies and sizes (which may, in turn, reflect age groups), than will the more biased sample of epiphyses.

#### QUESTIONS

This chapter investigates the patterns of bone loss and bone fracturing observed in the Sheffield sheep collection, sometimes considering the total collection as a whole, sometimes sub-dividing it into the carcass and non-carcass collections. Four questions are considered, and they concern the causes and effects of bone loss and breakage:

- (1) Has trampling affected the breakage patterns?
- (2) Have split lines (caused by weathering) affected the breakage patterns?
- (3) How does the level of intensity of damage affect the relative frequencies of element parts?
- (4) Are unfused epiphyses more likely to be destroyed than fused epiphyses?

QUESTION 1: HAS TRAMPLING AFFECTED THE BREAKAGE PATTERNS?

Apart from carnivore damage, the main potential cause of bone breakage in the Sheffield sheep collection is trampling by animals. However, this is unlikely to have affected the longbone elements for the following reasons:

(1) In a comparable study of sheep bones, in which there was no scavenging by terrestrial carnivores (i.e. mammals), but the bones were available for trampling, no bone breakage was observed: Stallibrass (1984) showed that sheep longbones, recorded on the Scottish island of St. Kilda by Dr. P. Armitage and Prof. P. Jewell, showed no breakage despite their presence in areas that are heavily utilised by live sheep (Armitage, pers. comm.). St. Kilda has no terrestrial carnivores of fox or larger size, and other potential scavengers such as gulls and large raptors do not appear to have damaged the bones in any way (see Hewson, 1981, for a similar observation).

(2) The substrate on the Sheffield moors was usually soft throughout the three year study, and any trampling of bones is likely to have pushed them into the vegetation or earth, rather than to have broken them.

Gifford-Gonzalez et al. (1985) studied the effects of trampling of items into a soft substrate. Although they record edge damage incurred to lithics, they do not mention any damage to the bones.

(3) Even on a hard substrate, intact longbones are unlikely to break when trampled (by humans). Davies (1984) trampled intact sheep bones, (some of which had been boiled for thirty minutes to remove some of the grease), on a hard surface of tarmac. None of the longbones broke, although the ribs had a characteristic breakage pattern.

In the Sheffield sheep collection, although many of the ribs have suffered some bone loss, nearly all of them retain the head of the bone (i.e.: 119 out of 122, 98%). That is: each fragment represents an individual bone, rather than one portion of a broken rib.

### Conclusions

The results of these three studies, therefore, all suggest that trampling has had little or no effect on the breakage of the Sheffield sheep bones. However, on archaeological sites, various other factors may make trampling a more influential agent of breakage. Such factors include breakage caused by butchery prior to discard, which may interact with the presence of a hard substrate, (such as might occur in and around dwellings or on trackways). The degree of degreasing or weathering of bones may also affect their susceptibility to trampling, since chemical changes can reduce their mechanical strength (Hare, 1980; Behrensmeyer, 1975, 1978; Isaac, 1967).

QUESTION 2: HAVE SPLIT LINES (CAUSED BY WEATHERING) AFFECTED  
THE BREAKAGE PATTERNS?

Results

Table 9:1 presents the frequencies of split lines for the ten major element types in the total Sheffield sheep collection. It is clear that split lines are far more frequent for some element types than for others: some element types have no examples of split lines (i.e.: the scapula, humerus, pelvis and metacarpal), whilst the mandible has them in 29% of the cases. There is a trend for the split lines to be more common in the denser longbones, i.e.: those with thicker cortical bone and narrower marrow cavities (e.g.: the metatarsal, 20%; radius, 17% and tibia, 15%), than in those with thinner, more cylindrical cortical bone and larger marrow cavities (e.g.: the humerus, 0% and the femur, 4%), although the metacarpal (0%) contradicts the trend.

Discussion

Tappen (1969) and Tappen and Peske (1970) have shown that bones crack along lines of weakness in their structure, due to weathering processes of wet/dry or hot/cold environmental fluctuations. It is probable that, if the Sheffield sheep bones had weathered for a longer period of time, some of them would have split apart along these lines (see Behrensmeyer, 1978 for examples).

It is also probable that scavenging interacts with this

pattern of cracking in two ways:

(1) A bone may be cracked along most of the length of its shaft, but require some form of pressure (such as might be applied by the teeth of a carnivore, butchery tools, or trampling) in order to force it to split apart.

(2) Split lines occur along the shafts of longbones, but do not penetrate the epiphyseal areas (Tappen, 1969; personal observations of the Sheffield sheep bones). This is because the structure of the trabecula bone is not aligned in the same way as that of the cortical bone (Tappen, 1969).

The removal of the epiphyseal ends by consumption (or butchery), therefore, would permit the fission of the disparate parts of the shaft, which would otherwise be held together by the trabecula ends of the bone.

In the Sheffield sheep collection, there are no examples of bones that have actually split apart, either by weathering processes on their own, or by weathering process in conjunction with the action of carnivores and/or trampling. However, this may be due to the fact that bones tended to become buried (or consumed, or removed) before they reached any major stage of weathering (see Chapter 4 for a discussion of weathering and burial in the carcass collection).

Implications for archaeological sites

On archaeological sites, however, split lines might be more important with regard to breakage under a variety of circumstances such as:

- (1) a longer period of exposure to weathering processes prior to burial,
- (2) a speeded up process of weathering due to cooking (which intensifies wet/dry, hot/cold fluctuations), and
- (3) the routine removal of epiphyseal ends by butchery and/or carnivore scavenging.

Longitudinally split fragments should be studied for evidence of carnivore and butchery marks in order to identify the main agent of breakage.

Conclusions

This study suggests that some element types (e.g.: the radius, tibia and metatarsal) are likely to suffer more from fragmentation due to weathering cracks than are other elements (such as the humerus or femur). This factor may lead to a bias in the counts of fragment numbers for the different element types.

QUESTION 3: HOW DOES THE LEVEL OF INTENSITY OF DAMAGE  
AFFECT THE RELATIVE FREQUENCIES OF ELEMENT PARTS?

THE OBSERVED SEQUENCE OF BONE DESTRUCTION

The descriptions of damage observed to the 26 element types in the Sheffield sheep collection, given in Chapter 8, show that there is a considerable range of damage inflicted by the foxes on the sheep bones. Haynes (1980) also observes that the degree of damage may vary considerably, but notes that the sequence of damage is predictable.

A typical sequence of damage to a longbone observed in the Sheffield study is as follows:

- (1) flesh removal: no damage to the bone
- (2) superficial damage, e.g.: tooth grooves, occasional punctures
- (3) light damage, e.g.: broken edge, punctures, pitting
- (4) heavy damage, e.g.: end broken off, flake scars, pitting.

A fifth stage, observed by Payne & Munson (1985), but not in this study, would be:

- (5) extreme damage: splintering.

The sixth, and final stage, possibly represented in this study by the paucity of sternebrae, patellae, and hyoids is:

- (6) total consumption.

## THE ABILITY OF CANIDS TO SPLINTER BONES OF UNGULATES

The relative sizes of canid and ungulate species

Binford (1981) describes the ability of large dogs to splinter bones of caribou and sheep, and Payne & Munson (1985) show that large dogs are very able to crush and splinter modern, adult goat bones (see Payne & Munson, 1985: Plate 1 for photographic evidence).

The following list presents approximate or average weights for various types of canid and ungulate species:

(all weights in kilogrammes)

SPECIES	KG	(notes)	REFERENCE
<u>caribou</u>	<u>110</u>	<u>(liveweight)</u>	<u>(Binford &amp; Bertram, 1978:17)</u>
<u>caribou</u>	<u>101</u>		<u>(Binford, 1981:213)</u>
<u>sheep</u>	<u>45</u>	<u>(liveweight)</u>	<u>(Binford &amp; Bertram, 1978:17)</u>
<u>hill sheep</u>	<u>50</u>	<u>(liveweight)</u>	<u>(Alderson, 1976)</u>
<u>Soay sheep</u>	<u>26</u>	<u>(female)</u>	<u>(Alderson, 1976)</u>
<u>Soay sheep</u>	<u>40</u>	<u>(male)</u>	<u>(Alderson, 1976)</u>
<u>goat</u>	<u>50-75</u>		<u>(Alderson, 1976)</u>
<u>Dexter cow</u>	<u>300</u>		<u>(Alderson, 1976)</u>
<u>British White cow</u>	<u>450</u>		<u>(Alderson, 1976)</u>
<u>eskimos' dog</u>	<u>25-32</u>		<u>(Binford, 1981:37)</u>
<u>coonhound</u>	<u>25-30</u>		<u>(Payne &amp; Munson, 1985:32)</u>
<u>mastiff dog</u>	<u>29</u>		<u>(Hubbard, 1961)</u>
<u>beagle dog</u>	<u>14-18</u>		<u>(Hubbard, 1961)</u>
<u>fox</u>	<u>6-7</u>		<u>(Lloyd, 1980)</u>

Ratios of the weights of the carnivore and prey animals should give some indication of the ability of the former to break the bones of the latter.

NOTE: This crude level of comparison can not be extended to other types of mammal since the size and structure of teeth, jaw muscles etc. vary between taxonomic groups. Haynes (1982) has demonstrated

that different families of meat eaters (i.e.: ursids, canids and felids) inflict distinctive patterns of damage on the bones of ungulate species. In this comparison, only canids and artiodactyls are being used.

Ratios of weights of carnivores and prey species (in kilogrammes) are:

eskimo dog:caribou	25:110	to	32:101
	<u>1:4.4</u>	to	<u>1:3</u>
eskimo dog:sheep	25:45	to	32:45
	<u>1:1.8</u>	to	<u>1:1.4</u>
coonhound:goat	25:75	to	30:50
	<u>1:3</u>	to	<u>1:1.7</u>
fox:hill sheep	6:50	to	7:50
	<u>1:8.3</u>	to	<u>1:7</u>
mastiff dog:hill sheep	29:50		
	<u>1:1.7</u>		
mastiff dog:Soay sheep	29:40	to	29:26
	<u>1:1.4</u>	to	<u>1:0.9</u>
beagle dog:Soay sheep	14:40	to	18:26
	<u>1:2.9</u>	to	<u>1:1.4</u>
mastiff dog:Dexter cow	29:300		
	<u>1:10</u>		
mastiff dog:British White cow	29:450		
	<u>1:15.5</u>		
beagle dog:British White cow	14:450	to	18:450
	<u>1:32</u>	to	<u>1:25</u>

It is very clear from the data presented above, that the fox is 'disadvantaged' in terms of its weight in relation to that of its prey (i.e.: hill sheep), when compared to a large dog attacking a Soay sheep. Its ratio is more comparable to that of a mastiff dog attacking a Dexter cow.

The weights of Soay sheep have been included in these calculations since the bones of most prehistoric and historic sheep in Britain correspond very closely in size to those of the Soay or Orkney breeds (Wild, 1982). Similarly, Dexter cattle are more comparable to the pre-Roman and some post-Roman cattle than are most of the modern

breeds, and the larger cattle found from the Romano-British period onwards in Britain are comparable to medium-sized modern breeds such as the Shorthorn or British White (Jewell, 1963; Reynolds, 1979: 49-50).

Harcourt's review (1975) of the sizes of dogs recovered from archaeological sites in Britain demonstrates that dogs existed in a wide range of sizes in the Romano-British and Anglo-Saxon periods, from circa 23 - 72 centimetres in shoulder height (equivalent to cairn terrier to St. Bernard size). He also shows that large dogs were quite common in the Iron Age, and that medium to large dogs have been present on archaeological sites since the Mesolithic period.

#### Splintering observed in the Sheffield sheep study

It was noticeable in this study that none of the recovered bones consisted of splintered fragments. However, some of the smaller (probably unfused) bones did show signs of beginning to break in this way, although the splinters had not fully detached from the main shaft (see Plate 8:26 for two examples of tibiae with partially detached fragments of bone).

The lack of bones that have been broken across their shafts, and the paucity of signs of splintering in the Sheffield sheep collection are probably reflections of the small size of foxes in relation to the robust nature of modern sheep bones.

The interaction of butchery, cooking, weathering, trampling and  
carnivore scavenging on the breakage of bones

Binford (1981: 51, 56) notes that dogs splinter bones from a broken edge. Haynes (1981:445) makes a similar observation for larger carnivores and prey species, i.e.: although a carnivore may be too small to crush the cylinder of a longbone, it may be able to pull off splinters from an exposed edge. If bones are chopped through by butchery before being discarded or given to dogs, the resulting cylinders of longbones may be particularly prone to splintering by carnivores.

Similarly, bones that contain split lines are more likely to splinter if subjected to pressure (such as applied by biting or trampling) than are bones that are completely intact. Although it may be doubtful that dogs would habitually scavenge bones that had lost their flesh covering, and which had split due to normal weathering processes (Haynes, 1981:302-204), bones that had split due to pressures during cooking might still be attractive to carnivores: apart, possibly, from retaining a little flesh or cartilage, they would still retain most of their marrow content.

Conclusions

On archaeological sites, where scavenging dogs have had access to the bones of ungulate species, sheep bones may have been damaged more severely than those in the Sheffield study, and cattle bones may show patterns of damage quite similar to those observed here

for sheep. This is because of differences in size ratios of the animals concerned, i.e.: dogs tend to be larger than foxes, whilst early forms of sheep and cattle tended to be smaller and more gracile than modern breeds.

In particular, it is possible (if not probable) that the bones of sheep on archaeological sites may have been splintered by scavenging canids, although the bones of adult cattle may have been too large for them to have damaged in this way.

#### The ability of canids to consume bones

In previous chapters presenting the frequencies and rates of attack of the 26 element types (i.e.: Chapters 4-7), and in the descriptions of types of damage observed to the elements in the Sheffield sheep study (Chapter 8), it was suggested that examples of some of the smallest, more trabecular, element types may have been consumed entirely by the scavenging foxes. These elements are: the sternbrae, the patella and, possibly, the hyoid. Circumstantial evidence for these claims centres on the degrees of damage observed to other element types that have been partially consumed (such as the ribs, the distal femur, and the mandible).

Other authors, i.e.: Haynes (1981) and Binford (1981), have also noted a similar lack or paucity of small, trabecular bones and have also suggested that they may be consumed entirely. Direct observations of foxes consuming bones, however, are difficult to obtain, since they are mainly crepuscular or nocturnal in habits (Burrows, 1968).

Proof that canids are capable of eating these bones has been presented by Payne & Munson (1985). In experiments in which penned coonhound dogs were given portions of two goat carcasses to eat, only three of the four patellae were recovered after the meat had been consumed. Two of the patellae were recovered from faeces, the other from vomit. Payne & Munson also recovered several phalanges and an astragalus from faeces, and note that the bones have been partially dissolved by gastric juices. Payne & Munson's Plates 3 and 4 show that these bones have been reduced in size and strength, rendering them more susceptible to other agencies of destruction, such as trampling. Bones that are thought to have passed through the guts of dogs have also been found on archaeological sites.

Guilday found some very similarly eroded deer phalanges in an assemblage from a 17th Century A.D. Indian village (Guilday, 1971: 25 and Fig. 7k). He suggested that these phalanges had been swallowed whole, and noted that larger elements never showed this pattern of erosion (presumably being too large for dogs to consume), whilst the smallest elements were missing entirely (apparently having been completely digested).

Phalanges are rare in the total Sheffield sheep collection: BIs= 0.14, 0.07 and 0.09 for the proximal, medial and distal phalanges, respectively. Chapter 7 showed that the recovered examples are 'under-attacked' compared with their MUI values. It is possible that attacked examples were consumed and, therefore, unavailable for collection.

Other element types and parts that Payne & Munson recovered from faeces are: the distal humerus, the proximal ulna, the distal radius, carpals, the pelvis, the proximal and distal femur, the

proximal and distal tibia, the calcaneum and sesamoids. Some of these element types were sometimes rejected by the dogs (i.e.: were not eaten), but other types were only recovered from faeces; these are: carpals, the proximal and distal femur, the patella, the proximal tibia, medial and distal phalanges, and the distal sesamoids (all data taken from Payne & Munson, 1985: Table 2). The archaeological visibility of all of these elements or element parts, therefore, would be minimal. Ribs and vertebrae, unfortunately, were not fed systematically to the dogs, and so cannot be compared with the limb bone elements.

### Conclusions

Three lines of evidence all suggest that the smallest elements in the ungulate skeleton may be consumed entirely by scavenging canids.

(1) Payne & Munson (1985) have demonstrated in controlled experiments that large dogs can consume small bones from adult goat carcasses, i.e.: carpals, phalanges, sesamoids and the patella, as well as certain epiphyses, e.g.: the proximal tibia, and the proximal and distal femur. Other element parts may be consumed on some occasions but not on others, e.g.: the distal humerus, distal radius and the proximal ulna.

(2) Certain small element types are very rare or totally absent from the Sheffield sheep collection, and Binford (1981) and

Haynes (1981) both note similar paucities of the same element types in their collections of ungulate bones scavenged by canids, i.e.: sternebrae, the patella, the hyoid (and, in the case of the caribou and deer collections, caudal vertebrae).

(3) In the Sheffield sheep collection, the presence of damage to neighbouring elements (i.e.: the distal ends of ribs, the distal femur and proximal tibia, and the angle of the mandible) implies that the sternebrae, patella and hyoid, respectively, must also have suffered some damage.

Also, the severity of some of the damage observed to some of the larger elements, such as the pelvis, suggests that the foxes were certainly capable of destroying small bones of trabecular structure.

In the Sheffield sheep study, therefore, the smallest element types, i.e.: sternebrae, the patella, the hyoid and, possibly, all of the phalanges, are probably underrepresented due to total consumption by foxes, as well as to a collector's bias against the recovery of small bones (see Chapter 10).

If dogs have been active on an archaeological site, the surviving animal bone assemblage may be deficient in small bones due to the deprivations of the scavenging dogs, and any surviving small elements may be particularly fragile, if they have been partially digested by the dogs' gastric juices.

THE EFFECTS OF VARYING LEVELS OF INTENSITY OF DAMAGE  
OBSERVED IN THE SHEFFIELD SHEEP COLLECTION

Introduction

It was observed in this study, and noted by Haynes (1980, 1981, 1982, 1985) and Binford (1981) that damage to bones occurs in a range of degrees of intensity, and that this variability occurs both within and between element types. That is, even element types that tend to be damaged infrequently and lightly, such as the radius, do sometimes show severe forms of damage. Conversely, element types that tend to be damaged frequently and severely (such as the humerus) sometimes suffer only limited damage.

Factors that might influence the degree of damage inflicted on examples of a single element type include: the state of hunger of the carnivore, the types and amounts of alternative food sources, the numbers of carnivores involved, and the length of time for which the bones are available (Haynes, 1981). All of these factors are likely to be 'unknowns' for archaeological assemblages, although the numbers of dogs extant might be indicated by the frequencies of their burials and by their ages at death. The first three factors are also unknown quantities for the Sheffield sheep study, and will not be discussed further. The fourth factor, the length of time that the bones are available, is only known for some of the carcass bones, although the differences in degrees of weathering (see chapter 4) do suggest that the non-carcass bones have tended to be exposed for longer than most of the carcass bones.

Although the factors outlined by Haynes (1981) as

influencing the intensity of damage are beyond the scope of this thesis, the results of different intensities of damage can be investigated, by comparing the non-carcass and carcass collections of Sheffield sheep bones.

Chapter 7 established that the non-carcass bones have suffered more intensive damage than have the carcass bones, and the next section of this chapter shows how the degree of intensity of damage has important implications regarding the relative frequencies of element parts.

The observed relative frequencies of element parts in the  
Sheffield sheep collection

1: The total collection

Table 9:2 presents the frequencies of different parts of the ten major element types (other element types tended to be recovered whole, or not at all, see Chapter 7 and Table 7:6).

It is clear from Table 9:2 that some parts tend to survive far more frequently than others. For instance, all of the 30 humeri in the collection retain their midshaft region, and 25 (83%) also retain their distal epiphyses; but only 10 (33%) retain their proximal epiphyses, only 9 (30%) are complete, and 5 (17%) have been reduced to tubes lacking both ends of the bone. This pattern of survival contrasts strongly with that of the radius, which has an almost identical frequency (i.e.: N=29), but which has 23 (79%) complete bones, and only 2 (7%) reduced to tubes.

To a large extent, this pattern of survival can be explained by epiphyseal fusion age, as suggested by Brain (1969), and this factor is discussed in detail below, and again (in comparison with other potential explanatory factors) in Chapter 10.

#### Implications for analyses of archaeological faunal assemblages

Table 9:2 shows clearly that counts of the relative frequencies of these ten element types will vary according to which part of each type is counted (N.B. in Table 9:2 and throughout this discussion, 'epiphysis' is defined as meaning either the fused epiphysis or the unfused fusion surface). All methods of quantification of animal bones have some inherent biases, and it is beyond the scope of this dissertation to discuss them all in detail. Grayson (1984) covers most of them in depth.

One method used by Grant (1975, 1978, 1984) is the counting of 'epiphyses only'. Grant (1975) uses this in order to avoid the problems caused by differential fragmentation, but the method introduces its own, undesirable biases, including the exclusion of many unfused bones (see below).

Table 9:2 shows that, for the six major longbone elements, the only area to show 100% representation for all six types is the midshaft. Provided that the bones are not splintered longitudinally in this area, therefore, it is the most accurate indicator of the frequencies of each element type in this collection. This is because the bones have been attacked from the ends of the shaft inwards (see Chapter 8). Similarly, the only portion of the pelvis to survive in

100% of the recovered examples is the central area, i.e.: the acetabulum.

The midshaft of the ulna is so fragile that it does not necessarily survive to be recovered, and the most frequent area remaining for this element is the distal epiphysis, which is present in 91% of the cases. Similarly, there is no area of either the mandible or the scapula that survives in all examples. For the mandible, the tooth row is the best indicator of element frequency (it survives, in a measurable form containing all of the cheek teeth, in 95% of the cases) and, for the scapula, the neck or bicipital tuberosity are the best preserved areas (with 90% each). In this study, 'neck width' indicates that a measurement may be taken at this point. In fact, all examples of scapulae had some part of the neck present, which would give a 100% indication of the number of scapulae recovered.

Table 9:2 shows clearly that the least accurate indicators of element frequencies are some of the epiphyses. Although some element types each have one well represented epiphysis (e.g.: the metacarpal, with 100% of proximal epiphyses present) others have lost both epiphyses in several of the cases (e.g. 28% of the femora), and would clearly be underrepresented by any method that did not include counts of their midshaft areas. Table 9:1 also presents the frequencies of element tubes, and shows that there is a general trend for element types that split more frequently to have fewer examples of bone tubes, and vice versa e.g.:

humerus: 0% split lines, 17% tubes

metatarsal: 20% split lines, 0% tubes.

This trend can be explained by the structures of the bones (see above).

Table 9:2 shows that, for each of the seven longbone element types, one epiphysis survives more frequently than the other. Brain (1969) suggested that the relative survival of epiphyses is related to their fusion ages, and this is demonstrated in the next section and in Question 4. However, the next section shows that the relative survival of epiphyses is also affected by the level of intensity of the damage incurred.

#### 2: The non-carcass versus the carcass collections

Table 9:3 presents the raw frequencies of the epiphyses of each of the seven longbone elements in the carcass and non-carcass collections. It also presents the fusion ages of these epiphyses (Silver, 1969) and the raw frequencies of these element parts in Brain's collection of goat bones, which were recovered from the environs of Hottentot villages in Namibia (Brain, 1969). Brain's collection is considered to have been damaged more severely than either of the Sheffield collections because:

- (1) it has been damaged by humans as well as by canids,
- (2) the canids were dogs and, therefore, probably larger than the Sheffield foxes (see above), and
- (3) the collection contains many splinters of bones, which are characteristic of extreme damage (see above).

Table 9:3 arranges the collections in order of intensity of damage, i.e.: the Sheffield sheep carcass collection is the least intensively damaged collection of the three, the Sheffield non-carcass collection is in the middle, and Brain's collection is the most intensively damaged collection (using the criteria given in Chapter 7 and above).

There is a very clear trend for the ratios of later-fusing to earlier-fusing epiphyses to diminish as the intensity of damage increases. This is not only the case for the most severely damaged elements, e.g.: the humerus, with ratios of 0.50, 0.33 and 0.00 in the Sheffield carcass, Sheffield non-carcass and Brain's collections respectively, but also for the lightly damaged elements, such as the metacarpal, whose corresponding rates are: 1.00, 0.90, and 0.72. There is only one anomalous rate, and this is for the femur in the Sheffield non-carcass collection. Since the two epiphyses of the femur fuse at very similar ages (i.e.: 30-36, and 36-42 months; Silver, 1969), this minor discrepancy is considered to be of little importance.

It is significant that, although all of the elements show the same trend, the ratios for some element types show much greater rates of change than do those of others, e.g.: the ratios for the metacarpal change from 1.00 to 0.72, but those for the tibia show a very great change from 0.95 to 0.18. This uneven rate of change has important implications for the relative frequencies of element parts, i.e.: the rank orders of element parts will change according to the intensity of alteration, even when the assemblage is entirely derived from whole carcasses (as is the case for all three collections), and even when (in the case of the two Sheffield collections), the damage is entirely caused by scavenging canids, without any interference from

butchery or consumption by humans.

Table 9:4 presents the raw frequencies and rank orders of the longbone epiphyses in the same three collections. Some epiphyses, such as the proximal humerus, are disadvantaged even when the level of damage is relatively slight: the proximal humerus ranks last out of the twelve epiphyses in all three collections. Similarly, other epiphyses, such as the distal tibia, rank first or second regardless of the degree of damage. Other epiphyses, however, show very great changes in rank position, e.g.: the proximal tibia changes rank from 2nd. to 5th. to 10th. out of 12 as the degree of damage intensifies.

Spearman's rank order correlation analyses show that, using the twelve epiphyses quantified in all three collections, there is a greater difference between the Sheffield sheep carcass collection and the Sheffield sheep non-carcass collection than there is between the Sheffield non-carcass collection and Brain's collection of goat bones, despite the fact that the latter has been altered by humans as well as by canids:

Sheffield carcass & non-carcass:  $Rho=0.44$ ,  $N=12$ ,  $p>0.05$

Sheffield non-carcass & Brain's goats:  $Rho=0.77$ ,  $N=12$ ,  $p<0.01$

Sheffield carcass & Brain's goats:  $Rho=0.30$ ,  $N=12$ ,  $p>0.05$

Total Sheffield sheep & Brain's goats:  $Rho=0.63$ ,  $N=12$ ,  $p<0.05$

There are two possible conclusions from these results:

- (1) canid scavenging overprints human alterations of epiphyseal frequencies
- (2) canids and humans tend to destroy the same epiphyses due to inherent characteristics of the bones themselves.

An evaluation of the first conclusion requires ethnoarchaeological experiments that are beyond the scope of this study, but the second conclusion is tested in Chapter 10, and the data are found to support it.

### Conclusions

The most accurate method of quantifying element frequencies in the Sheffield sheep collection (which has not been splintered), uses raw counts of the midshaft areas of the six major longbone elements, the distal end of the ulna, the acetabulum of the pelvis, the neck of the scapula and the tooth row of the mandible. The midshaft areas of the six major longbones and the acetabulum all survive in 100% of the recorded examples. The other three element types give 90-95% accuracy for element frequencies.

Other parts of the ten major element types survive in greatly varying degrees of frequency due to differential destruction by the foxes, e.g.: only 32% and 33% of the ulnae and humeri, respectively, retain their proximal epiphyses, whilst 95% of both the metacarpi and the metatarsi retain both of their epiphyseal ends.

Some of the elements, e.g.: the femur, are particularly likely to survive as tubes, with no epiphyses or fusion surfaces remaining, and would be severely underrepresented if element counts did not take this factor into account.

For each of the longbones, the earlier-fusing epiphysis survives more frequently than does the later-fusing epiphysis.

As the intensity of damage increases, the ratio of later-

fusing to earlier-fusing epiphyses declines, but the rate of this decline varies between element types.

This means that the relative frequencies of the twelve major longbone epiphyses change in their rank orders, according to the degree of alteration they have undergone, even if there is no human interference.

When bones are modified by humans as well as by scavenging canids, the same patterns of epiphyseal frequencies are seen, implying either that:

- (1) scavenging by canids can overprint alteration to bones caused by humans, or
- (2) canids and humans tend to destroy the same epiphyseal areas, due to the inherent natures of these element parts.

QUESTION 4: ARE UNFUSED EPIPHYSES MORE LIKELY TO BE DESTROYED  
THAN FUSED EPIPHYSES?

Introduction

The previous section of this chapter noted that, for each of the seven longbone elements in the Sheffield sheep collections, the earlier-fusing epiphysis is more frequent than the later-fusing epiphysis (see Table 9:3), and Chapter 10 investigates the relationship of fusion age with relative frequencies of epiphyses in more detail.

This section investigates the hypothesis that an epiphysis is more likely to be destroyed if it is unfused than if it is fused

N.B. an 'epiphysis' is defined here as meaning either a fused epiphysis or an unfused fusion surface.

In order to test this hypothesis, it is necessary to know the fusion states of all of the bones. Since the bones were not placed in a controlled experiment, but accrued by natural deaths, some bones were recorded for the first time after they had lost one or both of their epiphyses and so could not be recorded directly as having been fused or unfused. However, various lines of evidence have been used to extrapolate or estimate fusion data, i.e.:

(1) If a bone that has lost an epiphysis is one of a pair (i.e.: comes from a known, individual carcass) and its pair retains its relevant epiphysis, the two bones are assumed to have been at the same fusion state when the animal died.

(2) If the later-fusing epiphysis is present in a fused state, but the earlier-fusing epiphysis has been destroyed, the earlier-fusing epiphysis is assumed to have been fused.

(3) If the earlier-fusing epiphysis is present in a fused state but the later-fusing epiphysis has been destroyed, the bone may, occasionally, be judged to have been immature on the grounds of its small size and the texture of its bone (especially the presence of woven bone at the ends of the diaphysis). However, such cases were extremely rare, and usually a bone in this condition (i.e.: earlier-fusing epiphysis fused, later-fusing epiphysis destroyed) has had to be assigned to a '?' category for the fusion state of its destroyed epiphysis.

(4) Bones that have lost both epiphyses have also been assessed on the grounds of size and bone structure. Several of these bone tubes were probably unfused at both ends prior to the carnivore damage.

All fusion states that have not been directly observed have been classed as 'estimated' or '?' in the analyses (see Tables 9:5 and 9:6).

### Results

Table 9:5 presents the frequencies of element parts for the ten major element types, together with their fusion ages (using Silver, 1969), the numbers known and the numbers estimated to be fused and unfused, and the numbers that have lost their epiphysis through destruction.

Table 9:6 summarises these data and is arranged in order of epiphyseal fusion age. It shows that, for the distal humerus, the distal radius, the proximal and distal femur and the distal tibia, higher proportions of unfused than of fused epiphyses have been destroyed e.g.:

distal humerus:	11% fused	67% unfused	epiphyses destroyed
proximal femur:	18% fused	100% unfused	epiphyses destroyed
distal radius:	4% fused	17% unfused	epiphyses destroyed

The metapodials contradict the trend slightly, since one metacarpal and one metatarsal have each lost their fused distal epiphysis, but the sample size for unfused distal epiphyses is tiny

(one example for each element type), and so this fact is considered to be a very minor deviation from the trend.

Even when ranges have had to be given (due to lack of known fusion data for destroyed, later-fusing epiphyses), the same trend is apparent, i.e.:

proximal tibia: 0 - 32% fused    23 - 79% unfused epiphyses destroyed  
 proximal humerus: 0 - 62% fused    16 -100% unfused epiphyses destroyed.

That is, apart from the very minor deviation shown by the metapodials, (which may be due to small sample sizes), all of the elements that had some unfused epiphyses have lost higher proportions of the unfused examples than of the fused examples.

Table 9:6 also suggests another general trend, i.e.: the earlier an epiphysis fuses, the less likely it is to be lost, even when fused. One interesting exception to this is the olecranon, for which 68% of the fused epiphyses have been destroyed (this is the highest rate for any fused epiphysis, yet the olecranon fuses at an intermediate age). The olecranon has a very small epiphysis, and it is composed of thin, trabecular bone, even when fused. Its high rate of attack was noted in Chapter 7, in which it was suggested that the attachment of major tendons to the olecranon process encourages carnivore activity in this area. The earlier part of this chapter also noted that foxes can destroy thin areas of trabecular bone, and the olecranon appears to have been consumed quite easily. Similarly, the epiphyses of the ilium and ischium are very small areas of trabecular bone and, even when fused, probably present little difficulty to a fox intent on consuming the overlying muscles of the rump.

Table 9:7 uses a Spearman's rank order correlation analysis

to test the relationship of the sequence of epiphyseal fusion and the percentage loss of epiphyses, and shows that there is a statistically significant inverse correlation between the two variables, as expected, i.e.:

$$\text{Rho} = -0.77, \quad N=18, \quad p < 0.01.$$

That is, despite the tendency for the olecranon to lose its epiphysis even when fused, there is a general trend for the earlier-fusing epiphyses to suffer less destruction than the later ones. Table 9:6 suggests that this may even be the case when only fused examples are considered, but the lack of direct observations for some of the examples of later-fusing epiphyses precludes any statistical evaluation of this possibility.

### Conclusions

The data collected in the total Sheffield sheep collection show two major trends:

- (1) for each epiphyseal area, unfused examples are more likely to be destroyed than are fused examples, and
- (2) there is an inverse correlation of fusion age with epiphyseal survival.

SUMMARY

This chapter has considered four questions regarding the patterns of breakage and bone loss observed in the Sheffield sheep collections.

It has concluded that trampling probably has had little or no effect on the breakage of the bones in the collection, since none of them show any breakage across or through the bone, only the removal of projecting edges or ends of bones. Also, experimental studies by other authors suggest that, on a soft substrate, bones will tend to be pushed into the ground rather than broken (Gifford-Gonzalez et al., 1985), and that even on a hard substrate, whole bones are unlikely to break (Davies, 1984). However, it is possible that pre-trampling breakage (as caused by, for example, butchery) or weathering might make trampling a more influential agent of bone breakage for some archaeological assemblages.

Similarly, the investigation of split lines concludes that these, too, have not led to any breakage in the Sheffield sheep collection, although the cracks do render the bones more susceptible to breakage under pressure.

It is likely that split lines interact with other factors such as butchery, trampling and carnivore activity and, whilst being insufficient to have caused the separation of bone parts in the Sheffield sheep collection (prior to removal, consumption or burial), they may be of more relevance in other circumstances (such as might pertain to some archaeological assemblages) in which the bones are also subject to other breakage-related agencies.

Since split lines tend to be much more frequent in some

element types than in others (i.e.: they tend to be commonest in the mandible and in the denser longbones of the lower limbs than in the more tubular longbones of the upper limbs), their influence on bone breakage is probably uneven, and may lead to differential fragmentation of element types. This possibility must be taken into consideration by analysts of faunal assemblages if assessments are made of the relative frequencies of element types.

The intensity of damage inflicted by carnivores has important implications for counts of frequencies of both element types and element parts. The size of a carnivore in relation to that of its 'prey' will affect the degree of damage that it can inflict on the bones of the prey species. Other factors, such as competition for food, will also affect the degree and nature of the damage.

Other studies have shown that dogs can inflict severe damage on the bones of adult sheep and goats (Binford, 1981; Payne & Munson, 1981), and the average level of damage observed in the Sheffield sheep collection (considered to have been inflicted by foxes), is comparatively low. In the past, when sheep were more gracile than the hill breeds studied here, and the scavengers were dogs rather than foxes, the degree of damage caused by dogs to the bones of the sheep will probably have been more severe than most of that observed in the Sheffield sheep study. However, using average weights of canid and ungulate species as a crude guide to the ratios of predator to prey sizes, it is possible to suggest that the level of damage inflicted by foxes on the bones of hillsheep may be approximately comparable to that inflicted by medium to large dogs on the bones of early forms of domestic cattle on British prehistoric, Romano-British and early historic sites.

The smallest bones in an ungulate's skeleton, e.g.: sternebrae, phalanges, the patella and the hyoid, are particularly susceptible to total consumption by canids, and may be found on archaeological sites in reduced frequencies, or in an eroded state that suggests that they have been partially digested.

The level of intensity of scavenging also affects the survival of longbone epiphyses, some of which may be consumed by canids. Certain epiphyses are more susceptible to destruction than others, and for each element type, the later-fusing epiphysis is likely to survive less often than the earlier-fusing epiphysis. The ratio of frequencies of the two epiphyses is an indication of the degree of damage suffered by the bones.

The level of damage also affects the relative frequencies of the element parts, whose rank orders change according to the degree of damage. The close similarity of the epiphyseal frequencies in a carnivore-scavenged assemblage and a carnivore-and-human damaged assemblage suggests that either: (1) canid scavenging overprints human damage to bones, or (2) canids and humans damage the same element parts due to the intrinsic nature of those parts.

An assessment of the rates of loss of fused and unfused epiphyses shows that, for each epiphyseal area, a bone is more likely to have this area destroyed if it is unfused than if it is fused.

There is also an inverse correlation between the fusion sequence and element part survival (i.e.: the later an epiphysis fuses, the less likely it is to be recovered), and there is a possibility that, even when fused, later-fusing epiphyses are more likely to be destroyed than are earlier-fusing epiphyses.

Because of the loss of epiphyses, the midshaft regions of

the longbones are the most accurate indicators of element frequencies. Since the unfused epiphyses are more susceptible to destruction than are the fused epiphyses, ageing data using epiphyseal fusion will be biased against the recording of unfused examples.

It is possible that the size of a bone, as measured by its midshaft diameter, reflects the broad age group of the animal (although it will also be affected by sex, nutrition, breed, etc.). If future work can test this hypothesis, the use of midshaft diameters may be able to improve on age assessments of bones recovered from scavenged faunal assemblages.

An experimental use of midshaft diameters is made in an original analysis of Romano-British material, described in Chapter 12.

**CHAPTER 10: THE MAIN FINDINGS OF THE ACTUALISTIC STUDY  
AND AN INVESTIGATION OF THE ROLES OF INHERENT FACTORS**

INTRODUCTION

This chapter summarises the main findings of the actualistic study. Earlier chapters have demonstrated that frequencies and attack rates vary considerably between element types. This chapter investigates the relationships of various internal factors (see Chapter 3) with the observed data in the total Sheffield sheep collection. For some of the analyses, it gives greater detail than earlier chapters by using frequencies of element parts (i.e.: proximal and distal ends of longbones) rather than frequencies of element types.

The data used are:

- (1) Binford's Meat Utility Index (MUI) values (Binford, 1978),
- (2) rough estimates of absolute meat cover, extrapolated from Binford (1978),
- (3) Binford's marrow volume figures for whole elements (Binford, 1978),
- (4) Brain's frequencies of goat bones recovered from Hottentot villages and his figures for bone specific gravities (Brain, 1969 & 1984), and
- (5) Lyman's figures for bulk densities of element parts (Lyman, 1982 & 1985).

Table 10:1 and Figure 10:1 present the frequencies of elements and element parts recovered in the total Sheffield sheep collection, using the 26 main element types. Table 10:1 gives both the raw counts and the Brain's Index (BI) values, whereas Figure 10:1 gives only the Brain's Index values.

The analyses show that:

- (1) There is a definite bias against the recovery of small elements.
- (2) There is a positive correlation between an element's meat cover and its attack rate, and a weaker positive correlation between its marrow content and its attack rate.
- (3) The most frequent element types also tend to have the highest attack rates, excepting the smallest element types, which appear to have been reduced in numbers by consumption.
- (4) The bulk density of an element type or element part is only weakly correlated with its frequency. When the six tubular longbones are considered on their own, the frequencies of their parts are not significantly correlated with their bulk densities (contrasting with Brain's (1969) findings).
- (5) However, the bulk density values of element parts are very strongly correlated with the percentages of bones recovered that have had these parts destroyed.

SUMMARY OF THE FINDINGS OF THE ACTUALISTIC STUDY

The animal bones studied in the actualistic survey all derive from entire carcasses that received minimal or nil alteration by humans. The main carnivore in both areas is the fox, which is considered to have been the main agent of element destruction and redistribution. The collections have been studied regarding: element frequencies, rates of attack to element types, patterns of damage to element types, and the spatial redistribution of elements.

It is clear from all of the collections that:

- (1) Some elements are recovered more frequently than others:  
e.g.: tibiae are more numerous than femora.
- (2) Some parts of elements are recovered more frequently than others:  
e.g.: distal tibiae are more numerous than proximal tibiae.
- (3) Some elements are more likely than others to be transported away from carcasses:  
e.g.: forelimb and lower hindlimb elements are likely to be moved, but the axial skeleton is likely to remain in situ.
- (4) Some elements or element parts are attacked more frequently than others:  
e.g.: 97% of the pelves have been attacked, but only 21% of the proximal radii.
- (5) Some elements or element parts are attacked more severely than others:  
e.g.: ribs may be reduced to less than one quarter of their original lengths but radii tend to retain their full lengths.

- (6) Unfused epiphyses are particularly prone to destruction:  
e.g.: 100% of the unfused proximal femora have been destroyed,  
but only 18% of the fused proximal femora have been destroyed.
- (7) Each element type tends to have distinctive patterns of damage to  
different areas of the bone:  
e.g.: the proximal humerus tends to have its fusion surface  
destroyed and to have a scalloped edge to the remaining proximal  
shaft.
- (8) Some forms of carnivore damage are particularly characteristic,  
whilst others may be more difficult to assign to taphonomic agent:  
e.g.: punctures are very obvious, but mouthing marks are more  
subtle and may resemble pitting by soil acids or be  
obscured by subsequent erosion.

The rest of this chapter investigates the relationships of  
these observed patterns of element frequencies, rates of attack and  
partial bone loss with the inherent factors introduced in Chapter 3.

### 1: AN EVALUATION OF THE EFFECTS OF A BIAS AGAINST THE RECOVERY OF SMALL BONES

#### Methods

The very smallest bones of the body, i.e.: the sesamoids,  
the carpals and the smaller tarsals, are so scarce in all of the  
collections that they have not been considered in any of the  
calculations. Nearly all of the examples of these bones that have been

recovered were still attached by ligaments to larger bones and, therefore, do not form a valid comparison for archaeological material in which the linking ligaments have decayed. Payne (1972) and Levitan (1982) have demonstrated how a bias against the recovery of such small bones operates on archaeological sites where material is not routinely sieved.

In order to make a quantitative analysis of the suggested bias against small bones in the total Sheffield sheep collection, entire bones were measured to the nearest whole centimetre. In all cases, the measured elements were all fused. For some elements, all available specimens were measured. For those that had more abundant entire examples, a sample of five to seven bones were measured on an unsystematic basis, i.e.: these bones happened to be the first ones unpacked from their storage boxes. The measurements are given in Table 10:2.

### Results

Table 10:3 uses a Spearman's rank order correlation analysis to compare the frequencies of the 26 element types with their average intact sizes, and shows that there is a good correlation between the two variables:  $Rho=0.73$ ,  $n=26$ ,  $p<0.01$ .

The element type that shows the greatest discrepancy in ranks is the ribs. The ribs are far less frequent in the collection than would be expected with regard to their entire length, but Chapter 7 showed that these bones are often reduced to a fraction of their original length, and it is possible that fragments that have been

reduced in size have been overlooked. It has also been suggested (in Chapter 9) that ribs might be consumed almost entirely since they consist of very thin trabecular bone that is intimately associated with the covering flesh.

A second element type that shows a similar, although not quite so large, discrepancy between rankings in Table 10:3 is the hyoid. This element is very similar to the ribs in that it, too, consists of thin trabecular bone encased in meat, although the hyoid lacks the articular head of the ribs and is, therefore, even more susceptible to destruction during meat consumption. Only one hyoid was recovered in the total collection of 694 bones.

Surprisingly, perhaps, the lumbar vertebrae also show a discrepancy in ranks, although in this case they are more frequent than would be expected on the grounds of their size. This is probably due to one of two factors: (1) the vertebrae were all measured for their axial lengths, i.e.: from proximal to distal articulations of the body, not for their maximum widths which, if the transverse processes remain intact, may be considerably greater (e.g.: 10-11 centimetres, compared to 3 centimetres for the body of lumbar vertebrae). Probably more important, though, in the case of the lumbar vertebrae (since this factor also obtains for the thoracic vertebrae, which do not show such a discrepancy in ranks), is the fact that many of the lumbar vertebrae remained articulated for quite a long time after other parts of the skeleton had disarticulated (Stallibrass, in preparation). A block of five or six lumbar vertebrae is considerably larger and more conspicuous than is a single lumbar vertebrae lying in grassland.

## Conclusions

There is a strong positive correlation between the frequency of an element type and its average intact length, which demonstrates that there has been a bias against the recovery of the smaller elements. This is probably due to a combination of factors, i.e.: (1) the problem of visibility of small bones in a vegetated environment (which is similar to the problem of recovering small bones during unsieved excavations, see Payne (1972) and Levitan (1982)), and (2) the destruction of small bones by carnivore damage (see Chapter 9 for a discussion of the consumption of whole small bones by canids). Some larger element types, such as ribs and the hyoid, are probably disadvantaged as well, due to partial destruction by carnivores, whilst element types that tend to remain articulated for a long time, e.g.: lumbar vertebrae, have enhanced visibilities due to the greater sizes of the articular units.

## 2: THE RELATIONSHIP OF MEAT COVER TO PERCENTAGES OF ATTACKED ELEMENTS IN THE SHEFFIELD SHEEP TOTAL COLLECTION, USING DATA PUBLISHED BY BINFORD (1978)

A: MEAT UTILITY INDEX (MUI)

## Introduction

Binford (1978: 19-23) measured the absolute weights of butchered units of meat plus bone and the dry weights of filleted

bones for the carcasses of two sheep: one aged six months, the other six and one half years old. Binford's Meat Utility Indices (MUIs) are constructed so that the higher the ratio of meat to bone, the higher the MUI for that element. The element type with the highest ratio, the ribs, has an MUI of 100.00, and the other elements' ratios are expressed as a proportion of this figure.

Chapter 7 presented the hypothesis (Question 2B: page 124) that an element's rate of attack is positively correlated with the size of its meat cover. In Chapter 7, separate analyses were conducted for the carcass and non-carcass collections, and these showed that the statistical correlation of the two variables is strong for the carcass collection ( $p < 0.01$ ) but very weak for the non-carcass collection ( $p \sim 0.05$ ) (see page 125). The hypothesis is tested again, below, using the larger sample size of the total Sheffield sheep collection. Element types that do not conform to the general trend are identified, and the influences of some other variables are suggested.

### Results

Table 10:4 uses a Spearman's rank order correlation analysis to compare Binford's MUI figures with the percentages of element types showing signs of carnivore attack in the total Sheffield sheep collection. It shows that the statistical correlation between the two variables is not particularly strong:  $Rho = 0.57$ ,  $p < 0.05$ ,  $n = 17$ . The element types that show the greatest disparities between rankings on the two variables are the humerus, cervical and thoracic vertebrae, ribs and sternebrae.

The humerus is attacked far more often than would be expected from its MUI. Three possible reasons for this fact are:

(1) The difference in rankings is an artefact due to the recording systems utilised, i.e.: the MUI is a ratio of the total meat weight to the total bone weight for the element as a whole, although the humerus has very different amounts of meat over its proximal and distal ends. Similarly, the percentage of humeri that have been attacked refers to damage occurring anywhere on the element. In reality, the majority of both the meat cover and the incidences of carnivore attack occur at the proximal end of the bone. Although the location of the carnivore damage has been ascribed to specific areas of the bone (see Chapter 8) Binford's figures do not discriminate between the two ends, and so cannot be used in a more precise comparison.

(2) The difference in rankings may be genuine, and due to preferential attack of the proximal humerus in order to disarticulate the entire forelimb below the scapula. However, some of the removed forelimbs found in articular order still retained the scapula, and so this factor cannot fully explain the different rankings seen in Table 10:1.

(3) The MUI is a measure of the ratio of meat to bone weight, but it is possible that the absolute weight of meat cover is of greater relevance to rates of attack.

## B: MEATWEIGHTS

Introduction

The data given by Binford (Binford, 1979: Tables 1.1 & 1.2, pages 16 & 17) permit rough calculations of meat weights for the major elements. The calculations involve subtracting the dry bone weight from the gross weight for each element type. The residual weight should be mainly that of the meat cover, but it will also include the weight of any water lost from the bone during the drying process, and may also include the weight of some marrow (which may or may not have been lost through foramina during the boiling process). Throughout the rest of this thesis, the residual weight will be referred to as: 'meatweight'.

Results

Table 10:5 shows a Spearman's rank order correlation analysis of this residual 'meatweight' with the percentages of elements attacked in the Sheffield sheep total collection. The correlation is slightly stronger than that when the MUIs are used:  $Rho=0.68$ ,  $p<0.01$ ,  $n=16$ , and the discrepancy in rankings of the humerus is greatly reduced. However, the cervical vertebrae, ribs and sternebrae still show lower percentages of attacked bones than would be expected from their meat coverings.

Consumption

In the cases of the ribs and sternebrae, it is possible that the percentages of attacked bones are underestimates due to

- (a) problems of recovery of damaged ribs that have been reduced to a small size, or
- (b) the possibility of total consumption of attacked sternebrae (and possibly also of ribs).

Chapter 9 concluded that these element types are susceptible to consumption by canids, and Chapter 7 showed that many of the collected ribs have suffered considerable bone loss (see Table 7:6).

Access to elements

In the case of the cervical and thoracic vertebrae, the causes of the disparities in rankings are unknown. In both cases, the bones are less attacked than expected by their MUIs, and the cervical vertebrae show a similar pattern when the absolute 'meatweight' figures are used (see Table 10:5).

One possible explanation involves ease of access to bones in relatively fresh carcasses. During the three year study of the monitored carcasses, it was noticed that carcasses were usually opened up through the fleece at the anus and via the abdominal cavity and diaphragm into the heart cavity. The fleece was torn back from this central area, often remaining on the neck and head and on the lower limbs. Often, the cervical vertebrae stayed covered by fleece and were not attacked.

Each carcass tended to lie on its back or side, never on its front, although some of them were found in different positions at different times, indicating that they had been disturbed in between my visits. Some carcasses were dragged one to three metres away from their original positions. As a result of the carcasses lying on their backs or sides, the dorsal spines of the thoracic vertebrae were nearly always buried in the fleece and thus protected from scavengers. Chapter 8 describes the damage found on thoracic vertebrae and shows that the dorsal spine is, in fact, the most commonly attacked area. This suggests that thoracic vertebrae that are still fully or partially protected by the fleece will suffer little or no damage but that, if accessible, the dorsal spine will suffer preferential attack. The avoidance of covered thoracic vertebrae may explain the lower than expected frequency of attacked bones. It is pertinent that the lumbar vertebrae do not show such a discrepancy in rankings. In the case of the lumbar vertebrae the most frequently attacked area of the bone is the transverse spines, which protrude on one if not both sides when a carcass is lying on its back or side and are, therefore, easily accessible even if the fleece still underlies the carcass.

This factor of access to meat sources may also be involved in the frequencies of sternbrae and ribs in the collection, i.e.: the removal of the sternbrae and distal portions of ribs greatly facilitates access to the heart and lungs of a carcass. The easiest way for a carnivore to remove these thin, meat-covered elements is to consume them in conjunction with their overlying flesh.

Meatweight calculations

One final factor that may be involved in these considerations is the manner in which Binford allocated meat weights to underlying bones. This mainly affects three element types: the mandible, thoracic vertebrae and lumbar vertebrae. Binford gives a gross weight for the mandible that includes the tongue. Since the tongue is not attached to the mandible and can be removed without damage to this element, the 'meatweight' used in Table 10:5 has had the weight of the tongue subtracted. In a replicate analysis in which the tongue was included as meat-cover for the mandible, the correlation of rank orders was reduced slightly to  $Rho=0.61$  (from  $Rho=0.68$ ). Similarly, Binford includes the weight of the tenderloin in his gross weight for the thoracic vertebrae. Unfortunately, he does not give the weight of the tenderloin on its own. Since most of this meat is free of any underlying bone, there is little reason for the thoracic vertebrae to be damaged during its consumption. The 'meatweight' and MUI for thoracic vertebrae, therefore, are overestimates of the meat directly overlying this element. The inaccuracy for the lumbar vertebrae is similarly caused by the inclusion of the weight of the kidneys, for which Binford gives no separate figure.

## CONCLUSIONS

There is a general correlation between an element's rate of attack and the size of its meat cover.

The absolute size of the meat cover (using 'meatweights') has a stronger correlation than the ratio of the weights of meat to bone (MUI) with the observed rates of attack to element types in the total Sheffield sheep collection.

Despite the overall positive, statistically significant correlation, some element types do not conform to the general trend. In particular, the recovered examples of ribs, sternebrae and cervical vertebrae have been attacked less often than would be predicted from their meat cover values. In the case of the sternebrae (and, possibly, the ribs), it is probable that attacked examples tended to be destroyed (or drastically reduced in size), and hence failed to be collected. In the case of the cervical vertebrae, the foxes do not appear to have been intent upon consuming the flesh of the neck (this area was often left with its covering of fleece relatively intact). The reason for this pattern of behaviour is unknown. Slight inaccuracies may have affected the rankings of the mandible and thoracic and lumbar vertbrae, due to the manner in which Binford (1978) measured his meat and boneweights, but these are unlikely to have caused any major discrepancies.

### 3: THE RELATIONSHIP OF MEAT COVER TO ELEMENT FREQUENCIES

#### Introduction

If the amount of meat on an element is positively correlated with the amount of damage that that element suffers (as shown, above), then it is possible that not only will the meatier elements be

attacked more often, but elements with the greatest ratios of meat to bone weights may be consumed entirely. In that case, MUI values would be correlated inversely with the frequencies of elements in the collection.

### Results

Table 10:6 uses a Spearman's rank order correlation analysis to compare Binford's (1978) MUI figures with the frequencies of element types in the total Sheffield sheep collection, using Brain's Index values for frequencies. It shows that the two variables are almost completely non-correlated, although the figure is negative as expected:  $Rho = -0.07$ ,  $n=17$ ,  $p>0.05$ . It is interesting to note which elements do fit the predictions of an inverse correlation, i.e.: the ribs and the sternbrae, which rank first and second out of seventeen element types for Meat Utility Indices, but fifteenth and seventeenth for frequencies. Both of these two elements are composed of thin trabecular bone and they are, therefore the element types most likely to be consumed entirely (along with the hyoid, of which only one example was recovered, and which is embedded in the meat of the tongue).

4: A COMPARISON OF THE SHEFFIELD SHEEP DATA AND  
BINFORD'S (1978) MARROW CAVITY VOLUME FIGURES

Introduction

Binford (1978: 16) describes how marrow volumes were measured for elements from two sheep carcasses. It appears that only the shaft marrow volumes were measured, and that marrow within the trabecular bone at the epiphyseal ends was ignored. The figures given, therefore, are probably underestimates for complete bones. The description (Binford, 1978: 16) of how the volumes were measured precludes the allocation of volumes to proximal and distal ends of bones, although these are purportedly given in Table 1.6 (Binford, 1978: 24). The values presented in Binford's Table 1.6 are obviously equal divisions of (unspecified) figures, presumably those obtained from the central shafts of longbones and so, in this study, Binford's figures have been recombined and used for 'whole' bones only.

Table 10:7 tests the hypothesis that element types with large volumes of marrow will be attacked preferentially, by comparing the percentages of elements attacked in the total Sheffield sheep collection with Binford's (1978) figures for marrow contents in a Spearman's rank order correlation analysis.

Results

Table 10:7 shows a rather poor statistical correlation between the two variables:  $Rho=0.53$ ,  $p<0.05$ ,  $n=12$ .

The most notable exceptions to the general correlation are the pelvis, the scapula and the calcaneum. In all three cases, the percentage attacked is ranked considerably higher than the marrow volume for that element. For the scapula and pelvis, although the marrow volumes are small, the meat cover (represented both by the Meat Utility Index and by 'meatweight') is quite high. Similarly, although the calcaneum has a very low marrow content, it carries the insertions of a major muscle group. In all three cases, therefore, the amount of meat-cover (or associated meat-cover), appears to override the marrow volume as an influence on the percentages of elements attacked.

### Conclusions

Although marrow content (as given by Binford (1978)) is related to the percentage of an element type that is attacked, it is clear that meat cover is a more influential factor.

5: A COMPARISON OF THE SHEFFIELD SHEEP DATA WITH BRAIN'S  
COLLECTION OF GOAT BONES FROM VILLAGES OF HOTTENTOTS IN THE  
NAMIB DESERT AND WITH HIS SPECIFIC GRAVITY FIGURES  
(BRAIN 1969 & 1984)

### Introduction

Brain (1969) was the first person to publish data investigating the relative survival of elements or element parts. His

collection of goat bones from some Namib Desert Hottentot villages is influenced by three main factors:

- (1) butchery, cooking and consumption by people
- (2) scavenging by dogs
- (3) size selection during recovery from the ground surface.

Factors (2) and (3) are similar to factors operating on the Sheffield sheep collection, but factor (1) is a new variable not considered in the Sheffield study. Brain provides details of the effects of factor (1) on one young goat carcass that was recorded before the dogs could have access to it (Brain, 1969: 16).

#### Damage to goat bones by the Hottentot people

None of the bones was broken during the butchering of a goat but, during consumption, all marrow-containing bones were broken by being held on a rock anvil and hammered with another stone (Brain, 1969: 15).

The damage done to the young goat carcass over a period of two days (in which time the meat was fully consumed), is described in Brain (1969: 16). Typically, the unfused or more trabecular epiphyses and any thin projections of trabecular bone were the most seriously damaged areas of elements. Several epiphyses, e.g.: the proximal humerus, and the proximal and distal femur, and various trochanters were removed and the shafts were chewed back. Thoracic vertebrae suffered damage to their dorsal spines and transverse processes.

The only element types mentioned as being consumed entirely by the people were the caudal vertebrae (which do not exist in the

Sheffield sheep study due to the practice of docking lambs' tails soon after birth).

Apart from the deliberate breakage of the longbones, axis and pelvis, the damage due to consumption by people appears to be very similar to that caused by foxes in the Sheffield sheep study, i.e.: the same areas of certain element types tend to be attacked preferentially (e.g.: late-fusing epiphyses and thin projections of trabecular bone), all of them with large amounts of meat-covering.

However, there are a few differences, e.g.: the elements left undamaged by the Hottentot people were: the mandible, the atlas, the sacrum (which was attacked severely by the Sheffield foxes), the scapula (which was damaged frequently by the Sheffield foxes), and the pelvis (which was chopped through but unchewed by the Hottentots, but heavily chewed by the foxes).

Brain had only the one carcass as a control for the effects of people's powers of consumption but, since many of the bones were unfused, the damage is likely to have been relatively severe. Apart from the caudal vertebrae, none of the elements are recorded as having been consumed (N.B. Brain does not mention the sternbrae or hyoid in his description, but the ribs were only damaged slightly at the distal ends, and so sternbrae and hyoids may also have been damaged only slightly).

If, therefore, the damage to this one young goat is typical of the effects of consumption by humans, then the frequencies of elements recovered in Brain's goat bone collection should not be biased by preferential total destruction of elements, (excepting caudal vertebrae).

However, certain parts of elements (e.g.: proximal humeri)

may have suffered more destruction than in the Sheffield sheep collection, since they are known to have been attacked by humans as well as by dogs in the Hottentot goat collection. If this is the case, the Hottentots' goat bones should show a more intensive degree of damage, e.g.: a greater destruction of the less robust elements and element parts.

#### Element frequencies of Brain's goat bones

Brain quantified the recovered elements and element parts by calculating the numbers expected from entire carcasses using a Minimum Number of Individuals derived from the number of the most frequent element, (i.e.: 64 right mandibles. No attempt was made to match left and right mandibles by size or age group). The recorded number was then converted to a percentage surviving from the expected number.

Brain showed that, despite the lack of any known trading, exchange or differential spatial disposal of body parts by humans, the recovered frequencies of elements and element parts showed considerable variation, with different ends of long bones often showing very different survival percentages. Brain suggested that the main cause of these variations is the density of the bone parts themselves, i.e.: that the denser an element (or element part) the more likely it is to survive. Since an element becomes more dense once it has fused, it is clear that the fusion state of a bone will also affect its chances of survival.

Brain's element frequencies and specific gravity values

Brain pointed out (Brain, 1969: 19) that the structure of an element (or element part) is very important to its survival potential, and he considered that size, thickness of wall, and amounts of cancellous and compact bone are relevant variables. As an approximate measure of structure or density, Brain measured the specific gravity of each element. This increases with the ratio of compact to cancellous bone, and decreases with the size of the marrow cavity. He cut longbones through midway along their axes, in order to compare proximal and distal halves.

Brain found that an element's (or element part's) percentage survival was directly related to its specific gravity, and was indirectly related to its fusion time (as given in Cornwall, 1956).

'The conclusion to be drawn is simply that survival is not haphazard, but is determined by inherent qualities of the parts.'  
(my emphasis). (Brain, 1969: 20).

The important implication of this conclusion is that elements will be affected in ways that relate to their own properties rather than in ways determined by the properties of specific destructive agents, i.e.: a proximal humerus is likely to be damaged more severely than is a distal humerus, by either a human or a canid, because its structure (represented by its specific gravity) makes it inherently more susceptible to destructive agencies.

It should be noted that a lower specific gravity denotes a higher ratio of volume to weight. Structurally, this often entails either a thin-walled shaft or a volume of trabecular bone. Both of these structural forms give the bone a large surface area for its weight, and the greater the surface area, or the thinner the bone, the

more susceptible it is to chemical as well as to mechanical destruction. This factor will affect the rate at which a bone weathers (see Chapter 4).

Brain (1969) only gives specific gravity values for the proximal and distal ends of the four largest longbones, and only shows the correlation of percentage survival with specific gravity in a graphical manner, together with data for fusion time of sheep's elements taken from Cornwall (1956) (Brain, 1969: Table 4 and Figure 2). In his development of this theme, Brain gives the specific gravities for metapodials as well as for the larger limb bones (Brain, 1984: Table 4) and uses Noddle's (1974) data for fusion ages, which should be more accurate than those he used in 1969 since they pertain to goats rather than to sheep. A Spearman's rank order correlation analysis of the data in Brain's (1984) Table 7 gives statistical support to his claim for a strong correlation between percentage survival and specific gravity:  $Rho=0.89$ ,  $n=12$ ,  $p<0.01$ . The correlation between percentage survival and fusion age is also quite strong:  $Rho=0.74$ ,  $n=12$ ,  $p<0.01$ .

#### 6: A COMPARISON OF THE SHEFFIELD SHEEP DATA WITH BULK DENSITY FIGURES (FROM LYMAN 1982 & 1985)

##### Introduction

Unfortunately, Brain does not give specific gravity data for non-longbone elements, and so a similar test cannot be undertaken for the full collection. Lyman (1982 & 1985) does give density figures for

all elements and these are used to test the correlation of bone density with element frequency in the total Sheffield sheep collection.

Lyman (1985: 224-225) compares density values for proximal and distal ends of the four largest longbones given in three published sources: Brain (1969), Behrensmeyer (1975) and Binford and Bertram (1977). Lyman complains that he cannot judge from these publications precisely what forms of density (e.g. specific gravity, true density or bulk density) have been measured, and points out that the figures vary greatly. Because of the discrepancies he prefers to use his own data, originally given in his thesis (Lyman, 1982).

His own figures differ yet again from the three sources he has already quoted (Lyman, 1985: Table 1) but it is interesting to compare the rank orders of these four sets of figures. Although the absolute values do vary considerably, the rank orders show far less variability, and appear to fall into two pairs, possibly reflecting two different forms of density. Using the figures given in Lyman (1985: Table 1 & Table 2) the rank orders of 'density' values given by Brain (1969) and Lyman (1982) are very closely correlated:  $Rho=0.93$ ,  $p<0.01$ ,  $n=8$ , and those given by Behrensmeyer (1975) and Binford and Bertram ((1977), corrected in Binford (1981)) are even closer:  $Rho=0.95$ ,  $p<0.01$ ,  $n=8$ .

Because of the similarity of Lyman's figures to those given by Brain (1969), they have been preferred in this study in order to preserve consistency within the analyses. Also, Lyman (1982 & 1984) argues that bulk density (approximated by his Volume Density figures utilised here) is more relevant to considerations of bone frequencies than is true density.

A: SHEFFIELD SHEEP ELEMENT FREQUENCIES  
AND LYMAN'S (1982) BULK DENSITY FIGURES

Introduction

Table 10:8 presents a Spearman's rank order correlation analysis of the frequencies of elements in the total Sheffield sheep collection (represented by Brain's Index values) and the bulk densities of these elements given by Lyman (1982). If Brain's hypothesis is correct, then the frequencies of elements should be strongly and positively correlated with their bulk densities.

Results

The analysis shows that the correlation is statistically significant at the  $p < 0.05$  level, but not at  $p < 0.01$  ( $Rho = 0.37$ ,  $n = 30$ ).

It is interesting to note which elements show the greatest disparities in rank. The calcaneum, astragalus and proximal phalange are all less frequent than expected from their bulk densities. These low frequencies probably can be explained by the known bias against the recovery of small bones (see above), which, itself, may be compounded by preferential consumption by the foxes of small, trabecular bones (see Chapter 9).

The atlas and cervicals are both more frequent than expected on the grounds of their bulk densities. This chapter described earlier how the neck of a carcass was often left protected by fleece, and this factor may explain the 'preferential' survival of these elements.

In contrast, the ribs are less frequent than expected, but

were observed to suffer acute attack early on in the sequence of carcass destruction.

The two element types where rank differences cannot be explained either by size bias or accessibility within a carcass are the pelvis and proximal tibia. The pelvis, in fact, was often one of the first elements to be attacked after the sheep's death, and the 'over-recovery' of these elements cannot be explained by the author.

If the analysis is restricted to the proximal and distal ends of the six tubular longbones (as in the analysis using Brain's goat data and specific gravity figures, see pages 223-224, above), the correlation is not statistically significant:  $Rho=0.32$ ,  $n=12$ ,  $p>0.05$ .

### Discussion

One possible reason for the less than perfect correlation shown between element frequencies and bulk density is the degree of intensity of attack. Chapter 7 showed that rates of partial bone loss vary between collections, and are related to rates of attack. Chapter 9 discussed the effects of intensity of attack on the preferential destruction of element parts, and Table 9:3 demonstrated how the ratios of frequencies of later-fusing to earlier-fusing epiphyses decrease as the intensity of damage increases. Although areas of lower bulk density may be attacked preferentially, therefore, they need not be precluded from recovery, unless the degree of attack is particularly severe.

B: PERCENTAGES OF ELEMENT TYPES ATTACKED IN THE SHEFFIELD SHEEP  
TOTAL COLLECTION AND LYMAN'S (1982) BULK DENSITY FIGURES

Introduction

Table 10:9 uses a Spearman's rank order correlation analysis to test the hypothesis that the percentages of elements that show signs of attack are inversely correlated with the elements' bulk densities (taken from Lyman (1982)). That is, elements with lower bulk densities should show higher rates of attack.

Results

The result of the analysis supports the hypothesis, and the correlation is statistically significant at the  $p < 0.01$  level ( $Rho = -0.47$ ,  $n=30$ ).

Conclusions

In the total Sheffield sheep collection, bulk density values for elements (or element parts) are correlated more strongly with rates of attack than with their frequencies. In this collection, therefore, it appears that most elements have tended to survive the foxes' attacks, although many have been damaged or partially destroyed.

In a more severely damaged assemblage, however, such as

Brain's (1969) collection of goat bones that had been damaged by humans as well as by canids, the greater loss of the ends of some longbones may lead to a stronger correlation between the bulk densities and frequencies of elements (or element parts).

On archaeological sites, where dogs have been active as scavengers, sheep bones may show patterns of element frequencies similar to those in Brain's goat bone collection, whilst cattle bones might show element frequencies more similar to those in the Sheffield sheep collection, due to the different size ratios of the canids and ungulate 'prey' species involved (see Chapter 9). Deviations from these patterns might be due to the involvement of other taphonomic agencies, including human behaviour patterns.

C: PERCENTAGES OF BONES WITH A FUSION SURFACE MISSING  
AND LYMAN'S (1982) BULK DENSITY FIGURES

Introduction

Table 10:10 presents the percentages of bones recovered in the total Sheffield sheep collection that have had a fusion surface (whether fused or unfused) removed by carnivores. The primary data are given in the detailed tables of patterns of damage to element types presented with Chapter 8, i.e.: they correspond to the proportions of bones that have had the relevant end of the shaft recorded as 'BROKEN OFF'.

In an archaeological assemblage, elements may be missing due to Cultural Transforms, e.g.: patterns of waste disposal or trading,

and so this method of recording the data may give a more accurate indication of what elements should have been recoverable, but have suffered partial destruction by scavenging canids.

Table 10:10 uses a Spearman's rank order correlation analysis to compare the percentages of bones missing a fusion surface with the bulk densities of those ends (i.e.: halves) of the bones, using the six tubular longbones.

### Results

Table 10:10 shows that there is a strong, inverse, correlation between bulk density values and the percentages of element parts that have had a fusion surface removed, i.e.:  $Rho = -0.89$ ,  $n=12$ ,  $p < 0.01$ .

### Conclusions

The bulk density of an element (or element part) is closely related to that element's (or element part's) potential for survival and recovery. However, in a moderately scavenged assemblage, it may be more closely related to partial destruction than to total destruction.

On archaeological sites, absolute frequencies (i.e.: raw frequencies) or relative frequencies (i.e.: Brain's Index values) may have been affected by several variables, particularly Cultural Transforms, that can cause element parts from a single carcass to be deposited in disparate areas, causing intra- or inter-site lateral

variation (see Maltby, (1979)). The proportion of the recovered examples of element types that have had a fusion surface destroyed by a carnivore, therefore, is probably a better indication of the extent of destruction caused by scavenging carnivores than is the absolute (or relative) frequency of that element.

#### SUMMARY

In this chapter, the rank orders of element frequencies and percentages of elements attacked in the Sheffield sheep total collection have been compared with data published elsewhere for element Meat Utility Indices, 'meatweights' and marrow volumes (all: Binford, 1978), specific gravities (Brain, 1969) and bulk densities (Lyman, 1982). The element frequencies in the Sheffield collection have also been compared with the average lengths of complete examples of each element type in the collection and, in Chapter 9, measures of damage to element parts have been compared with fusion ages (Silver, 1969). Unfortunately, some of the published sources do not discriminate between proximal and distal ends of longbones. Binford (1978), in particular, tends to amalgamate element types into anatomical units (e.g.: pelvis plus sacrum), which restricts the detail available for comparisons.

The results of the Spearman's rank order correlation analyses are summarised below:

## ELEMENT FREQUENCY (REPRESENTED BY BRAIN'S INDEX (BI) VALUES)

BI & whole element size	Rho =	0.73	n=26	p<0.01
BI & 'meatweight'	Rho =	0.64	n=15	p<0.01
BI & 'meatweight'	Rho =	0.44	n=16	p<0.05
BI & bulk density	Rho =	0.37	n=30	p<0.05
BI & bulk density	Rho =	0.32	n=12	p>0.05
BI & fusion age	Rho =	0.31	n=13	p>0.05
BI & Meat Utility Index	Rho =	-0.07	n=17	p>0.05

## PERCENTAGE OF ELEMENT TYPE (RAW FREQUENCY) MISSING A FUSION SURFACE (% MISS)

% MISS & bulk density	Rho =	-0.89	n=12	p<0.01
% MISS & fusion age	Rho =	0.79	n=18	p<0.01

## PERCENTAGE OF ELEMENT TYPE ATTACKED (% ATTACK)

% ATTACK & bulk density	Rho =	-0.47	n=30	p<0.01
% ATTACK & 'meatweight'	Rho =	0.68	n=16	p<0.01
% ATTACK & MUI	Rho =	0.57	n=17	p<0.05
% ATTACK & marrow content	Rho =	0.53	n=12	p<0.05

## A: ELEMENT FREQUENCIES

The best correlation of a variable with element frequency (represented by Brain's Index) in the total Sheffield sheep collection uses the variable of intact element size (Rho=0.73, n=26, p<0.01). This result implies that the main source of bias in the collection is due to human failure to pick up small bones from a vegetated ground surface, probably compounded by the hypothesised loss of some of the smaller, more trabecular bones, due to consumption by foxes.

The comparison of element frequencies with Binford's (1978) Meat Utility Index (MUI) is hampered by the lack of detail provided by

Binford regarding element parts. His MUI is a measure of the ratio of meat to bone weight and is almost totally non-correlated with the element frequencies in the Sheffield sheep collection ( $Rho = -0.07$ ). More important than the ratio of meat to bone weight is the absolute 'meatweight' that covers each element. This has had to be calculated by extrapolating from Binford's (1978) gross weights and dry bone weights, but it does explain at least some of the variability in element frequencies:  $Rho = 0.44$ ,  $n = 16$ ,  $p < 0.05$ .

One element type, the sternebrae, has a huge anomaly in this analysis, probably due to its small size, i.e.: it ranks fourth out of seventeen for meat per bone, but ranks seventeenth out of seventeen for frequency (Brain's Index = 0.04). The frequencies of this element may be biased by two factors: (1) its very small size (which also affects the phalanges, which do not show such a large anomaly), and (2) the combination of small size and trabecular construction that makes it (alone out of the elements considered in this analysis) particularly susceptible to total consumption. If this element is left out of the analysis because of its particularly susceptible characteristics, the correlation of meat cover and element frequency is increased to  $Rho = 0.64$ ,  $n = 15$ ,  $p < 0.01$ .

Although Brain found that his specific gravity measures correlated very well with his frequencies of longbone element parts ( $Rho = 0.89$ ,  $n = 12$ ,  $p < 0.01$ ) and the rank order for his specific gravity figures correlates extremely well with those given by Lyman for bulk density ( $Rho = 0.93$ ,  $n = 12$ ,  $p < 0.01$ ), the element frequencies in the Sheffield sheep collection do not show a very strong correlation with Lyman's figures:  $Rho = 0.37$ ,  $n = 30$ ,  $p < 0.05$ . If the analysis is restricted to the twelve longbone epiphyseal ends that were used in the analysis

of Brain's data, in order to avoid the known bias against the recovery of small bones, the correlation becomes not statistically significant:  $Rho=0.32$ ,  $n=12$ ,  $p>0.05$ .

Most of the analyses undertaken with element frequencies have had to use frequencies of undivided elements (i.e.: without separating proximal from distal ends of longbones), and the one analysis that does use the full data (with Lyman's (1982) bulk density data) shows a low correlation coefficient. It was suggested, above, that this might be due to a relatively low level of intensity of attack and that a closer correlation might be found with percentages of attacked elements.

#### B: PERCENTAGES ATTACKED

The analyses using percentages of attacked elements tend to show higher correlation coefficients than those using element frequencies. Lyman's (1982) bulk density figures are strongly (and inversely) correlated with the percentages of element types showing signs of carnivore damage:  $Rho= -0.47$ ,  $n=30$ ,  $p<0.01$ . This correlation is stronger than that between the same bulk density figures and the Brain's Index values of the bones, suggesting that the foxes have preferentially damaged, but not destroyed, the more susceptible (i.e.: less dense) elements.

The next best correlation coefficient is produced by an analysis that compares the percentages of elements attacked with their residual 'meatweights' (see Table 10:5). The absolute weight of meat

covering an element definitely seems to be correlated more closely than is Binford's MUI both with the percentages of elements showing signs of attack and with element frequencies (see the summary tables, above).

It would be interesting to re-analyse the data with meatweights for element parts (i.e.: distinguishing between proximal and distal ends of longbones) if such data could be obtained.

The percentages of elements attacked are also correlated with marrow volume, using Binford's data for whole elements (some of which have been combined into units):  $Rho=0.53$ ,  $n=12$ ,  $p<0.05$ . Again, it would be interesting to see how these analyses would be affected by the use of more detailed data.

### CONCLUSIONS

For an assemblage that derives from whole carcasses of small ungulates that have been moderately scavenged by canids, but not affected by humans, the best predictor of element frequency (using the 26 main element types) is average intact element size. That is, a collector bias against the recovery of small bones, probably compounded, to some extent, by the total destruction by the canids of some examples of the smallest element types, will certainly affect the frequencies of the element types that are recovered.

Of the other inherent factors that have been investigated in this study, absolute 'meatweight' values are correlated more closely with element frequency than are either Binford's (1978) Meat Utility Index or Lyman's (1982) bulk density figures.

In a moderately scavenged assemblage, such as the total Sheffield sheep collection, the carnivores may tend to damage rather than to destroy elements. In a more intensively altered assemblage, such as that collected by Brain (1969), total destruction of elements (or element parts) may be more common, resulting in a strong correlation between the frequencies and the bulk densities of elements.

This greater loss of element parts may not be due, solely, to the activities of humans. Chapter 9 discussed the evidence for destruction of bone by canids, and concluded that dogs are certainly capable of destroying epiphyseal ends of longbones, and of consuming in toto smaller elements of the ungulate skeleton. The degree of damage inflicted by canids is affected by several variables, including the size ratio of the 'predator' and 'prey' species, the amount of alternative food supplies, time available, numbers of carnivores involved, etc. (see Chapter 9). Chapter 11 shows how similar the total Sheffield sheep collection and Brain's (1969) goat bone collection are in many ways, and it should not be assumed that the differences outlined here are due to differences in alteration patterns caused by canids and humans. Chapter 9 demonstrated that people and carnivores tend to damage the same areas of bone, due to the inherent susceptibilities of those areas. Differences in degree of intensity of damage, therefore, may be due to influences from canids, or people, or a combination of the two agencies, in any ratio.

In order to ascertain which agency is responsible for the destruction of an element part (and, possibly, of an element type), patterns of alteration to the recovered examples must be studied, for evidence of chewing by carnivores (see the descriptions of types of

damage inflicted by canids, in Chapter 8), and/or of butchery by humans.

On archaeological sites, where patterns of human behaviour (i.e.: Cultural Transforms) may have led to lateral variation in the deposition of element types, thus precluding the recovery of certain elements, the proportions of elements recovered that are missing their fusion surfaces might be a better indication of the degree of bone loss through carnivore scavenging than the actual frequencies of the element parts recovered. In this way, a distinction may be drawn between the absence of element types that were never deposited in the excavated area, and a paucity or absence of elements (or element parts) that have been preferentially destroyed by canids.

COMPARISONS OF THE SHEFFIELD SHEEP COLLECTION WITH OTHER COLLECTIONS  
OF CARNIVORE-SCAVENGED UNGULATE BONES, AND A CONSIDERATION OF THE  
IMPLICATIONS FOR ARCHAEOLOGICAL ASSEMBLAGES

INTRODUCTION

The discussions in Chapter 10 demonstrated that several variables appear to affect the relative survival of different element types from scavenged carcasses, and the different frequencies with which they are attacked. These variables include both inherent factors pertaining to the elements themselves, and external factors that affect the intensity of damage. The complex interaction of the variables makes it difficult to predict precisely what patterns of element frequencies to expect in a scavenged assemblage, unless the relative influences of the different variables are already known.

However, comparisons with several other assemblages indicate patterns that tend to recur under certain circumstances. Data have been taken, from a variety of published sources, for ungulate bone assemblages that have been affected either by carnivores only, or by carnivores and humans. For most of these studies, the main carnivore species has been a canid (either wolf or dog). Within the collections that have suffered from carnivores alone, a distinction is made (as in the Sheffield sheep collection) between total surface collections, remains of known carcasses, and remains recovered from carnivore dens.

The comparisons show that there are basic patterns that tend to typify these different context types despite large geographical differences, and differences in local environmental conditions. It is

probable, therefore, that these basic patterns also obtained in the past for these context types, and should be recognisable in archaeological assemblages.

### 1: CARNIVORE-SCAVENGED COLLECTIONS

#### HILL'S (1975) SURFACE COLLECTIONS OF WATERBUCK AND TOPI BONES, AND THE SHEFFIELD SHEEP COLLECTION

##### Introduction

Binford has summarised some of Hill's (1975) data on surface collections of ungulate bones that have been scavenged by a variety of carnivores in two areas of East Africa (Binford, 1981: Table 5.02, columns (6) & (14)). The original data are presented in Hill (1975): Tables 15, 16 & 17). Collections of bones of two ungulate species have been taken from this body of data to compare with the Sheffield sheep collection. Both assemblages derive from surface collections of bones.

One is a collection of topi bones from a combination of delta flat and delta pond environments in the Lake Rudolf area (Binford, 1981: Table 5.02, column (6)), and the other is a collection of waterbuck bones combining material from two separate collections of the same area, made two years apart, in the Murchison Falls National Park, Uganda (Binford, 1981: Table 5.02, column (14)). The average body weight for these two species is considerably higher than that for the Sheffield sheep (i.e.: 82 kg. and 131 kg. for the topi and

waterbuck respectively, compared with circa 50 kg. for the hill sheep), but the average body weight for their scavengers is probably also considerably higher than that of foxes. Both areas contain lions, hyaenas, jackals and large birds, which are all known locally to be scavengers of ungulate carcasses (Hill, 1975).

Hill comments (1975: 76) that the ground vegetation cover in both areas is very sparse, that each area was searched twice, and that even small bones were visible. Visibility and recovery of smaller elements in these collections, therefore, should be much better than in the Sheffield sheep collection where visibility was sometimes hampered by growing vegetation, although weathering of bones probably occurs more rapidly in the East African environments (Behrensmeyer, 1978).

### Results

A Spearman's rank order correlation analysis of the element frequencies (using Brain's percentage survival) shows that the two East African collections are correlated strongly with each other:  $Rho=0.85$ ,  $n=26$ ,  $p<0.01$ . The strong correlation between these two collections is particularly impressive since each collection is, in fact, an amalgamation of two smaller collections made either at different times or in different areas, besides containing species of different sizes.

The element frequencies in these two collections, having been shown to be consistent amongst themselves, are now compared with the Sheffield sheep collection, which comes from a different

continent, a different environment, and involves a smaller species of ungulate. The results of Spearman's rank order correlation analyses are presented below:

waterbuck & topi:	Rho = 0.85	n=26	p<0.01
waterbuck & sheep total:	Rho = 0.53	n=26	p<0.01
topi & sheep total:	Rho = 0.31	n=26	p>0.05
waterbuck & sheep carcasses:	Rho = 0.67	n=26	p<0.01
topi & sheep carcasses:	Rho = 0.76	n=26	p<0.01

Three of the four analyses have results that are significant at the  $p<0.01$  level of confidence suggesting that, despite the different habitats etc., the basic pattern of destruction and removal of elements by scavenging carnivores is influenced mainly by the internal factors pertaining to the skeletal and muscular anatomy of the ungulate carcass itself.

However, it is also clear that both the waterbuck and the topi collections are correlated more closely with the Sheffield sheep carcass collection than with the total sheep collection (Rho=0.67 and Rho=0.76, compared with Rho=0.53 and Rho=0.31).

### Conclusions

The stronger statistical correlations with the Sheffield sheep carcass collection, rather than the total Sheffield collection, suggest that the East African collections are, in fact, selective samples of the populations of bones in the landscape, and that some

items may have been removed preferentially by scavengers and re-deposited elsewhere, e.g.: in underground or semi-subterranean dens, such as those illustrated by Mills and Mills (1977), Hill (1979) and Brain (1981).

BINFORD'S (1981) COLLECTION OF BONES FROM 24 CARIBOU KILLED  
BY WOLVES, AND THE SHEFFIELD SHEEP COLLECTION

Introduction

Binford (1981) gives the survival percentages of elements recovered from 24 caribou carcasses known to have been killed by wolves (Binford, 1981: Table 5.01, column (26)). If canid-scavenged carcass collections have a consistent pattern of element frequencies, then this collection should show a strong correlation with the Sheffield sheep carcass collection. Both collections consist of residual material from canid-scavenged ungulate carcasses, although the prey and scavenger species are both smaller in the Sheffield study than in Binford's.

Results

Table 11:1 presents a Spearman's rank order correlation analysis which shows that the two collections are correlated quite strongly:  $Rho=0.72$ ,  $n=27$ ,  $p<0.01$ . One of the biggest anomalies is the ranking of the scapula, which is considerably 'under-represented' in

the Sheffield collection. This was also the case when the Sheffield carcass collection was compared with the waterbuck and topi assemblages and may be an idiosyncrasy of the Sheffield collection, since it shows a consistent deviation from the pattern shown by all three other collections.

If the suggestion (above) that Hill's surface collections of topi and waterbuck bones are the remains of scavenged carcasses is correct, then these collections should also each correlate with Binford's known caribou carcass collection. This is, indeed, the case:

waterbuck & caribou carcasses:  $Rho = 0.88$   $n=26$   $p<0.01$

topi & caribou carcasses:  $Rho = 0.87$   $n=26$   $p<0.01$

#### DISCUSSION OF CARCASS COLLECTIONS

The comparisons of these collections of elements remaining from scavenged carcasses of various ungulate species, i.e.: sheep, caribou, topi and waterbuck, that have been scavenged by a variety of carnivores, including: foxes, wolves, lions and hyaenas, in three different continents, i.e.: Europe, North America and Africa, suggest that there really are patterns of survival that are consistent for ungulate carcasses that have been scavenged by carnivores, even when immediate circumstances such as climate and habitat and degree of intensity of damage vary. These results support Brain's suggestion (quoted in Chapter 10) that it is the inherent qualities of an ungulate's skeletal anatomy that are the major influences on the relative survival of element types, with or without any human

interference.

The results also suggest that variations will occur according to what part of the bone population is sampled, i.e.: the in situ remains of scavenged carcasses, the removed remains of carcasses (such as might be found in carnivore dens) or a general mixture of the two. It was only by comparison with collections known to be from scavenged carcasses that Hill's surface collection was shown to be a selective, rather than a total, collection of remains.

BINFORD'S (1981) COLLECTION OF CARIBOU BONES FROM  
A WOLF DEN, AND THE SHEFFIELD SHEEP COLLECTION

Introduction

Binford also has a collection of caribou bones recovered from a wolf den (Binford, 1981: Table 5.01, column (28)). The element frequencies of this collection are expected to be correlated with the sub-collection of sheep bones recovered from the fox dens in the Sheffield sheep study, since they have both been accumulated by a canid species scavenging from ungulate carcasses.

Results

Despite the small sample size of the Sheffield sub-collection (there are only 96 bones in the combined 'articulated' and isolated fox den groups, spread between 27 element types used in the

analysis). A Spearman's rank order correlation analysis of the element frequencies in the two assemblages shows a statistically significant correlation:  $Rho=0.56$ ,  $n=27$ ,  $p<0.01$ .

#### DISCUSSION OF CANID DEN ASSEMBLAGES

It is noticeable that both the wolf den assemblage of caribou bones and the combined fox den assemblage of sheep bones contain mainly limb bones (including lower limb bones), with few elements from the axial skeleton, whereas the topi, waterbuck, caribou and sheep carcass assemblages are all particularly rich in axial skeletal elements, and particularly low in bones from the lower limbs.

### 2: COLLECTIONS AFFECTED BY HUMANS AS WELL AS BY CANIDS

#### INTRODUCTION

Two sources have been used for assemblages of ungulate bones that have been affected by humans as well as by canids. Brain (1969 & 1984) describes his collection of goat bones that had been partially butchered and consumed by Hottentots before being discarded and made available to scavenging dogs, and Binford and Bertram (1977) describe sheep bones that had been butchered, cooked and partially consumed by Navajo Indians before being discarded to scavenging dogs.

Brain (1969) comments that only caudal vertebrae were eliminated by human activity before dogs could affect the assemblage,

and Binford and Bertram (1977) similarly note that there was no destruction of 'archaeologically visible' elements by butchery or consumption by humans (Binford & Bertram, 1977: 104). The Navajo collection used here combines Binford and Bertram's two winter and summer site collections, to make it more comparable with Brain's general village refuse, which was not restricted to a season.

BINFORD AND BERTRAM'S (1977) COLLECTION OF SHEEP BONES  
FROM TWO NAVAJO SETTLEMENTS, BRAIN'S (1969) COLLECTION  
OF GOAT BONES FROM HOTTENTOT VILLAGES, AND THE  
SHEFFIELD SHEEP COLLECTION

Table 11:2 presents a Spearman's rank order correlation analysis of element frequencies in the collections of bones from the Hottentot and Navajo settlements, and shows that they correlate strongly:  $Rho=0.63$ ,  $n=24$ ,  $p<0.01$ .

The main differences between the two collections are:

(1) the relative frequencies of lower limb elements (especially metapodials), which are far more frequent in Brain's collection of Hottentots' goat bones than in the Navajo settlements, and

(2) the relative frequencies of elements with low bulk densities (i.e. proximal tibia, cervical and lumbar vertebrae and ribs) which are far more common in Binford and Bertram's collection of Navajos' sheep bones.

Both of these characteristics may be explained by taphonomic

factors, i.e.: the difference in lower limb representations may be due to different methods of butchery and/or of discard of butchery waste. It is also possible that the lower limbs have been removed by dogs more often from the Navajo sites, but this is unlikely since the higher frequencies of the 'susceptible' element parts in the Navajo collection suggest that this collection has undergone less intensive destruction by humans and/or dogs than has the Hottentot goat bone collection.

That these two collections are general collections, and not specialised carcass remains or carnivore collections is demonstrated by comparisons with the Sheffield data.

Table 11:3 presents a Spearman's rank order correlation analysis of Brain's Hottentots' goat bones with the total Sheffield sheep collection. The correlation is strong:  $Rho=0.76$ ,  $n=25$ ,  $p<0.01$  and the minor differences can be explained by the greater intensity of attack undergone by the goat bones (see above). If the Hottentots' goat collection is compared with the Sheffield sheep carcass collection, the correlation is reduced considerably (although it is still statistically significant at the  $p<0.01$  level of confidence:  $Rho=0.56$ ,  $n=25$ ).

#### THE MAKAPANSGAT ASSEMBLAGE OF FOSSIL UNGULATE BONES

Brain (1969) suggested that the Makapansgat cave assemblage of fossilised ungulate bones was similar to the 'generalised' human and carnivore refuse assemblage from the Hottentot villages, and a Spearman's rank order correlation analysis shows that there is,

indeed, a strong correlation between the element frequencies in these two collections:  $Rho=0.81$ ,  $n=25$ ,  $p<0.01$ . The element frequencies of the Makapansgat collection are also strongly correlated with those of the total Sheffield sheep collection:  $Rho=0.72$ ,  $n=25$ ,  $p<0.01$ , but have almost no correlation at all with those of the Sheffield sheep carcass collection:  $Rho=0.04$ ,  $n=26$ ,  $p>0.05$ . That is, the Makapansgat assemblage is definitely not composed of the remains of scavenged carcasses.

A further analysis compares it with the remains of caribou bones recovered from the Bent Creek wolf den collection (Binford, 1981). Table 11:4 uses a Spearman's rank order correlation analysis to compare the element frequencies in the Makapansgat assemblage with those from this known wolf den, and the result shows a very strong correlation:  $Rho=0.87$ ,  $n=24$ ,  $p<0.01$ .

There is a very large anomaly between the ranking of the atlas in the two assemblages (the atlas is placed ten ranks higher out of 24 places in the wolf den assemblage). The reasons for this discrepancy are unknown, but the atlas was also one of the greatest 'non-conformist' elements in the analysis comparing Binford's wolf den collection with the Sheffield sheep fox den sub-collection. In this analysis, the atlas also ranked particularly high in the wolf den collection (i.e.: 12.5 ranks above its position in the fox den collection,  $n=27$ ). It appears, therefore, that, like the anomalous frequency of the scapula in the Sheffield sheep collection, the atlas has an atypical position in Binford's caribou collection. In Binford's collection, the atlas appears to be associated with the skull, i.e.: skull,  $BI=48.0$ ; atlas,  $BI=52.0$ ; compared with the axis,  $BI=74.0$ , but it is unknown whether or not this association occurs in Brain's

collection, since he does not give frequencies for the skull.

Because of the very large anomaly caused by the atlas in the comparison of the Makapansgat and caribou assemblages, it has been omitted from a replicate analysis, in which the correlation between the two collections becomes even stronger:  $Rho=0.92$ ,  $n=23$ ,  $p<0.01$ .

Although Brain correctly suggested that specific gravity is correlated with element survival, the results from these analyses suggest that the Makapansgat collection represents, not only those elements that survive well due to their dense structure, but a collection of items that were selected by carnivores and taken into a den.

These findings contradict Brain's conclusion that the Makapansgat collection resembled that of the goat bones from Hottentot villages. Brain (1969) believed that he had shown that the relative frequencies of elements in the Makapansgat assemblage were determined mainly by the structure of the bones themselves (i.e.: by their specific gravities), but a comparison of the Makapansgat collection with Lyman's (1982) bulk density figures shows that the correlation, although quite strong, is considerably weaker than that shown by the collection with the wolf den assemblage, i.e.:

Makapansgat & bulk density:  $Rho = 0.60$ ,  $n=23$ ,  $p<0.01$

Makapansgat & wolf den:  $Rho = 0.92$   $n=23$ ,  $p<0.01$

These analyses show how important it is to be aware, not only of the inherent variables that affect element survival, e.g.: size, bulk density, meat cover and marrow content, but also the behavioural factors that can alter the basic pattern caused by these

underlying variables, including: the intensity of scavenging, and the nature of the context of deposition (e.g.: does the collection contain remains of scavenged carcasses, items removed to den sites, or a general, surface collection?).

### CONCLUSION

The analyses in this thesis have shown that certain factors affect the relative survival of elements from ungulate carcasses, even in different continents and habitats. Inherent factors pertain to the nature of the elements themselves and include: size, structure (i.e.: bulk density), fusion state, meat cover and marrow content.

Generally, the effects of these INHERENT variables are:

#### **SIZE**

The smaller the size of an element, the less likely it is to be recovered (due to either: (a) observer bias against small bones, and/or (b) total destruction by carnivores).

#### **BULK DENSITY**

The lower the bulk density value of an element (or element part), the less likely it is to survive carnivore scavenging.

#### **FUSION STATE**

An unfused epiphysis is less likely to survive than is a fused epiphysis.

**MEAT COVER**

An element (or element part) with a larger amount of meat cover is more likely to be attacked.

**MARROW CONTENT**

The greater the amount of marrow content, the more likely an element is to be attacked.

Compounding the effects of these internal variables are the effects of external factors, which include behavioural characteristics of scavengers, and lateral variations in the contexts of re-deposition.

The effects of some of these EXTERNAL variables are:

**INTENSITY OF SCAVENGING**

A more intensive degree of scavenging leads to:

- (A): A higher percentage of elements showing signs of carnivore attack.
- (B): A higher percentage of areas of elements showing signs of carnivore attack.
- (C): A higher percentage of elements missing their epiphyses.
- (D): Fewer elements remaining per individual.
- (E): A greater disparity in element frequencies.
- (F): A greater frequency of splintered bones.

**SPATIAL REDISTRIBUTION**

The element frequencies will also reflect the selection of certain element types by scavengers for removal to quiet areas for consumption. Typical assemblages would be characterised by the following traits:

**Scavenged carcasses:** mainly axial elements, i.e.: vertebrae, head (skull, mandible and hyoid), ribs, and possibly also pelves and sacrum.

**Carnivore dens:** mainly limb bones, especially lower limb bones, with high percentages of elements and element areas showing signs of attack by carnivores.

**Total collections:** all parts recovered, but element frequencies mainly reflecting inherent factors pertaining to the element's size, structure and meat cover.

**IMPLICATIONS FOR ARCHAEOLOGICAL ASSEMBLAGES**

Regarding element survival, all of the inherent factors that pertain to properties of the elements themselves should have obtained for archaeological assemblages. Similarly, the intensity of scavenging should have had similar effects on archaeological assemblages, although these may have been compounded by the effects of human activities such as butchery or breakage for marrow extraction (as noted by Brain (1969)). The agent of element (or element part)

destruction should be identifiable from the marks on the remaining bones, i.e.: most carnivore tooth marks are very distinctive (see Chapter 8), and should be distinguishable from chopped edges.

The spatial distribution of elements on archaeological sites is likely to have been affected by scavenging in similar ways to those noted in this study but, again, may also have been affected by human behaviour patterns. For instance, elements may be sorted by humans prior to their initial disposal (as suggested by Halstead et al 1978) and then redistributed by scavenging dogs.

The patterns of damage to the recovered bones may help to indicate whether or not elements should have survived scavenging, had they been deposited in that area. If the degree of scavenging is slight or moderate, and large element types such as the humerus are completely missing, then it is probable that they were not originally deposited in the excavated area. However, if scavenging has been intense (indicated by the proportion of chewed bones, and the degree of damage to recovered bones), then a lack of the more susceptible elements, such as sternebrae or ribs, does not preclude the possibility that they had been discarded in that area, but have been destroyed by scavengers before they could become buried.

The results of this study suggest that it is possible to identify the remains of whole carcasses that have been redistributed by scavenging canids in three main types of context, i.e.:

- (1) scavenged carcasses (residual items)
- (2) carnivore accumulations (transported items)
- (3) general scatters (a mixture of (1) and (2)).

All three types of context may be found on archaeological

sites and should be indentifiable by the patterns of element frequencies summarised above.

Many sites, or areas of sites, may contain the scavenged remains of carcasses, in which case the element frequencies in the assemblages should resemble those in the Sheffield sheep carcass collection and Binford's (1981) collection of 24 wolf kills of caribou (see Table 11:4).

Similarly, carnivore den assemblages may well occur on archaeological sites. Dogs do not always use subterranean areas as dens, but they do have preferred lying up areas to which they take food to eat in peace, and bitches use sheltered areas in which to bring up their puppies (Beck, 1973). In modern settlements, such quiet areas include sites under steps and in abandoned buildings, and both of these context types are likely to occur in archaeological situations.

The author suggests that occupation of an abandoned building by dogs rather than by humans might be characterised by relative frequencies of elements that resemble those in the Sheffield combined fox den sub-collection and Binford's (1981) wolf den assemblage.

The pattern shown by these assemblages includes the following aspects:

- (A) Large numbers of limb and lower limb elements.
- (B) Very few axial elements.
- (C) A very high percentage of bones showing signs of carnivore damage.
- (D) A low number of elements per individual.

A general scatter of bones remaining from scavenged carcasses should resemble the total Sheffield sheep collection, and

would include both residual and transported items (probably showing differing degrees of damage). In this type of collection, the main influences on element frequencies are inherent factors such as the size, structure and fusion states of the elements themselves.

It should be remembered that, in any scavenged assemblage, unfused epiphyses are likely to have been preferentially destroyed.

The final part of this thesis, Chapter 12, is a case study that considers an archaeological assemblage from a Romano-British military site in West Yorkshire. It is particularly concerned with testing the hypothesis that the Roman army brought entire animals or carcasses into the fort. It also investigates the age structure of the animals, taking the possible effects of selective epiphyseal destruction into consideration.

**CHAPTER 12: AN ARCHAEOLOGICAL CASE STUDY USING DATA FROM  
A ROMANO-BRITISH SITE IN CASTLEFORD, WEST YORKSHIRE, ENGLAND**

**INTRODUCTION**

This chapter applies the results of the actualistic study of fox scavenging of modern sheep and deer carcasses (Chapters 2 - 9), together with the results of the comparisons of these data with those of other studies (Chapters 10 & 11), to some archaeological material recovered from a Romano-British military site in Castleford, West Yorkshire, England.

The site was part of an annexe to a Roman fort, and excavations conducted by the West Yorkshire Archaeological Rescue Unit in the late 1970s recovered over 3,000 animal bones, mainly of cattle and sheep-goat. Many of these bones show signs of having been chewed by carnivores.

The author wished to investigate whether this military site had been self-sufficient in its meat supplies, or whether the army had acquired animals (and/or meat) from elsewhere. In order to do this, the author had to ascertain:

- (1) Whether whole animals were represented at the site or only selected joints of meat.
- (2) The age groups of the animals represented.

Since dog bones are present in the collection, and marks of carnivore teeth are quite frequent on the bones of other species, the author was aware that the investigation of these two questions would require an assessment of how badly, and in what ways, scavenging by

canids might have biased the relative frequencies of different element types and of bones of different age groups.

Specific questions that are investigated in this case study are:

QUESTION 1: Have the bones been scavenged by canids?

QUESTION 2: Do the frequencies of elements resemble those in the Sheffield sheep collection?

QUESTION 3: Do the frequencies of elements resemble those in Brain's (1969) collection of goat bones from Hottentot villages?

QUESTION 4: Has there been a bias against the preservation and recovery of the bones of younger individuals?

The results of the analyses suggest that:

(1) Whole carcasses of cattle and of sheep-goat were deposited at the site, and the relatively low frequencies of certain element types of both species can be explained by a bias against the recovery of smaller bones during the excavation, together with the preferential destruction or fragmentation of certain element types by scavenging canids, and people.

(2a) The age groups of sheep-goat bones recovered in the collection are widespread and include those of young and very old animals. The sheep-goat, therefore, may have been raised by the military based at the site.

(2b) The age ranges of the cattle bones recovered tend to be more

restricted, coming mainly from adult animals, with very few young animals represented. Many of the cattle, therefore, may have been bought in (either as carcasses or as live animals), rather than raised by the military.

Without an assessment of the role of scavenging canids at Romano-British Castleford, these analyses would have had very different results, since: (1) the recovered element types (of sheep-goat in particular, but also of cattle to some extent) suggest that only selected body parts were deposited at the site, and (2) the post-cranial ageing data (using fusion age criteria) are ambiguous and difficult to interpret.

The results of an experimental use of midshaft diameters of longbone and girdle elements in this study suggest that this method has considerable potential in analyses of age, size and sex distributions of archaeological fauna, even when the material has been scavenged by canids.

### THE SITE, METHODOLOGY AND MATERIALS

#### The Romano-British site of Castleford, West Yorkshire

The material used in this case study comes from Romano-British deposits in Castleford, West Yorkshire (see Figure 1:1 for a location map). The site (Castleford Site 1) was excavated in the late 1970s by the West Yorkshire Metropolitan County Council as part of a rescue programme for urban archaeology.

Castleford Site 1 was part of the annexe to a Romano-British

fort, and was occupied for a few decades in the late First Century AD. It is situated close to the River Aire and the soils are mainly clays, with some areas of sands or gravels.

The excavated material comes from a variety of context types including ditches, pits, road surfaces, a turf-built rampart, a latrine and an assortment of small linear features.

The site was excavated using picks and shovels and by trowelling, and the soil was not sieved. Experiments conducted by Payne (1972) and Levitan (1982) showed that many of the smaller bones present at a site are not recovered unless the soil is sieved. Therefore, it is very probable that small elements and fragments are underrepresented in the Castleford collections.

#### Recording methods for the archaeological data

##### Fragment shapes

The animal bones were identified by the author, and the shapes of the fragments of sheep bones were recorded on the same series of printed sheets as those used for the Sheffield sheep bones. Fragments of cattle, pig, horse and dog bones were recorded on similar sheets drawn for each species by the author for a future study comparing butchery patterns for bones of different species.

For Castleford Site 1 a maximum of 25 bones was recorded for each element type of each species from each context. This limit was imposed to reduce any redundancy of data, but was never reached by any of the sheep elements, and only by the commonest of the cattle

elements.

### Element frequencies

All data were recorded in numerical codes and processed on a Prime computer at the University of Sheffield, using procedures within the Statistical Packages for Social Sciences (SPSS) (Nie et al 1975). An interface system of callipers and teletype failed to materialise for several months, and then failed to work, so all data were recorded by hand on computer data sheets and then typed up by staff in the Dept. of Computer Science (to whom I am extremely grateful).

Minimum Numbers of Elements (MNEIs) had to be calculated after the material had been recorded, as the accession numbers of the finds bags did not permit visual grouping of remains from single contexts during the identification period. In order to establish Minimum Numbers of Elements, only fragments retaining fifty percent or more of their original lengths have been counted. This is to avoid over counting of fragmented bones.

### Details of the variables used in this study

#### **Columns 12-14: Species identifications**

Some fragments could not be assigned to species. These were identifiable as mammal, bird etc., and the mammal bones were attributed to a size category such as 'cattle-sized', 'sheep-sized',

'rabbit-sized' etc.. Since there are no examples of roe deer at the site, and all identified dog vertebrae are intact, the 'sheep-sized' ribs and vertebrae have been assumed to be almost entirely from sheep, although it is possible that a few comminuted fragments of young pig have been incorrectly included in this category.

#### **Columns 15-17: Element type**

Elements that were commonly recovered as fragments were recorded as parts or as totals, i.e.: long bone fragments could be recorded in one of four ways:

- (1) proximal epiphysis plus or minus shaft,
- (2) shaft only,
- (3) distal epiphysis plus or minus shaft, and
- (4) proximal and distal epiphyphyses both present

(N.B. if the bone was unfused, the fusion surface was substituted for 'epiphysis'). Scapulae, pelves and skulls were recorded in similar ways. The femur had an extra category of

- (5) 'shaft only, but including the supracondylar fossa'.

This is often the most frequently surviving diagnostic area for femur fragments, and was utilised in calculations of Minimum Numbers of Elements (MNEs).

#### **Column 19: Completeness category**

This variable is exactly the same as that used for the modern Sheffield sheep bones. That is, fragments were classified as retaining 1-25%, 26-50%, 51-75%, 76-99% or 100% of their original total length (completeness categories 1, 2, 3, 4 and 5, respectively).

**Columns 20-22: Fusion**

The three columns represent: 20-the proximal epiphysis; 21-the proximal tuberosity (for the humerus, femur and tibia); and 22-the distal epiphysis, for each longbone element. Fusion surfaces of other bones, e.g.: vertebrae and the pelvis, are assigned in similar ways. 'Fusion' is classified in the same way as for the Sheffield sheep bones. That is, a fusion surface is recorded as 'fully fused'; 'fused, but with the fusion line still visible'; 'in the process of fusing'; or 'unfused'.

**Columns 60-61: Chewing**

These two columns record the type and the location of chewing marks, respectively. Types of chewing effects are similar to those recorded for the modern Sheffield sheep and are defined in Chapter 3.

**Column 68: Size group**

Each fragment was assigned to a size group on the basis of its maximum dimension. The groups are in units of fifty millimetres:

GROUP	MAXIMUM DIMENSION
1	1-50 mm
2	51-100 mm
3	101-150 mm etc..

### The materials

Over 3,000 animal bones were recovered from stratified Romano-British contexts, and nearly all of them are in a good state of preservation. Their surfaces are seldom eroded, although several fragments have encrustations of concreted sands and gravels (see Stallibrass, 1985, for an analysis of preservation conditions).

The collection is dominated by the bones of domestic mammals, especially cattle and, to a lesser extent, sheep-goat. This study restricts itself to considerations of the cattle and sheep-goat bones. Bones of the third most frequent species, pig, are not discussed since the sample size is very small (the number of identified fragments of pig = 144, see Table 12:1).

### THE QUESTIONS

QUESTION 1: HAVE THE BONES BEEN SCAVENGED BY CANIDS?

### Results

The excavations of Castleford Site 1 recovered 3346 bones fragments, nearly all of which derive from mammals. Table 12:1 presents the frequencies of fragments identified to species or faunal group together with the numbers of chewed fragments. Of the 3293 mammal bone fragments, 200 (i.e.: 6%) have been chewed.

Evidence for the presence of dogs

Sixty-six dog bones were recovered from the site, generally mixed in with the bones of other species.

A minimum number of seven individuals are represented by right mandibles. Shoulder heights have been calculated from the complete lengths of longbones, using the indices published by Harcourt (1974). The results, from nine longbones, are:

ELEMENT	SHOULDER HEIGHT(S) (IN CENTIMETRES)
Humerus	36
Radius	35, 37
Ulna	36
Femur	39
Tibia	29, 32, 37, 43

These heights range from that comparable to that of a small terrier, to that of quite a large dog, likely to have weighed approximately 16 - 18 kilogrammes. Only one of the 66 dog bones shows signs of having been chewed.

The only other carnivore species represented in the faunal remains at the site is the cat (four identified fragments). It is unlikely that any major form of damage to sheep-goat or cattle bones has been caused by this species since its teeth are so small compared to the size of the bones of the 'prey' species.

The only other species likely to have scavenged animal bones are humans and pigs. It was beyond the scope of this study to investigate the effects that scavenging pigs might have on the bones of other species. Since the toothmarks observed on the Castleford Site 1 material are very similar to those observed in the actualistic

study, they are considered to have been caused by canids (probably domestic dogs rather than wolves or foxes), either during the use or shortly after the abandonment of the site.

### Rates of chewing

The rates of chewing vary quite considerably between the species, which may indicate that they were disposed of in different ways: cattle = 5.65%, pig = 9.72%, sheep-goat = 14.58%. Most of the cattle sized, pig sized and sheep-goat sized bone fragments are splinters, and the comparative paucity of chewing evidence on these bones (i.e.: only 3% - 4%) may be due to the nature of the fragmentation. Kent (1981) and Haynes (1980) both note that splintering of bones by canids often fails to leave any obvious diagnostic marks on the bones. Splintered bones were not observed in the modern collection of sheep bones, and so the author does not have any directly comparable data.

Some element types were chewed more frequently than others. Of the sheep-goat bones, the mandibles were chewed very rarely, i.e.: only one bone out of 55 (2%) (see Table 12:2). This contrasts strongly with the modern Sheffield sheep data, and may indicate that mandibles (and, possibly, head bones generally) were disposed of quickly after the animal was killed or butchered, without access by scavenging dogs. In contrast, sheep-goat limb bones tended to suffer much higher rates of chewing, i.e.: humerus = 26%, radius = 29%, metacarpal = 21%, pelvis = 19%, femur = 16%, tibia = 18% and metatarsal = 32%. A similar pattern is shown by the cattle bones (see Table 12:3).

### Patterns of damage

The chewing marks and some of the fragmentation patterns observed on the Castleford Site 1 sheep-goat bones are very similar to those noted in the Sheffield sheep collection (particularly to the more severe cases, in which epiphyses have been removed or destroyed). Plates 12:1, 12:2 and 12:3 show examples of chewed humeri, radii and femora, respectively. In each case, one example is from the modern Sheffield sheep collection whilst the other is Romano-British. All three plates demonstrate how similar some of the forms of damage are in the ancient and modern examples.

Several of the cattle bones also exhibit clear traces of having been chewed by carnivores. Again, the patterns match those observed in the actualistic study, but in this case they tend to resemble the less severe examples of modern damage (probably due to their greater size).

### Causes of fragmentation

Some of the fragmentation of the Castleford Site 1 bones is due to butchery rather than to chewing. Table 12:2 presents the frequencies of chopped fragments for sheep-goat and cattle in the Castleford Site 1 collection, using the twelve medium or large sized element types that were defined in the actualistic study (see Chapter 10 and Table 10:2). Sample sizes for the smaller element types tend to be very small, particularly for the sheep-goat bones, and have not been used in all of the following analyses.

Unlike the Sheffield sheep collection, which was not butchered in any way, many of the Castleford animal bones have been chopped through, either transversely or, less commonly, longitudinally (or both). Twenty-five percent of the total sheep-goat bones and 48% of the sheep-goat sized fragments have been chopped through. The 'cattle' bones show higher rates, i.e.: 49% of the total cattle fragments have been chopped through, and 69% of the cattle-sized fragments. This contrasts with the rates of chewing, which are considerably higher for the sheep-goat than for the cattle bones.

### **Sheep-goat fragments**

Figure 12:1 presents a scattergram of the relationships between the degree of completeness (using the ratios of Whole Bone Equivalents to total fragment numbers (WBE/N ratios)) and the percentages of fragments that have been chewed or chopped through for the eleven medium or large sized element types recovered in the Castleford sheep-goat collection (no examples of the twelfth element type, the sacrum, were found). These data are also given in Table 12:3. A Spearman's rank order correlation analysis shows that the WBE/N ratios are positively correlated with the percentages of element fragments chewed:  $Rho = 0.75$ ,  $n = 11$ ,  $p < 0.01$ . That is: the more fragmented the bones are, the less likely they are to show signs of having been chewed.

A similar analysis shows that there is no significant correlation between the WBE/N ratio and the percentages of fragments of element types that have been chopped through:  $Rho = -0.09$ ,  $n = 11$ ,

$p > 0.05$ . The results of this analysis suggest that the major cause of fragmentation is not chopping (unless this was achieved by crude bone smashing using a blunt instrument). Alternative possible causes include trampling, and scavenging by canids.

Experiments by Davies (1984) showed that whole long bones of modern sheep resist trampling pressure by a human and are unlikely to break. However, it is possible that butchered bones, such as some of those found at Castleford, present less resistance than whole bones, and it is also likely that some bones were subjected to trampling by large hoofed mammals (such as horses and cattle), which would have exerted greater pressure than Davies.

The results of the first analysis (showing that the more fragmented bones show less frequent evidence of chewing) are compatible with the effects of scavenging canids as a major influence on bone breakage. It was predicted in Chapter 9 that the dogs at Castleford would have been able to inflict greater damage than that observed in the modern study, due to the different size ratios of the canids and ovicaprids concerned. The observations made by Kent (1981) and Haynes (1980), mentioned above, suggest that a greater comminution of longbone shafts need not be accompanied by a corresponding increase in the frequency of toothmarked fragments, and this might explain the frequent recovery of splintered but unmarked fragments of sheep-goat and sheep-goat sized longbone shafts.

N.B. In subsequent studies, the author has recorded whether or not each longbone fragment retains its full circumference (for at least a part of its length). This variable reflects the degree of splintering in an assemblage, and would be pertinent to this discussion. Its usefulness was indicated by the results of this study, but the extra

information that it would confer is not sufficient to warrant a full reanalysis of the material.

Of the three causes of fragmentation considered here, therefore, chopping is definitely responsible for some of the breakage (i.e.: for those fragments that have been chopped through), and trampling has probably contributed to some extent, but scavenging by canids is probably the major influence involved.

### **Cattle fragments**

In Chapter 9 it was suggested that the relatively minor degree of damage observed in the Sheffield sheep collection when compared to that observed to have been inflicted by large dogs on modern goat carcasses by Payne and Munson (1985) might be due to the ratios of body size of the scavenging canid and 'prey' species. That is, the degree of damage observed in the Sheffield sheep collection of modern sheep scavenged by foxes might be more comparable to that inflicted by Romano-British dogs on cattle bones rather than on 'unimproved' sheep bones. If this is the case, the dogs are unlikely to have splintered the shafts of cattle longbones to any great degree.

Figure 12:1 presents a scattergram of the relative intactness of the twelve medium or large element types of cattle bone collected at Castleford Site 1, together with the percentages of chewed examples and of chopped examples of these element types. The raw data for this figure (for both species) are given in Table 12:3.

A Spearman's rank order correlation analysis shows that there is an almost total lack of any statistical correlation of the

WBE/N ratio for cattle bones with the percentages of element types chewed:  $Rho = -0.05$ ,  $n = 12$ ,  $p > 0.05$ , but a similar analysis shows that there is a strong, inverse, correlation between the WBE/N ratios and the percentages of chopped fragments:  $Rho = -0.71$ ,  $n = 12$ ,  $p < 0.01$ . That is, for the cattle bones, the degree of fragmentation appears to be due mainly to butchery by humans rather than to damage by scavenging canids, whilst the reverse is true for the sheep-goat bones. It was noted, above, that the average rates of chopped fragments are also considerably higher for the cattle and cattle-sized assemblages than for the sheep-goat and sheep-goat sized assemblages, and this fact emphasises the greater role of butchery in the fragmentation of the cattle bones.

### Conclusions

Some of the Castleford Site 1 animal bones have been scavenged by dogs. The remains of at least seven dogs have been found in the collection, and many of the bones of other species show carnivore toothmarks similar to those observed on the modern fox-scavenged bones in the Sheffield sheep collection.

There are significant differences in the rates of damage by scavenging dogs observed on the sheep-goat and cattle bones in the Castleford collection, i.e.:

- 1) the fragments of sheep-goat bones have a higher average rate of chewing (15%) than do those of cattle (6%), and
- 2) the degree of fragmentation of sheep-goat bones is strongly correlated with the frequency of chewing marks, but not with

the frequency of being chopped through.

- 3) In contrast, the degree of fragmentation of cattle bones is strongly correlated with the frequency of being chopped through, but not with the frequency of chewing marks.
- 4) Average rates of chopping are also much higher for the cattle and cattle-sized fragments than for the sheep-goat and sheep-goat sized fragments.

These results indicate that the degree of damage caused by dogs to sheep-goat bones is considerably more intense than that caused to cattle bones. This is probably due to the sizes of the scavenging dogs in relation to those of the 'prey' species. It is also possible that bones of the two species were disposed of in different ways, with the sheep-goat bones being more accessible to dogs. A future study might be able to link the types of species and element with those of depositional context, but previous work (Stallibrass, 1985) suggests that diagenetic biases caused by varying preservation conditions associated with the different context types may preclude this refined form of analysis at Castleford Site 1.

QUESTION 2: DO THE FREQUENCIES OF ELEMENTS RESEMBLE THOSE IN THE SHEFFIELD SHEEP COLLECTION?

The calculation of element frequencies

The Castleford site 1 animal bones are far more fragmented than were the Sheffield sheep bones, and it cannot be assumed that each fragment represents an individual bone. Using the 26 main element

types: there are 527 fragments of sheep-goat bones with a Minimum Number of Elements of 212 (i.e.: 2.49 fragments per element); and there are 1647 fragments of cattle bones representing 700 elements (i.e.: 2.35 fragments per element).

Using the Whole Bone Equivalent to fragments ratios (WBE/N ratios) for the twelve medium or large element types, Tables 12:2 and 12:3 show that the degrees of fragmentation vary considerably, even between different types of longbone.

A variety of agencies can fragment bones on archaeological sites, e.g.: butchering by humans, fracturing by humans for marrow extraction, scavenging by canids, trampling by people and animals, compaction in the soil after burial, damage during excavation, etc..

In order to avoid biases due to differential fracturing, either between element types, species types, or collections, it is necessary to standardise frequencies to Minimum Numbers of Elements (MNEIs) before element frequencies are compared. To do this, two methods have been used in this study:

- 1) the counting of the most commonly occurring diagnostic part of an element (e.g.: an epiphysis, foramen, muscle attachment, or measuring location), and
- 2) the use of Whole Bone Equivalents (WBEs) (used in this study only for rib fragments, which tend to lack diagnostic areas in this collection).

Table 12:6 presents the areas used for the estimates of Minimum Numbers of Elements for the 12 medium or large element types of both sheep-goat and cattle. It is clear that the midshaft is often the best preserved diagnostic area of sheep-goat longbones (as it is in the Sheffield sheep collection; see Figure 9:1 and Table 9:2),

whilst this is never the case for the cattle bones. This difference may be the result of several factors including: (1) the preferential loss of sheep-goat epiphyses (due to their smaller sizes), and (2) the preferential fragmentation of cattle longbone shafts (indicated by the greater frequency of fragments showing signs of having been chopped through longitudinally, see below: QUESTION 4).

For both species, the minimum number of ribs is greater using Whole Bone Equivalents (WBEs) than by counting the most diagnostic portion (the articular head of the bone), i.e.: sheep-goat: number of articular heads = 19, WBE = 23; cattle: number of articular heads = 31, WBE = 61. This contrasts with the Sheffield sheep collection, in which nearly all rib fragments retain their articular heads. One factor that may have influenced this different pattern of survival concerns patterns of disarticulation. In the Sheffield sheep study, it was observed that the scavenging foxes tended to attack bones at their epiphyses or muscle attachments (see Chapter 8). It was also observed (see Chapter 4) that ribs tended to stay articulated for a relatively long period to the thoracic vertebrae. Whilst articulated, the vertebral processes protect the articular heads of the ribs from attack, which would explain why most ribs are damaged at their sternal ends. If ribs were disarticulated from the thoracic vertebrae before being discarded at Castleford Site 1, scavenging dogs would have had access to the whole ribs, including the articular heads, which might have attracted considerable damage due to their muscle attachments.

Tables 12:4 and 12:5 and Figure 12:2 present the Brain's Index values of the 26 element types of sheep-goat and cattle bones that were recovered from Castleford Site 1. These data should be

compared with those presented in Tables 4:1 and 4:2, Table 10:1 and Figure 10:1, for the modern collection of Sheffield sheep bones that have been scavenged by foxes.

### Results

#### Brain's Index values of sheep-goat bones at Castleford Site 1 compared with those of the Sheffield sheep collection

Figure 12:2 shows that a preponderance of jaw, girdle and limb bones of sheep-goat were recovered at Castleford Site 1, with axial/thoracic and foot bones very poorly represented.

N.B. it should be noted that fragments of ribs are, in fact, quite numerous (ribs account for 156 out of 527 fragments, see Figure 12:2) but are probably underrepresented by the use of the Whole Bone Equivalent method of estimating the minimum number of elements. The use of the diagnostic portion (the articular head), would have reduced the Brain's Index value even further: from  $BI=0.06$  to  $BI=0.05$ .

Visually, this collection appears to resemble the transported collection of sheep bones (see Figure 6:5) more than the total Sheffield sheep bone collection (see Figure 10:1), but a series of Spearman's rank order correlation analyses shows that this is not the case, although the results are very close (and both are more significant than is a comparison with the residual material).

Cas. 1 S-G & total Sheffield sheep:  $\text{Rho} = 0.85$   $n=26$   $p<0.01$   
Cas. 1 S-G & transported Sheffield Sheep:  $\text{Rho} = 0.80$   $n=26$   $p<0.01$   
Cas. 1 S-G & residual Sheffield Sheep:  $\text{Rho} = 0.64$   $n=26$   $p<0.01$

Key: Cas. 1 S-G = Castleford Site 1 sheep-goat collection

The main differences in the element frequencies of the total and residual versus the transported assemblages of Sheffield sheep concern the axial/thoracic element types, especially the ribs and vertebrae. Fragments of ribs in the Castleford sheep-goat collection are quite common (see above), and probably are severely underrepresented by the calculation of Minimum Numbers of Elements. The main differences between the Castleford and total Sheffield sheep collections, therefore, are the paucities of vertebrae, and of the smaller, end-of-limb bones (such as the astragalus, calcaneum, navicular-cuboid and phalanges).

Payne (1986, pers. comm.) and Coy (1986, pers. comm.) have both noted that modern large dogs are quite capable of consuming totally the vertebrae of modern sheep.

The paucity of small ankle/wrist or foot bones, and of axial/thoracic elements in the collection of sheep-goat bones from Castleford Site 1, therefore, may be due to a stronger size bias operating at Castleford Site 1 than in the Sheffield sheep collection due, possibly, to recovery difficulties during the excavation, and/or to the smaller size of the Romano-British sheep (see below).

Brain's Index values for cattle bones at Castleford Site 1 compared with those of the Sheffield sheep collection

Figure 12:2 shows a pattern of element recovery for cattle bones that is very similar to that shown in Figure 10:1 for the total Sheffield sheep collection and, again, a Spearman's rank order correlation analysis of the Brain's Index values shows that this correlation is quite close:

Cas. 1 cattle & total Sheff. sheep:  $Rho = 0.83$   $n = 26$   $p < 0.01$ .

As with the sheep-goat material, however, the Castleford Site 1 cattle bones have Brain's Index values slightly closer to those of the transported collection than the residual or total collections:

Cas. 1 cattle & transported Sheff. sheep:  $Rho = 0.86$   $n = 26$   $p < 0.01$

Cas. 1 cattle & residual Sheff. sheep:  $Rho = 0.60$   $n = 26$   $p < 0.01$ .

Again, this may be due to recovery techniques favouring the larger element types and mimicking the transported assemblage, but it is also possible that vertebrae were deposited elsewhere on (or even off) the site.

Element frequencies for sheep-goat and cattle bones at Castleford Site 1 and their relationships with average intact sizes and with bulk density values (using Lyman, 1982).

Other factors that may have influenced the frequencies of element types in the Castleford Site 1 sheep-goat and cattle bone collections are: (1) a size bias against the recovery of smaller bones, and (2) differential rates of diagenesis in the soil, represented by the bulk density values of the different element types (using Lyman's 1982 figures).

1) The operation of a size bias in the recovered collections

Spearman's rank order correlation analyses show that the frequencies of elements (using Brain's Index values) of both sheep-goat and cattle are correlated significantly with their average intact sizes.

Cas. 1 sheep-goat BI & intact size:  $Rho = 0.76$   $n = 26$   $p < 0.01$

Cas. 1 cattle BI & intact size:  $Rho = 0.68$   $n = 26$   $p < 0.01$

The correlation of element size and frequency is stronger for the sheep-goat collection than for the cattle collection, suggesting that there is an absolute size threshold for recovery (i.e.: if everything below a certain size is likely to be overlooked by the excavators, more of the sheep-goat elements will be disadvantaged, due to the overall smaller body size of the species). It is also possible that

the smallest element types tended to be consumed by the dogs (see Chapter 9).

Figure 12:3 shows the relationships of the Castleford Site 1 sheep-goat and cattle Brain's Index (BI) values with those of the total Sheffield sheep collection. There is a dense cluster of 16 element types for sheep-goat bones that have Brain's Index values of  $<0.10$  in the Castleford Site 1 collection, and which have higher BI values in the Sheffield sheep collection. These 16 element types are: the hyoid, sternbrae, the patella, medial phalanges, distal phalanges, the calcaneum, proximal phalanges, ribs, the navicular-cuboid, thoracic vertebrae, the astragalus, the axis, the sacrum, cervical vertebrae and lumbar vertebrae. Fourteen of these element types are 'small' (see Table 10:2) and the remaining two types, i.e.: ribs and the sacrum, are both heavily reduced in size (both in the Castleford Site 1 collection and in the total Sheffield sheep collection: see Figure 7:4).

That is, the size bias against the recovery of small bones appears to have been stronger in the Castleford Site 1 collection than in the Sheffield sheep collection, probably due either to: (1) collection techniques, and/or to (2) a greater degree of destruction due to the greater size of the dogs in relation to that of the sheep in the two collections.

The Brain's Index values of elements in the Castleford Site 1 cattle collection, however, show a close correlation with those in the total Sheffield sheep collection. This result suggests that the cattle bones at Castleford Site 1 have suffered less from a bias against the recovery of small bones than have those of sheep-goat at the same site. This is compatible with the size differences between

the two species. The results also support the prediction made in Chapter 9 (on the grounds of comparative body sizes), that the degree of damage inflicted by dogs on the bones of Romano-British cattle might be similar to that observed on the bones of modern hillsheep scavenged by foxes.

Figure 12:3 shows two element types of cattle that do not fit the general correlation. These are: the scapula and the tibia. The scapula is unusually frequent in the Castleford Site 1 collection, for an unknown reason. The tibia is relatively less frequent in the Castleford Site 1 collection than in the total Sheffield sheep collection, but may be underrepresented by the Brain's Index value, since one large context (a ditch) contained many tibia shaft fragments that had been chopped through longitudinally. Many of these longitudinal fragments retain less than one half of their original length and are, therefore, excluded from the calculation of the Minimum Number of Elements (from which the Brain's Index values are calculated).

## 2) The relationships of element frequencies with their bulk density values (using Lyman, 1982)

Spearman's rank order correlation analyses show that element frequencies and bulk density values (using Lyman, 1982) do have statistically significant correlations. However, the Rho values are less than those in the analyses that compared Castleford Site 1 element frequencies with those in the Sheffield sheep collections, or with average intact sizes, i.e.:

Cas. 1 S-G BI and bulk density values:  $Rho = 0.56$   $n = 23$   $p < 0.01$

Cas. 1 cattle BI & bulk density values:  $Rho = 0.46$   $n = 23$   $p < 0.05$

Although element frequencies, therefore, are related to bulk density values, it is clear that bulk density is not the dominant factor regarding element frequencies in either the sheep-goat or the cattle collections from Castleford Site 1.

### Conclusions

The element frequencies of sheep-goat and cattle bones, recovered from Castleford Site 1, correlate strongly with those in the Sheffield sheep collection. The sheep-goat collection appears to have suffered a greater degree of bone loss than that observed in the Sheffield sheep collection, due to a combination of a greater degree of destruction by canids and a greater bias against the recovery of smaller bones. The greater degree of destruction was predicted (in Chapter 9) from the estimated size ratios of the canids and ovicaprids concerned. The level of influence (or relevance) of bulk density appears to be lower than that of either: (1) canid scavenging, or (2) a size bias.

The pattern of element frequencies of sheep-goat bones resembles the transported collection of Sheffield sheep bones slightly more than the total collection, but the difference is very small and may not be significant. The apparent similarity may be due to the greater influences of the size and scavenging biases in the Castleford Site 1 collection, which may mimic the lack of smaller bones

(including vertebrae) observed in the transported collection. Alternatively, the paucities of vertebrae and articular heads of ribs may be due to their having been deposited elsewhere.

The cattle bone collection has a pattern of element frequencies that is very similar to that observed in the Sheffield sheep collection, and has suffered less than the sheep-goat collection from a bias against the preservation and/or recovery of smaller elements. The close similarity of the two collections was predicted in Chapter 9 on the basis of body size ratios. Again, the results of analyses using the transported and total Sheffield collections are extremely similar, and the comparative paucity of vertebrae and rib articulations may be explained in a variety of ways.

Apart from the vertebrae and rib heads (which may have tended to be deposited elsewhere), remains of whole carcasses of both sheep-goat and cattle appear to have been deposited in the excavated area.

QUESTION 3: DO THE FREQUENCIES OF ELEMENTS RESEMBLE THOSE IN BRAIN'S (1969) COLLECTION OF GOAT BONES FROM HOTTENTOT VILLAGES?

### Results

#### Frequencies using epiphyses

Table 12:7 presents the frequencies of epiphyses (including unfused fusion surfaces) for the Castleford Site 1 sheep-goat and

cattle bones, and should be compared with Table 11:3 for data regarding Brain's (1969) collection of goat bones from Hottentot villages.

Spearman's rank order correlation analyses show that the frequencies of element types and parts of both sheep-goat and cattle bones from Castleford Site 1 are very similar to those recovered by Brain (Brain, 1969: Table 1):

Cas. 1 S-G and Brain's goats:  $Rho = 0.84$   $n=25$   $p<0.01$

Cas. 1 cattle & Brain's goats:  $Rho = 0.88$   $n=25$   $p<0.01$

In Brain's modern study, he knew from the villagers that the remains of whole carcasses had been deposited in the area (i.e.: people had not traded joints of meat into or out of the area). The differential representation of these epiphyseal portions of the bones, therefore, was due to preferential consumption (by humans and/or by dogs), burial and recovery. These agencies are also known or likely to have been operative at Castleford Site 1, and the similar frequencies, therefore, suggest that the remains of whole carcasses of sheep-goats and cattle were also deposited at Castleford Site 1, rather than selectively traded joints of meat. There are no particularly anomalous element types or parts in either of these analyses and, therefore, it is probable that vertebrae and ribs of both sheep-goat and cattle were deposited in the excavated areas of Castleford Site 1, and that their poor representations in the recovered collections are due to taphonomic factors such as scavenging, butchery and diagenesis, rather than to differential spatial disposal.

The correlations of the frequencies of elements and element

parts in the two Castleford collections with those in the total Sheffield sheep collection are not quite so close as those with Brain's goat collection, possibly due to the comparatively slight level of alteration caused by the scavenging foxes to the hillsheep bones:

Cas. 1 sheep-goat BI and tot. Sheff. sheep:  $Rho=0.67$   $n=25$   $p<0.01$

Cas. 1 cattle & total Sheff. sheep BIs:  $Rho=0.69$   $n=25$   $p<0.01$

The stronger correlations of the Castleford and Hottentot data may be due to, for instance, either: (1) the addition of human influence to that of canids, or (2) a higher level of destruction (regardless of the agent(s) involved).

In comparisons with data gathered by other authors, it was shown (in Chapter 11) that the degree of destruction observed in the Sheffield sheep collection is relatively slight compared to that which canids are capable of inflicting. The following series of analyses investigate the role of differing levels of destruction. They have been restricted to the proximal and distal ends of the six major longbone elements, in order to eliminate the problem of different degrees of bias against the recovery of smaller element types. It can be seen that the frequencies of these twelve element parts in Binford's (1981) collection of wolf-killed caribou bones correlate more closely with the Castleford data than do the frequencies in the Sheffield sheep collection:

Cas. 1 sheep-goat & Brain's goat bones:	Rho = 0.79	n=12	p<0.01
Cas. 1 sheep-goat & Binford's caribou:	Rho = 0.64	n=12	p<0.05
Cas. 1 sheep-goat & total Sheffield sheep:	Rho = 0.51	n=12	p~0.05
Cas. 1 cattle & Brain's goat bones:	Rho = 0.91	n=12	p<0.01
Cas. 1 cattle & Binford's caribou:	Rho = 0.76	n=12	p<0.01
Cas. 1 cattle & Total Sheffield sheep:	Rho = 0.66	n=12	p<0.05

N.B.: These analyses were conducted using raw frequencies, but would have given identical results if Brain's Index values had been used, since there are identical numbers of each of these epiphyses in any individual.

The Castleford sheep-goat and cattle bones show identical patterns, with the correlations being strongest with Brain's (1969) collection, quite strong with Binford's (1981) collection, and least strong with the Sheffield sheep collection. In each case, the cattle collection shows a higher value of Rho than does the sheep-goat collection.

Binford's (1981) collection of caribou bones has suffered a greater degree of destruction than that observed in the Sheffield sheep collection (see Chapter 11), and shows a greater degree of similarity to the Castleford collections, even though there has been no human influence on the destruction of the bones. These results, therefore, implicate the level of destruction as an influence on the relative frequencies of elements (and element parts) recovered in a collection, regardless of the specific identity(ies) of the agent(s) of destruction. Chapters 3 and 10 discussed the influences of inherent factors on elements' potentials for survival, and it is difficult to

discriminate in this study between the effects of humans and canids on the survival of elements and element parts, since the effects of these two species appear to augment rather than to complement each other, presumably because they are all interacting with the inherent factors pertaining to the elements themselves.

### Conclusions

The frequencies of elements and element parts (i.e.: epiphyses) in both the sheep-goat and the cattle collections from Castleford Site 1 do correlate strongly with those in Brain's (1969) collection of goat bones from Hottentot villages.

Since Brain's collection consists of the remains of whole carcasses, that were not affected by selective trading of body parts (either into or out of the area), it is very probable that the Castleford collections also represent the remains of entire carcasses rather than of selected joints of meat.

The analyses do not show any anomalous elements or element parts. In particular, the ribs and vertebrae (which appeared to be underrepresented at Castleford in comparison to the Sheffield sheep collection) fit the pattern shown by Brain's data and, therefore, were probably deposited at Castleford in anatomical frequencies. Their apparent underrepresentation at Castleford is probably due to their susceptibility to a greater level of destruction than that observed in the Sheffield study.

It is beyond the scope of this study to investigate the specific effects of humans on the bones of ungulates, but the results

of these analyses suggest that they enhance those of scavenging canids, and that the relative frequencies of elements and element parts are affected more by the level of destruction (whether inflicted by canids, humans, or both) rather than by the identification of the specific agent of destruction. These results support the suggestion made in Chapters 3 and 10 that inherent factors pertaining to the bones themselves (such as: size, bulk density, etc.) influence their chances of survival and recovery.

QUESTION 4: HAS THERE BEEN A BIAS AGAINST THE PRESERVATION AND RECOVERY OF THE BONES OF YOUNGER INDIVIDUALS?

#### Introduction

There are two major sources of ageing data from a skeleton: (1) dental criteria, such as tooth eruption sequences (e.g.: Silver, 1969), tooth wear patterns (e.g.: Grant, 1982; Payne, 1973; Deniz & Payne, 1982), counts of annuli (e.g.: Stallibrass, 1982) and crown heights (e.g.: Carter, 1979; Klein et al, 1981), and (2) epiphyseal fusion criteria of post-cranial elements (e.g.: Silver, 1969). The dental data can often provide quite detailed information, whereas the epiphyseal fusion data are limited to assessments of whether a bone belonged to an individual that died when it was younger than or older than the age at which that epiphysis tends to fuse.

However, fusion data can be of considerable use in two circumstances: (1) when jaws have not been recovered (possibly due to their deposition elsewhere, e.g.: at a specialised butchery locality),

and (2) when it is possible that jaws and post-cranial elements derive from different individuals (e.g.: it is possible that small, young individuals might be imported whole to a site, whilst larger, older individuals might be imported as joints of meat).

The use of midshaft diameters and fusion data in the  
modern Sheffield sheep collection

The actualistic study of sheep carcasses proved that fusion surfaces of unfused bones can be destroyed more often than those of fused examples, indicating a bias against the recovery of ageing data for younger individuals (see Chapter 9).

Figure 12:4 shows the distribution of tooth wear scores (using Grant, 1982) and Table 12:9 presents the fusion data for the total Sheffield sheep collection. Since the bones all derive from whole carcasses (whether they were recovered 'in situ' or after removal to other locations, such as the fox dens), the tooth eruption and wear pattern should match that of the post-cranial fusion data, unless one of these groups of data has suffered a taphonomic bias. Since all of the tooth rows were recovered intact (even if the bone of the jaw had been damaged) it is assumed here that the mandibles present a genuine representation of the age distribution of the animals at death. Since it is known, however, that unfused epiphyses were biased against, the discrepancies between the tooth and post-cranial patterns are assumed to be due to the bias against the survival and recovery of young post-cranial epiphyses.

It is clear from Table 12:9 that the unfused examples of later-fusing epiphyses are particularly poorly represented. Since all of the bones derive from entire carcasses, every example of an unfused early-fusing epiphysis (such as a distal humerus) should be complemented by unfused examples of all later-fusing epiphyses (such as the distal metapodials, proximal humerus or proximal femur), whereas the converse is not true. However, although there is a slight trend for later-fusing epiphyses to be represented more commonly by unfused examples than are the earlier-fusing epiphyses, this trend falls far short of the predicted pattern. One element part is anomalous: this is the distal tibia, which has the highest ratio of unfused to fused epiphyses of all of the element types considered here. Almost one third of its examples are unfused. However, the distal tibia is also the commonest epiphysis (or fusion surface) recovered in this collection (N=37), and these two facts may be related. That is, the high frequency may be due simply to a better recovery rate of unfused epiphyses. The shaft of the distal tibia is particularly robust (although this is not reflected by Lyman's (1982) bulk density figures, which give it a rank of fourth out of the twelve major longbone epiphyseal halves (see Table 10:8)).

In the discussion of the results of the actualistic study (see CHAPTER 9) it was suggested that midshaft diameters might be a better indicator of age distribution than ratios of fused to unfused epiphyses, if post-cranial data are to be used. This suggestion assumes that age and overall size are related, which is an assumption that has not been proved, and which may be complicated by the effects of sex on size and maturation rates, as well as by individual genetic variations in growth potential. Other specialists are currently

investigating this assumption (Payne, 1986, pers. comm.).

Meanwhile, an experimental analysis of the modern material in the Sheffield sheep collection is presented here as an original, heuristic device. The relative ages of the mandibles have been assessed using Grant's (1982) method of tooth wear analysis. Midshaft diameters have been measured using von den Driesch's (1975) method; for the longbones, the measurement taken is the SD, for the scapula it is the neck width: SLC, and for the pelvis it is the ilial shaft width: SH.

It is known that the animals stocked on this moor at the time of the study were either ewes, wethers, or lambs of less than one year of age (Ken Addlington, farm manager, pers. comm., 1980).

### Results

The data presented in histograms in Figure 12:6 are very encouraging. The tooth wear scores (using Grant's 1982 method) show a preponderance of adult scores between 34 and 45, with a skewing towards some younger individuals with scores of 3 to 27 (total N=20). N.B. Scores marked with a '?' in the figures refer to jaws that have one molar missing or damaged. Scores for these jaws have been estimated following Grant's 1982 recommendations.

Midshaft diameters for the radius (N=32), metacarpal (N=21), pelvis (N=32), tibia (N=44) and metatarsal (N=23) all show very similar distributions, with the radius and pelvis measurements possibly indicating slight bimodality. Those for the scapula (N=21), humerus (N=31) and femur (N=25) show less skewed patterns, and have

normal distributions with low kurtosis values (i.e.: for these elements, the distribution curves are long and low, simply showing a wide range of values with no clusterings).

It is notable that the measurements of bones that have lost both of their epiphyses (represented by the '?' boxes in the figures) tend to lie at the smaller ends of the scales. The actualistic study (see Chapter 9) showed that unfused epiphyses are more likely to be destroyed than are their fused counterparts, and it is probable, therefore, that these bone tubes derive from young (i.e.: totally unfused) bones. If the fusion data alone were being used to assess the age distribution of these bones, the younger bones would clearly be disadvantaged.

The use of midshaft diameters in this case appears to enhance that of the tooth wear data, since:

- (1) the sample sizes tend to be larger (possibly due to mandibles having been overlooked whilst lying flat in the vegetation; a bias that is unlikely to occur on archaeological sites), and
- (2) the measurement data can be combined with fusion data.
- (3) In the case of the pelvis, an assessment of sex can also be made.

Figure 12:65 presents the measurements of the minimum widths of the shafts of the ilia, together with sex assessments made using the criteria described by Armitage (1977: Figure 14, Table 10 and text). This figure shows clearly that the smaller measurements tend to belong to pelvises of adult females and juvenile males, whereas the larger measurements (even when unfused) tend to belong to males. The three probably castrate pelvises occupy medial positions. This natural

death assemblage, therefore, tends to contain young males (probably less than one year of age) and mature females.

### Conclusions

In the Sheffield sheep collection, the distributions of midshaft diameters of longbone and girdle elements are very similar to that of the mandibular tooth wear scores. Since all of the bones derive from a group of whole carcasses, it is probable that both measures reflect the same factor(s). The tooth wear score is considered to reflect the relative age of an animal at death (Grant, 1982) and the midshaft diameter is considered to reflect the overall size of an animal (von den Driesch, 1975) which, in turn, reflects the age of an animal within its genetic and environmental constraints (see above).

If, therefore, the jaws and postcranial elements found in an archaeological assemblage derive from whole carcasses, the distributions of tooth wear scores should match those for midshaft diameters, although there will be some variability in the latter due to non-age factors including the sex of the individuals. However, variability due to sex differences can be turned to advantage by investigations of the pelvis, using the ilial shaft width compared to fusion data and an assessment of the sex of the bone. In this way, both the age and the sex of each individual can be assessed, giving more information than either dental or fusion data can provide.

The use of midshaft diameters and fusion data in the Castleford Site 1materialIntroduction

In the preceding section, it was demonstrated that midshaft diameters appear to reflect age groups of post-cranial remains and, when taken in conjunction with fusion data, can give a useful indication of the age structure of a death assemblage, which is more comprehensive and gives greater detail than the information available from fusion data alone. Sex data can also be considered together with the measurements for remains of the pelvis. This section applies a similar analysis to the Romano-British bones of sheep-goat and cattle that were recovered from Castleford Site 1.

A. The sheep-goat dataResults

Figure 12:7 presents the tooth wear scores of the sheep-goat mandibles (using Grant's 1982 method), together with the midshaft diameters of the longbones. The tooth wear scores show a distribution that is quite similar to that noted in the total Sheffield sheep collection. That is, there is a main group of adult mandibles, with scores of circa 27-45, and some mandibles from younger individuals with scores of 2 - 23. The distribution is skewed towards the older age range with a tail in the younger group, and may be slightly

bimodal.

Some of the longbone elements have very small sample sizes for midshaft diameters (e.g.: humerus, N=4, femur N=7), but the elements with larger sample sizes (such as the radius, N=29; tibia, N=27 and metatarsal, N=23) show very similar distributions to that shown by the tooth wear scores, with a cluster in the larger range, and a tail in the smaller range. The metatarsal histogram hints at a slightly bimodal distribution, with a smaller peak of smaller individuals. The Castleford material was recorded and returned to the excavators whilst the actualistic study was still in progress, and ilial shaft widths and pelvic sex criteria were not recorded. The fusion data hint at the possibility that young males may have died whilst their bones were at similar sizes to adult females (see, for examples, the distribution of sizes and fusion states of the measured radii), but this cannot be confirmed by independent sexing criteria.

### Conclusions

The close similarities of the histograms of tooth wear scores and midshaft diameters presented in Figure 12:7 suggest that the cranial and post-cranial remains of sheep-goat recovered at Castleford Site 1 came from whole carcasses rather than selected joints.

## B. The cattle data

### Results

Figure 12:8 presents similar data regarding tooth wear scores and midshaft diameters for the cattle bones recovered at Castleford Site 1. Most of the longbone elements have very small sample sizes due to the fragmentation of the material (which are shown, above, to be correlated with the rates of chopping). For instance, the humerus, radius and femur have sample sizes of N=3 to N=9, but the metapodials (especially the metatarsal) have large samples, and the neck width of the scapula has the largest sample size of any measurement in the cattle bone collection (N=63).

The mandibular tooth wear scores tend to cluster in the adult range (i.e.: 31 of the 34 jaws score 31-50), with a slight hint at bimodality, and there are three young adult scores of 24-28. There are no mandibles from young calves. The youngest mandible is probably that with a score of 24, which has the M3 visible in its crypt (a stage of tooth eruption that would suggest that it died at the age of approximately 24 - 30 months if it were a modern animal (Silver, 1969)). The metatarsal midshaft diameters show a similar tight clustering of measurements, with three slightly larger bones. However, the radius and metacarpal suggest that one or three younger individuals are represented by post-cranial elements, with unfused early-fusing epiphyses.

The largest sample, that of the neck widths of the scapulae, combines the evidence shown by the mandibles and the radius, metacarpal and metatarsal, by indicating a major clustering, probably

bimodal, of 'middle range' measurements, with three rather small widths and five rather larger widths. Unfortunately, the fusion data for the scapulae are not very informative, since the bicipital tuberosity of the scapula fuses at a very early age (circa 6-8 months in modern animals: Silver, 1969), and 60 of the 63 measured scapulae (including all of the smallest examples) have fused tuberosities. There is a suggestion of bimodality in the distribution of the majority of the measurements, which may represent different ages for different sex groups, but this cannot be tested with the scapulae themselves.

### Conclusions

Mandibles and post-cranial elements of cattle bones recovered at the Romano-British military site of Castleford Site 1 probably derive from whole carcasses rather than selected joints since the size and tooth wear distributions of the two groups of data are very similar. Neither group of data demonstrates the presence of any very young individuals. Probably the youngest animals were of about two years of age at death, and some of the animals appear to have been quite old at death (e.g.: those with tooth wear scores of 50, by which stage there is very little left of the crowns above the gumline).

The population of cattle, therefore, appears to have been one that was bought in, rather than raised at the site (unless the inevitable natural deaths of very young individuals were buried or deposited elsewhere in the fort or annexe) and there is no evidence to suggest the importation of 'veal' calves. The soldiers appear to have

had access to the meat of prime (i.e.: adolescent) beef animals, plus adult (possibly old) females and/or castrates who had outlived their usefulness as milk and/or draught animals.

### Discussion

Castleford is situated at the confluence of the Rivers Aire and Calder, at the junction of the Coal Measures (to the west) with the Magnesian Limestone (to the east). The water requirements of the two species would make the limestone more suitable for the sheep than for the cattle, whilst cattle might be well suited to the lower, damper landscape of the Coal Measures.

In his survey of Romano-British faunal assemblages, King (1978) noted that the assemblages from Roman military sites tend to be dominated by the bones of cattle, regardless of the types of local environment. This fact may be linked to the army's system of provisioning (Davies, 1971).

At Castleford, it is probable that the sheep, which appear to have been raised locally, were pastured on the plateau of the Magnesian Limestone to the east. The cattle, however, may not have been raised in the immediate vicinity of the fort, although the landscape appears to be suitable. Future studies of local, non-military settlements might be able to ascertain how far away the cattle were raised before being sent into the fort.

Despite the availability of sheep pastureland close to the site, the army at Castleford appears to have depended primarily on imported cattle (either alive or dead) for their meat supplies, and

only to have augmented their provisions with locally-raised sheep.

#### SUMMARY

The results of the analyses presented in the actualistic study (Chapters 2 - 9) have been applied in this case study to an assessment of Romano-British material from the annexe to a fort in Castleford, West Yorkshire, that was occupied in the late 1st Century AD.

The author wished to assess whether the army had been self-sufficient in meat supplies, or whether they had acquired provisions from elsewhere. Specifically, she needed to ascertain:

- (1) whether whole animals or selected joints were represented, and
- (2) the age distribution of the animals.

It is apparent that the material has been scavenged by canids, evidenced by the presence of large numbers of fragments bearing toothmarks, and by the presence of breakage patterns that are very similar to those observed in the Sheffield sheep collection, which had been scavenged by foxes. The bones of sheep-goat and of sheep-goat sized animals have much higher rates of chewing than do those of cattle and cattle sized animals. This may indicate that bones of the two species were disposed of in different ways, with dogs having greater access to bones of sheep-goat. The carcasses also appear to have been processed in different ways, since the cattle and cattle sized fragments have been chopped through far more frequently.

The size bias against the recovery of smaller bones appears

to have been greater at Castleford Site 1 than in the Sheffield study, and has preferentially affected the sheep-goat bones (which tend to be smaller than those of cattle).

The level of destruction of elements and element parts also appears to have been higher at Castleford Site 1 than in the Sheffield study. This is indicated by the greater frequency of the more severe patterns of damage observed in the sheep-goat bones, and the similarity of patterns of damage to cattle bones to those observed for the (smaller) sheep bones in the Sheffield collection. These results fit the prediction (made in Chapter 9) that the level of destruction of Romano-British cattle bones by dogs would be similar to that observed on modern sheep bones scavenged by foxes, due to the similar ratio of the body sizes of the canids and ungulates concerned.

Rank orders of element frequencies for both the sheep-goat and cattle collections from Castleford Site 1 are very similar to those in the Sheffield sheep collection, although vertebrae and the articular heads of ribs appear to be underrepresented in the sheep-goat collection. This may be due to the greater level of destruction at Castleford.

This appears to be confirmed by a comparison of the Castleford data with Brain's (1969) collection of goat bones recovered from Hottentot villages. These bones are known to derive from whole carcasses, and to have suffered destruction by both humans and dogs. The element frequencies of this collection correlate more strongly with those of the two Castleford Site 1 collections than do those of the Sheffield sheep collection, and the vertebrae and ribs no longer appear to be anomalous.

Both the sheep-goat and cattle bones recovered from

Castleford Site 1, therefore, appear to derive from whole carcasses. The underrepresentation of certain element types (or element parts) can be explained by the effects of scavenging canids, consumption by humans, and a bias against the recovery of smaller elements.

The last part of this chapter is an experimental use of an original method to assess the age (and/or size) of post-cranial elements. A method of age, sex and size assessment of pelvis is also demonstrated to have considerable potential.

By comparing the distributions of tooth wear scores (Grant, 1982) with those of midshaft diameters (von den Driesch, 1975), the author has shown that the cranial and postcranial material appear to derive from the same population of individuals (confirming the earlier results that indicate that whole carcasses are represented). In addition, the age distribution of the animals was assessed, using the same data. The use of this new method allows bones that have lost both of their epiphyses to be included in the age assessments. The standard practice of counting epiphyses only would severely have underrepresented bones in the younger age groups.

The sheep-goat assemblage includes examples of young and very old individuals, and probably derives from a locally raised flock. In contrast, the cattle bones come mainly from sub-adult or adult individuals, and there is a complete lack of calf bones. The cattle, therefore, probably were not raised locally, but must have been bought in, either as carcasses or on the hoof.

The local environs of Castleford include equal areas of Magnesian Limestone and Coal Measures, but it appears that the main meat supply at Castleford was beef acquired from outside the fort, which was supplemented to a small degree by locally raised mutton.

These results confirm King's (1978) suggestion that the Roman army in Britain had a sophisticated system of provisioning that was not necessarily dependent on its own, immediately localised resources.

**OVERVIEW**

This thesis has considered some of the effects that scavenging canids have on the bones of ungulate species (specifically on the bones of sheep, roe deer, red deer and cattle). Other researchers (e.g.: Haynes, 1980, 1981, 1982, 1985; Binford, 1978, 1981; Hill, 1975, 1979), in North America and East Africa, have demonstrated that wild carnivores (including wolves) and domestic dogs can alter radically the nature of a bone assemblage deriving from whole carcasses, even when there is no interference from humans.

It is necessary that faunal analysts should be able to discriminate between the effects of cultural and non-cultural biases, before any characteristics of an archaeological assemblage are attributed to past human activities.

Since most excavated holocene sites in Europe, Asia and North America have provided evidence for the presence of dogs, together with carnivore-damaged bones of non-canid species, the author suggests that most of these archaeological assemblages have undergone taphonomic biases due to scavenging by dogs.

Modern ethnographic work (e.g.: Kent, 1981; Walters, 1985) shows that bones of smaller species are preferentially susceptible to destruction by scavenging dogs. The work presented here does not investigate the comparative survival potentials of bones of different species, but studies the comparative survival of (1) element types, (2) element parts, and (3) fused and unfused epiphyses, within single species of ungulates. The study of patterns of bone destruction caused by human activities was beyond the scope of this thesis, but is

currently being studied by other researchers (see Johnson, 1985).

In a three year actualistic study, modern foxes were studied as an analogy for dogs (since it was not logistically possible to feed large numbers of carcasses to dogs under controlled circumstances). Foxes belong to the same taxonomic family as dogs and are very similar in terms of their anatomy and feeding habits, although they are smaller than most domestic dogs. In the main study area, close to Sheffield, foxes had access to the naturally accruing carcasses of hillsheep in an area of temperate grass moorland. Here, the destruction, disarticulation, weathering, redistribution and burial of the carcass remains were monitored over a three year period, before a final collection was made of any bones remaining on the surface. In the second study area, in Grizedale Forest, Cumbria, foxes had access to natural deaths of roe deer and red deer. Bones of these two species were collected from the scavenged carcasses during two one-week field visits set one year apart. In both areas, foxes were the main (or only) resident mammalian predator.

The collections of sheep, roe deer and red deer carcass remains all show similar distributions of element types, with certain types being poorly represented in all three collections. The Sheffield sheep collection appears to have undergone more severe taphonomic losses than either of the two Grizedale deer collections, probably due to the longer time period involved plus a greater number of foxes in relation to that of the 'prey' species.

It was found that, in these temperate environments, bones tend to become buried within circa 18 months of an animal's death, and only minor examples of weathering alteration were observed. Only skulls tend to remain unburied and to show any major signs of

weathering alteration.

The Sheffield sheep collection was sub-divided into residual and carnivore-transported assemblages, since some of the bones were recovered from monitored carcasses, whose death sites were known, whilst others were recovered from a group of fox dens located within the study area. The element frequencies in the two assemblages show that axial/thoracic elements (e.g.: vertebrae and ribs) tend to remain in the residual locations, whilst limb bones tend to be removed by the foxes (often as articulated forelimbs and lower hindlimbs).

In all of the collections, the smallest element types are poorly represented. This is probably due in some cases to the effects of a bias against the recovery of small items from the vegetated landscape, but in other cases it may be due to the consumption or destruction of the bones by the foxes.

Rates of attack to elements tend to correlate with the attractiveness of the elements, i.e.: to the amount of meat cover, but the strength of muscle attachments is also an important influence. Inherent factors pertaining to the elements (such as average intact size, meat cover and bulk density values) also relate to their survival rates.

Comparisons with collections published by other authors show that certain element types are consistently preferentially attacked by carnivores. In moderately damaged assemblages these element types tend to show high rates of attack. In severely damaged assemblages, these element types suffer preferential destruction (or partial destruction). These patterns are consistent across a wide range of ecological settings, for both residual and transported types of assemblage, as well as for more general accumulations.

The results of the actualistic study of Sheffield sheep demonstrate specifically which element types are likely to be lost from a canid-scavenged assemblage in a temperate setting, together with the typical forms of damage incurred to each element type. It also demonstrates that unfused epiphyses are more likely to be destroyed than are fused epiphyses.

These results were then used as a reference base for a case study analysing faunal material from a Romano-British site at Castleford, West Yorkshire. The excavation was a typical urban rescue 'dig', and the material was not preselected for any reason relating to taphonomy. The overall rate of chewed fragments (i.e.: 6%) is quite low and does not suggest that the assemblage has suffered any unusual degree of scavenging.

The element frequencies for both sheep-goat and cattle show considerable variation, which might be interpreted as the selective deposition of specific body parts. However, by comparing these patterns of frequencies with those in the actualistic study, it is clear that the unequal distributions of elements can be explained by biases caused by canid scavenging and recovery methods. There is no need to invoke cultural practices to explain the apparent inequalities.

The analysis of epiphyseal destruction in the modern study highlighted the need for a method of ageing for post-cranial material that does not rely on the recovery of bones retaining their fusion surfaces. In the case study, an original method was used to compare the age structure of the post-cranial material with that of the mandibles. This method uses midshaft diameters, fusion criteria and sex assessments of the pelvis. It appears to be very successful and

merits further research. The results of the analyses suggest that, not only were whole carcasses deposited at Castleford (rather than selected joints of meat), but that the sheep-goat were raised locally whilst the cattle were acquired from elsewhere.

It is clear that the results of this actualistic study have a wide application for archaeological assemblages. It should not be assumed that all attributes of holocene material are due to human activities. Rather, the presence of dog bones and/or of carnivore-toothmarked bones of other species should alert an analyst to the fact that an assemblage has been biased by the activities of scavenging canids. These biases can be quite severe, and will not only affect the relative frequencies of elements but will also affect the nature of the fusion data surviving for post-cranial elements.

Faunal analysts, therefore, should be aware that they may be dealing with scavenged assemblages, should take steps to identify how such scavenging may have affected the recovered material, and ensure that they do not mis-assign the results of non-cultural activities to past human behaviour.

## BIBLIOGRAPHY

- Alderson, L. 1976 The Observer's Book of Farm Animals. London: Frederick Warne & Co.
- Andrews, P. & Cook, J. 1985 Natural modifications to bones in a temperate setting. Man (N.S.) 20:675-691
- Armitage, P.L. 1977 The Mammalian Remains from the Tudor Site of Baynard's Castle, London: A Biometrical and Historical Analysis. Ph.D. Thesis. London: Royal Holloway College and the British Museum (Natural History)
- Barone, R. 1976 Anatomie Comparee des Mammiferes Domestiques. Tome Premier. Osteologie. Fascicule 2 (Atlas). 2nd edition. Paris: Vigot Freres
- Beck, A. 1973 The Ecology of Stray Dogs: A Study of Free-ranging Urban Animals. Baltimore: York Press
- Behrensmeyer, A.K. 1975 The taphonomy and palaeoecology of Pleio-Pleistocene vertebrate assemblages east of Lake Rudolf, Kenya. Bulletin of the Museum of Comparative Zoology 146: 473-578
- Behrensmeyer A.K. 1978 Taphonomic and ecologic information from bone weathering. Paleobiology 4:150-162
- Binford, L.R. 1978 Nunamiut Ethnoarchaeology. New York: Academic Press
- Binford, L.R. 1981 Bones. Ancient Men and Modern Myths. New York: Academic Press
- Binford, L.R. & Bertram, J.B. 1977 Bone frequencies and attritional processes. In L.R. Binford (ed.) Background studies for theory building New York: Academic Press. Pages 77-153
- Bokonyi, S. 1974 History of Domestic Mammals in Central and Eastern Europe. Budapest: Akademia Kiado
- Bradley, O.C. 1959 Topographical anatomy of the dog. 6th edition. Revised by T. Grahame. London & Edinburgh: Oliver & Boyd
- Brain, C.K. 1969 The contribution of Namib Desert Hottentots to an understanding of australopithecine bone accumulations. Scientific Papers of the Namib Desert Research Station 39:13-22
- Brain, C.K. 1981 The Hunters or the Hunted? An introduction to African Cave Taphonomy. Chicago: University of Chicago Press
- Burrows, R. 1968 Wild Fox. Newton Abbot: David and Charles
- Carter, H.H. 1975 A guide to the rates of toothwear in English lowland sheep. Journal of Archaeological Science 2: 231-233
- Casteel, R.W. 1972 Some biases in the recovery of archaeological faunal remains. Proceedings of the Prehistoric Society 36: 382-388

- Casteel, R.W. 1977 Characterization of faunal assemblages and the minimum number of individuals determined from paired elements: continuing problems in archaeology. Journal of Archaeological Science 4: 125-134
- Cherry, J.F., Gamble, C. & Shennan, S. (Eds.) 1978 Sampling in Contemporary British Archaeology. Oxford: British Archaeological Reports, British Series 50.
- Cleminson, N. 1979 The preservation of long bones - an experimental approach. Unpublished B.A. dissertation, Department of Archaeology, University of Southampton
- Clinging, V. & Whiteley, D. 1980 Mammals of the Sheffield Area. Sheffield: Sorby Natural History Society. Sorby Record Special Series No. 3.
- Clutton-Brock, J. 1981 Domesticated Animals from Early Times. London: British Museum (Natural History) and William Heinemann
- Clutton-Brock, J., Corbet, G.B. & Hills, M. 1976 A review of the family Canidae, with a classification by numerical methods Bull. Brit. Mus. (Nat. Hist.) Zool. 29(3): 117-199
- Corbet, G.B. & Southern, H.N. (eds.) 1977 The Handbook of British Mammals. 2nd. edition. Oxford: Blackwell Scientific Publications
- Crader, D.C. 1974 The effects of scavengers on bone material from a large mammal: an experiment conducted among the Bisa of the Luangwa Valley, Zambia. In C.B. Donnan & C.W. Clewlow (eds.) Ethnoarchaeology. Los Angeles: Institute of Archaeology, UCLA. Monograph IV of the Archaeological Survey. Pages 160-173
- Crader, D.C. 1984 The zooarchaeology of the storehouse and the Dry Well at Monticello. American Antiquity 49: 542-558
- Davies, C.M. 1984 An Experiment on Trampling as a Destructive Taphonomic Factor. Unpublished B.A. dissertation. Department of Archaeology & Prehistory, University of Sheffield
- Davies, R.W. 1971 The Roman Military Diet. Britannia 2: 122-142
- Deniz, E. & Payne, S. 1982 Eruption and wear in the mandibular dentition as a guide to ageing Turkish Angora goats. In B. Wilson, C. Grigson & S. Payne (eds.) Ageing and Sexing Animal Bones from Archaeological Sites. Oxford: British Archaeological Reports, British Series 109. Pages 155-205
- Driesch, A. von den 1976 A Guide to the Measurement of Animal Bones from Archaeological Sites. Harvard: Peabody Museum of Archaeology and Ethnology. Peabody Museum Bulletin 1.
- Eadie, W.R. 1949 Red fox transports play or training items to new den. Journal of Mammalogy 30:308
- Everton, R.F. 1982 The animal bone. In R. Leech (Ed.) Excavations at Catsgore 1970-1973. A Romano-British Village. Bristol: Western Archaeological Trust. Excavation Monograph No. 2. Pages 141-146

Gerrard, F. 1977 Meat Technology. 5th. edition. London: Northwood Publishing Co.

Gifford, D.P. & Behrensmeyer, A.K. 1977 Observed formation and burial of a recent human occupation site in Kenya. Quaternary Research 8:245-266

Gifford-Gonzalez, D.P. et al. 1985 The third dimension in site structure: an experiment in trampling and vertical dispersal. American Antiquity 50:803-818

Gould, R.A. 1980 Living Archaeology. Cambridge: Cambridge University Press

Grace, E.S. 1976 Interactions between men and wolves at an Arctic outpost on Ellesmere Island. Canadian Field Naturalist 90: 149-156

Grant, A. 1975 The animal bones. In B.W. Cunliffe Excavations at Portchester Castle, 1, Roman. Reports of the Research Committee of the Society of Antiquaries of London No. 32:378-408

Grant, A. 1978 The animal bones. In B.W. Cunliffe Excavations at Portchester Castle, 3, Medieval, The Outer Bailey and its Defences. Reports of the Research Committee of the Society of Antiquaries of London No. 34: 213-238

Grant, A. 1982 The use of tooth wear as a guide to the age of domestic ungulates. In B. Wilson, C. Grigson & S. Payne (eds.) Ageing and Sexing Animal Bones from Archaeological Sites. Oxford: British Archaeological Reports, British Series 109. Pages 91-108.

Grant, A. 1984 Animal husbandry. In B. Cunliffe (ed.) Danebury. Volume 2. The Excavations 1969-1978: The Finds. London: Council for British Archaeology Research Report No. 52: 496-548

Grayson, D.K. 1973 On the methodology of faunal analysis American Antiquity 38: 432-439

Grayson, D.K. 1979 On the quantification of vertebrate archaeofaunas In M.B. Schiffer (ed.) Advances in Archaeological Method and Theory. Volume 2. New York: Academic Press. Pages 199-237

Grayson, D.K. 1984 Quantitative Zooarchaeology: Topics in the Analysis of Archaeological Faunas. London: Academic Press

Guilday, J.E. 1970 Animal remains from archaeological excavations at Fort Ligonier. Carnegie Museum Annals 42: 177-186

Guilday, J.E. 1971 Biological and archaeological analysis of bones from a 17th Century Indian village (46 PU 31), Putnam County, West Virginia. West Virginia Geological and Economic Survey: Report of Archaeological Investigations No. 4.

Halstead, P., Hodder, I. & Jones, C. 1978 Behavioural archaeology and refuse patterns: a case study. Norwegian Archaeological Review 11: 118-131

Harcourt, R.A. 1974 The dog in prehistoric and early historic Britain. Journal of Archaeological Science 1: 151-175

## BIBLIOGRAPHY

## BIBLIOGRAPHY

- Hare, P.E. 1980 Organic geochemistry of bone and its relation to the survival of bone in the natural environment. Pages 208-219 in A.K. Behrensmeyer & A.P. Hill (Eds.) Fossils in the Making. Vertebrate Taphonomy and Paleocology. Chicago: University of Chicago Press
- Harris, S. 1977 Distribution, habitat utilization and age structure of a suburban fox (Vulpes vulpes) population. Mammal Review 7: 25-39
- Haynes, G. 1980 Evidence of carnivore gnawing on Pleistocene and Recent mammalian bones. Paleobiology 6: 341-351
- Haynes, C.A. 1981 Bone Modifications and Skeletal Disturbances by Natural Agencies: Studies in North America. Ph.D. thesis. Washington D.C.: Catholic University of America
- Haynes, C. 1982 Prey bones and predators: Potential ecologic information from analysis of bone sites. OSSA(1980) 7: 75-97
- Haynes, C.A. 1985 On watering holes, mineral licks, death, and predation. Pages 53-71 in J.I. Mead & D.J. Meltzer (eds.) Environments and Extinctions: Man in Late Glacial North America Orono, Maine: Centre for the Study of Early Man, University of Maine at Orono. Peopling of the Americas Series.
- Hewson, R. 1981 Scavenging of mammal carcasses by birds in West Scotland J. Zool. Lond. 194:525-537
- Hill, A.P. 1975 Taphonomy of Contemporary and Late Cenozoic East African Vertebrates. Ph.D. thesis. University of London
- Hill, A.P. 1979 Disarticulation and scattering of mammal skeletons. Paleobiology 5: 261-274
- Hill, A.P. & Behrensmeyer, A.K. 1984 Disarticulation patterns of some modern East African mammals Paleobiology 10: 366-376
- Hubbard, C.L.B. 1961 The Observer's Book of Dogs. London: Frederick Warne & Co.
- Isaac, C.Ll. 1967 Towards the interpretation of occupation debris: some experiments and observations. Kroeber Anthropological Society Papers 37: 31-57
- Jensen, B. & Sequira, D.M. 1978 The diet of the red fox (Vulpes vulpes L.) in Denmark. Danish Review of Game Biology 10: 1-16
- Johnson, E. 1985 Current developments in bone technology. In M.B. Schiffer (Ed.) Advances in Archaeological Method and Theory. Volume 8. New York: Academic Press. Pages 157-235
- Kent, S. 1981 The dog: an archaeologist's best friend or worst enemy-- the spatial distribution of faunal remains. Journal of Field Archaeology 8: 367-372

- King, A. 1978 A comparative study of bone assemblages from Roman sites in Britain. Bulletin of the Institute of Archaeology, University of London 15: 207-232
- Klein, R.G. et al. 1981 The use of dental crown heights for constructing age profiles of red deer and similar species in archaeological samples. Journal of Archaeological Science 8: 1-31
- Knol, E. 1986 Farming on the banks of the River Aa. The faunal remains and bone objects of Paddepoel 200 B.C. - 250 A.D.. Palaeohistoria 25, 1983: 145-182 plus fiche.
- Kramer, C. 1982 Village Ethnoarchaeology: Rural Iran in Archaeological Perspective. London: Academic Press
- Kruuk, H. 1972 The Spotted Hyaena. Chicago: University of Chicago Press
- Kuyt, E. 1972 Food habits of wolves on barren-ground caribou range. Canadian Wildlife Service Report Series. Volume 21: 6-36
- Lawrence, B. 1967 Early domestic dogs Zeitschrift fur Säugetierkunde 32:44-59
- Lever, C. 1979 The Naturalised Animals of the British Isles. London: Granada
- Levitan, B. 1982 Excavations at West Hill, Uley, 1979: The Sieving and Sampling Programme. Bristol: Western Archaeological Trust. Occasional Papers No. 10.
- Lloyd, H.G. 1980 The Red Fox. London: Batsford
- Lyman, R.L. 1979 Available meat from faunal remains: A consideration of techniques. American Antiquity 44:536-546
- Lyman, R.L. 1982 The Taphonomy of Vertebrate Archaeofaunas: Bone Density and Differential Survivorship of Fossil Classes. Ph.D. thesis. University of Washington. Ann Arbor: University Microfilms
- Lyman, R.L. 1984 Bone density and differential survivorship of fossil classes. Journal of Anthropological Archaeology 3: 259-299
- Lyman, R.L. 1985 Bone frequencies: Differential transport, in situ destruction, and the MUI. Journal of Archaeological Science 12:221-236
- MacDonald, D.W. 1977 The Behavioural Ecology of the Red Fox, *Vulpes vulpes*: A Study of Social Organisation and Resource Exploitation. D. Phil. Thesis. Oxford
- MacDonald, D.W., Boitani, L. & Barrasso, P. 1980 Foxes, wolves and conservation in the Abruzzo mountains. In E. Zimen (Ed.) The Red Fox. Symposium on Behaviour and Ecology. The Hague: Dr. W. Junk b.v. Publishers. Pages 223-235

- Maltby, M. 1979 Faunal Studies on Urban Sites. The Animal Bones from Exeter 1971 - 1975. Sheffield: Department of Prehistory & Archaeology, The University of Sheffield. Exeter Archaeological Reports Volume 2.
- Mills, M.C.L. & Mills, M.E.J. 1979 An analysis of bones collected at hyaena breeding dens in the Omsbok National Park. Annals of the Transvaal Museum 30:145-153
- Montague, A. 1942 On the origin of the domestication of the dog. Science 96 (no. 2483):111-112
- Morgan, N.T. 1985 Animal bones. In K. Blockley Marshfield. Ironmongers Piece Excavations 1982 - 3. An Iron Age and Romano-British Settlement in the South Cotswolds. Oxford: British Archaeological Reports 141: 330-352
- Mueller, J.W. et al. (Eds.) 1975 Sampling in Archaeology. Tucson: University of Arizona Press
- Nie, N.H. et al. 1975 SPSS Statistical Package for the Social Sciences. 2nd. edition. New York: McGraw-Hill
- Niewold, F.J.J. 1974 Irregular movements of the Red Fox Vulpes vulpes determined by radio tracking. XI Int. Congr. Game Biol. Stock. Sept 3-7:331-337
- Olsen, S.J. 1985 Origins of the Domestic Dog, The Fossil Record. Tucson: University of Arizona Press
- Payne, S. 1972 On the interpretation of bone samples from archaeological sites. In E.S. Higgs (Ed.) Papers in Economic Prehistory. Cambridge: Cambridge University Press
- Payne, S. 1973 Kill-off patterns in sheep and goats: the mandibles from Asvan Kale. Journal of Anatolian Studies 23:281-303
- Payne, S. & Munson, P.J. 1985 Ruby and how many squirrels? The destruction of bones by dogs. In N.R.J. Fieller, D.D. Gilbertson & N.G.A. Ralph (Eds.) Palaeobiological Investigations. Research Design, Methods and Data Analysis. Symposia of the Association for Environmental Archaeology No. 5B. BAR International Series 266. Pages 31-39 + 5 tables, 6 plates & 1 figure.
- Schaller, G.B. 1972 The Serengeti Lion. Chicago: University of Chicago Press
- Silver, I. 1969 The ageing of domestic animals. In D. Brothwell & E.S. Higgs (Eds.) Science in Archaeology (2nd. edition). London: Thames & Hudson. Pages 283-302
- Stains, H.J. 1975 Distribution and taxonomy of the Canidae. In M.W. Fox (Ed.) The Wild Canids. Their Systematics, Behavioral Ecology and Evolution. N: Van Nostrand Reinhold. Pages 3-26

## BIBLIOGRAPHY

## BIBLIOGRAPHY

Stallibrass, S.M. 1982 The use of cement layers in teeth for the absolute ageing of mammals. In B. Wilson, C. Grigson & S. Payne (Eds.) Ageing and Sexing Studies of Animal Bones. Oxford: British Archaeological Reports. British Series 109. Pages 109-126

Stallibrass, S.M. 1984 The distinction between the effects of small carnivores and humans on post-glacial faunal assemblages. In Grigson, C. & Clutton-Brock, J. (Eds.) Animals and Archaeology: 4. Husbandry in Europe. Proceedings of the fourth conference of the International Council for Archaeozoology, London, April, 1982. Pages 259-269 Oxford: BAR (British Series) 226

Stallibrass, S.M. 1985 Some effects of preservational biases on interpretations of animal bones. In N.R.J. Fieller, D.D. Gilbertson & N.G.A. Ralph (Eds.) Palaeobiological Investigations. Research Design, Methods and Data Analysis. Oxford: British Archaeological Reports. International Series 266. Pages 65-72 plus 6 figures.

Stallibrass, S.M. In preparation. Natural disarticulation patterns of sheep skeletons.

Swire, P.W. 1978 Laboratory observations on the fox (Vulpes vulpes crucigera) in Dyfed during the winters of 1974/75 and 1975/76. British Veterinary Journal 134: 398-405

Tappen, N.C. 1969 The relationship of weathering cracks to split-line orientation in bone. American Journal of Physical Anthropology 31: 191-198

Tappen, N.C. & Peske, G.R. 1970 Weathering cracks and split-line patterns in archaeological bone. American Antiquity 35: 383-386

Thawley, C. 1981 The mammal, bird, and fish bones. In J.E. Mellor & T. Pearce The Austin Friars, Leicester. Leicester: Leicestershire County Council and the Council for British Archaeology. Leicestershire Archaeological Field Unit Report. CBA Research Report 35. Pages 173-175, plus Fiche No. 2

Toots, H. 1965 Sequence of disarticulation in mammalian skeletons. Contributions to Geology 4: 37-39

Voorhies, M. 1969 Taphonomy and population dynamics of an early Pliocene vertebrate fauna, Knox County, Nebraska. Contrib. Geol., Spec. Paper No. 1 Wyoming: University of Wyoming Press

Walters, I. 1985 Bone loss: One explicit quantitative guess. Current Anthropology 26: 642-643

Watson, J.P.N. 1972 Fragmentation analysis of animal bone samples from archaeological sites. Archaeometry 14:221-228

Watson, J. 1979 The estimation of the relative frequencies of mammalian species: Khorokitia 1972. Journal of Archaeological Science 6: 127-137

White, J., Yeats, A. & Skipworth, G. 1979 Tables for Statisticians 3rd. edition. Cheltenham: Stanley Thornes

## BIBLIOGRAPHY

## BIBLIOGRAPHY

Wilson, R. 1978 Methods and results of bone analysis. In M. Parrington (Ed.) The Excavation of an Iron Age Settlement, Bronze Age Ring-ditches and Roman Features at Ashville Trading Estate, Abingdon (Oxfordshire) 1974-76. London: Oxfordshire Archaeological Unit and the Council for British Archaeology. Pages 110-126

Wilson, R. 1985 Degraded bones, feature type and spatial patterning on an Iron Age occupation site in Oxfordshire, England. In N.R.J. Fieller, D.D. Gilbertson & N.G.A. Ralph (Eds.) Palaeobiological Investigations. Research Design, Methods and Data Analysis. Oxford: British Archaeological Reports, International Series 266. Symposia of the Association for Environmental Archaeology No. 5B. Pages 81-93, plus 5 tables and 2 figures

Yellen, J.E. 1977 Cultural patterning in faunal remains: evidence from the !Kung bushmen. In D.W. Ingersoll et al. (Eds.) Experimental Archaeology. New York: Columbia University Press. Pages 271-331

IJzereef, G.F. 1981 Bronze Age Animal Bones from Bovenskarspel. The Excavations at Het Valkje. Amersfoort: Uitgave Rijksdienst voor het Oudheidkundig Bodemonderzoek. Nederlandse Oudheden 10. Project Noord-Holland 1.

Zimen, E. & Boitani, L. 1979 Status of the wolf in Europe and the possibilities of conservation and reintroduction. In E. Klinghammer (Ed.) The Behavior and Ecology of Wolves. Proceedings of the Symposium on the Behavior and Ecology of Wolves, 23-24 May, Wilmington, N.C.. New York: Garland STPM Press. Pages 43-83