# IDENTIFYING CHICKEN BREEDS IN THE ARCHAEOLOGICAL RECORD: A GEOMETRIC AND LINEAR MORPHOMETRIC APPROACH 

Thesis submitted for the degree of<br>Doctor of Philosophy at the University of Leicester

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2018

Alison Foster<br>Identifying Chicken Breeds in the Archaeological Record:

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#### Abstract

Domestic fowl remains are a small but significant element of many post-Iron Age bone assemblages, reflecting the importance of the many roles of this species, whether in augury, entertainment or different aspects of food-production. Size and shape variation in archaeological chicken bones has long been recognised as a possible indicator of different breeds or types associated with these roles, implying selection for favourable characteristics and the development of specialisation in poultry-keeping. This study investigates the potential of shape-analysis for identifying bone shape variation that may characterise particular morphotypes, helping to elucidate the processes of domestication and selection and the means and motivations behind breed development.

The thesis explores the potential for geometric morphometrics to complement traditional biometrical analysis in identifying osteological differences in domestic fowl remains. By focusing on shape independent of size, GMM offers a new approach, identifying subtle variations in bone morphology which would not otherwise be detected. GMM techniques were applied to selected post-cranial bone elements from modern domestic fowl of known-breed, age and sex, revealing consistent morphological similarities and differences in some breeds. These methods were then applied to archaeological elements from Romano-British, Anglo-Saxon and Early Modern deposits, with the aim of identifying progressive breed development within this wide chronology. Analysis of linear metrical data from the same modern and archaeological material enabled comparisons to be made between the two techniques.

The findings support the use of both measurement ratios and GMM methods for determining breed-related variation in selected chicken elements and suggest a strong potential for extending the research using additional bone elements and 3D imaging techniques.


## Acknowledgements

Foremost thanks must go to my supervisor, Dr Richard Thomas, for his assistance, expertise and patience. Thanks also to friends and family members who have supported me throughout: to Elizabeth Foster, Angela Sykes and Trish Roberts who proof-read several sections; to Paul Foster for defusing IT-related crises; to Tyr Fothergill for advice and guidance and to Ophélie Lebrasseur for much-needed moral support and cheerful encouragement, especially during the final stages of writing-up.

I am indebted to the following people who facilitated access to reference material in institutional or private reference collections: Polydora Baker (Heritage England); Umberto Albarella (University of Sheffield); David Orton (University of York); Jo Cooper and Judith White (Natural History Museum, Tring) and Sheila Hamilton-Dyer. For access to the archaeological assemblages I am grateful to Mike Morris and Julie Edwards at Cheshire West and Chester Council (Chester); Terry O'Connor and the University of York (Uley), Gabor Thomas and Zoe Knapp, University of Reading (Lyminge); Naomi Sykes and Chris Loveluck, University of Nottingham, North Lincolnshire Museum (Flixborough); Sussex Archaeological Society, in particular Rob Symmons (Fishbourne Palace); and York Archaeological Trust (Coppergate).

Analysis of the modern breeds would not have been possible without the enthusiastic and generous assistance from the poultry breeding and showing community who not only donated chickens for the modern reference collection but also shared a wealth of expertise and advice. I am especially grateful in this respect to Peter Smith, Stephen Elliot and Julia Keeling and to the late David Scrivener.

Finally, I must fully acknowledge the University of Leicester College of Social Sciences, Arts and Humanities for funding the PhD as part of the AHRC Cultural and Scientific Perceptions of Human-Chicken Interactions Project.

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## I Introduction

The domestic chicken, descendant of the Red Junglefowl (Gallus gallus), has over the last 4500 years been transported around the world; no other livestock species is more numerous or more widely established. From the early domesticated birds - small and brilliantly coloured - cross-breeding and selection has produced an enormous number of different breeds in a wide variety of shapes and sizes. Some are kept for recreation, such as game varieties bred for cock-fighting and purely ornamental exhibition bantams, while others are valued for utility purposes: the prolific egg-producers and large, meaty table-birds. It is the extreme forms of these utility birds, the massproduced and intensively-managed layers and broiler fowl, which make up the majority of an estimated world population of 19 billion domestic chickens (FAOSTAT 2014).

Numerous detailed narratives focusing upon poultry husbandry survive from the early modern period, notably works by Conrad Gessner (2010), Conrad Heresbach (1577), Leonard Mascall (158I), Ulisse Aldrovandi (1600, translated by Lind 1963) and Gervase Markham (16/4). However, while these texts provide considerable information about the care and character of the domestic fowl, the history of chicken breed development and the relationship between ancient antecedents and contemporary populations remains poorly understood. It is clear, though, that selection for perceived favourable characteristics in domestic fowl has been occurring from at least Roman times; for example, $1^{\text {st }}$-century agricultural commentator Columella (De Re Rustica 8.2.8) recommends chickens with five toes whereas Varro (De Re Rustica 3.9.4) states that the toes should be "of unequal length". A deeper understanding of breeding and the pressures of selection would help identify the development of desirable traits and elucidate the way in which humans have manipulated the size, shape and appearance of these birds, ostensibly for economic purposes but also for less tangible motives such as sport, social status and the love of novelty. Information on breed development will also be used to address the emergence of specialisation in poultry-keeping and wider questions relating to cultural exchanges and trade links.

Geometric morphometrics has been used routinely and successfully to address a variety of research questions in biology where shape is a factor, which makes it particularly appropriate for this study. There has not, however, been any previous
attempt to apply the technique to domestic fowl remains, on either modern or archaeological material, for breed identification or any other objective. The application of geometric morphometrics to post-cranial chicken bones is therefore both innovative and has real potential to identify breeds, or types, of chicken in archaeological material with confidence, for the first time.

This study forms part of a larger project: the AHRC-funded 'Cultural and Scientific Perceptions of Human-Chicken Interactions' in which researchers from the Universities of Leicester, Bournemouth, Nottingham, Roehampton, Oxford and York undertook to investigate the domestication and early husbandry of chickens and present a comprehensive review of the cultural and environmental impact of the spread of domestic fowl into Europe.

## I.I Why chickens?

The domestic chicken has, over the past 5000 years, been transported from its ancestral homeland in the jungles of South-East Asia across China, India and through the Middle-East into Europe, Africa, and across the Atlantic and Pacific oceans to the Americas and, much more recently, Australasia. Today it is the most numerous and widely established livestock species on the planet and an important source of protein for millions of people.

Despite its ubiquity, much is still unknown about the journey of the chicken from the forest to the farmyard: the majority of research into the domestication process has until recently focused upon large mammals. The reasons for this are complex but one explanation may be the perceived economic and military advantages the domestication of cattle, caprines, pigs and horses gave to early societies and the political consequences of these advantages. Although the relationship of chickens and humans is an ancient one, its impact is not so easily quantified.

As well as helping to identify the development of desirable traits, information on breed development can also be used to investigate the emergence of specialisation in poultry-keeping and breed identification and will contribute to wider questions relating to cultural exchanges and trade links - in some cases it may be possible to use the introduction of breeds as a relative dating technique. In addition, studying chickens can
tap into both traditional and new questions asked of faunal data in numerous areas from economy to influence of animal agency and biographical approaches.

## I. 2 Research questions

The primary research questions are:

- Are the different morphological characteristics of chicken breeds reflected in shape variations in the post-cranial skeleton and if so, are these variations consistent and reliable?
- Can they be identified using traditional osteometrics and geometric morphometrics and used to detect different types of chicken in the archaeological record? If so, can spatial or chronological variation be seen in assemblages of domestic fowl remains?
- If breed-related shape variation exists in the post-cranial skeleton, are these differences more apparent in some elements than others?
- Does geometric morphometrics offer a more reliable method of differentiation than traditional osteometrics?


## I. 3 Project objectives

The project objectives are to:

- Review historical records of poultry breeds
- Compare bone shape variability between individuals from modern poultry breeds of reputed historical ancestry
- Compare these modern datasets with archaeological datasets
- Review historical records in light of archaeological data


## I. 4 Research aims

The research will develop methodologies to enable an exploration of whether chicken breeds can be identified in the archaeological record using the major elements of the post-cranial skeleton and an applied combination of traditional osteometry and geometric morphometrics. This will increase understanding of the spatial and temporal
origins of modern chicken breeds and inform on the social and economic pressures driving selection and breed development.

## I. 5 Overview of the thesis

The preceding chapter has justified the importance and intellectual contribution of this research project, defined the research question, aims and objectives which underlie the analysis and interpretation of the materials described in Chapter 3 and outlined the main themes of the study.

Chapter Two lays out essential background information and context for this study. This comprises a review of the domestication of the wild Junglefowl, the spread of chickens worldwide and the development of the wide variety of chicken breeds seen in the present day. The possible causes of shape variation in bones are discussed and the breed histories and morphologies of the chickens most relevant to the study are detailed. Potential biases arising from the modern reference data are also acknowledged.

Materials used in the study are described in Chapter Three. These include the modern and archaeological chicken bones obtained for the study, together with modern reference bones from some other closely-related Galliformes. Information is given on the sources of the reference material and background information is presented on the assemblages from the various archaeological excavations. This chapter also describes in detail the post-cranial elements selected for comparative analysis covering relevant themes such as biomechanics and previous research into each element.

Chapter Four outlines the methods employed for data capture and analysis and comprises three sections. The first consists of an introduction to geometric morphometrics, describing the development and past applications of the technique, the theory of shape-change and landmark placement. The second part explains the methods which will be used in the linear biometrics analyses and includes descriptors for the new measurements devised for furcula and pelvis. The third gives information on the ordination techniques and statistical tests employed.

Chapter Five present the results from the linear biometrical analyses. A variety of methods were used, most of which were devised to investigate morphological differences between individual disarticulated bones. In the first section kernel density estimates were applied to the greatest length measurements of long bones from sites of different periods to reveal concentrations indicating different sexes or possibly types within each assemblage; the second section presents a study of both the modern and archaeological bones using measurement ratios, devised to capture breed-related morphological variation in a more effective way than simple raw metrics. Data collected from modern skeletons were used to investigate whether the relative proportions of long bones from the same individuals varied according to breed or type and to establish a standard for comparison with archaeological skeletons. The final two sections of this chapter present the results from two studies which introduce novel metrics applied to modern furculae and pelves with the aim of developing a method for investigating body-weight/flight ability and identifying sex in archaeological material.

The geometric morphometric results are presented in Chapter Six. Measurement error was calculated and eliminated as a significant source of variation in the landmark configurations. The subsequent sections run various statistical analyses to examine the morphology of four post-cranial elements from modern chickens and archaeological remains using GMM, finally comparing the results from both this method and shapeanalysis using measurement ratios which was developed in the previous chapter.

Chapter Seven applies geometric morphometrics to the post-cranial elements of modern common pheasant, guinea fowl and black grouse together with archaeological chicken bones. These closely-related and similarly-sized species can be difficult to distinguish using qualitative methods, leading to incorrect interpretations and/or underestimates of presence in assemblages. GMM successfully separates the four groups, highlighting similarities and differences and revealing potential issues identifying unimproved guinea fowl.

Chapter Eight interprets, compares and discusses the results, using the project objectives as a framework for the discussion. The reliability of claimed ancestries of reputedly ancient poultry breeds and types is returned to and the measurement ratio and GMM study results are assessed regarding their effectiveness at identifying bone shape variability in coracoids, humeri, tibiotarsi and tarsometatarsi.

Chapter Nine concludes the thesis by evaluating the advantages and disadvantages of the shape-analysis techniques developed, contextualises the findings in a historical and archaeological framework and recommends further research directions.

## 2 The development of chicken breeds

## 2.I Introduction

The first section of this chapter concerns the development of the domestic fowl, beginning with evidence concerning its origins and initial domestication in South-East Asia and its subsequent dispersal throughout the world. There then follows a discussion of breed development through a combination of local adaptation and conscious selection and a review of documentary and archaeological evidence for different morphotypes in the past. The second section looks at causes of shape variation in domestic fowl bones which relate to, among other factors, domestication and breed-development. The final two sections consider breeds of chicken initially suggested for the study by poultry heritage experts. Reasons why modern specimens of these breeds may or may not accurately represent ancient breeds and types are acknowledged and the breeds' value and relevance to the project re-evaluated in the light of the review.

### 2.2 Origins - domestication and dispersal

All modern breeds of domestic chicken are descendants of the Red Junglefowl (Gallus gallus L. 1758) native to South-East Asia, with recent studies confirming a smaller genetic contribution from the Grey Junglefowl (G. sonneratii Temminck 18I3) (Liu et al 2006; Eriksson et al 2008; Sawai et al 20I0). Archaeological and genetic evidence point to several independent domestication events in South-East Asia, China and India, all within the natural range of the Red Junglefowl (Crawford 1990; Kanginakudru et al 2008; Storey et al 2012) and a relatively rapid domestication process (Rubin et al 2010). Debate continues over the earliest domestication and the widely cited 8000 BC date proposed by West and Zhou (1988) is being increasingly challenged (Peters et al 2016). The earliest securely dated domestic chicken bones, ca. 2500 BC , are now believed to originate from Harappan Culture sites in the Indian subcontinent. The chronology and direction of the following dispersal is largely unknown and is also the subject of some controversy (Thomson et al 2014; Xiang et al 2014; Peters et al 2015; Peters et al 2016). An overland route from China via the Silk Road is a theoretical
possibility (West and Zhou 1988) but the associated difficulties and hazards of such a journey have been highlighted (Petrov 194I and Petrov 1995, cited in Corti et al 2010) and sea trading routes are considered a more likely option. In any event it is clear that, by the $3^{\text {rd }}$ millennium $B C$, chickens had been transported far beyond their natural range, with remains of domesticated types being found in Egypt, Israel, Iran, Anatolia and Syria (summarised by Redding 2015). From here they were introduced to Europe (mainly during the $I^{\text {st }}$ millennium BC ), some perhaps brought by the Phoenicians travelling from the Fertile Crescent to their Western Mediterranean colonies. The most recent evidence points to an introduction to Britain during the Middle Iron Age: small numbers of bones are present from 500 BC (for example, those from White Horse Stone, Kent (Kitch 2006), plus a hen and a cock deposited in a Middle Iron Age pit, Houghton Down, Hampshire (Best et al In press)) but significant numbers are rare until IOO BC. This is followed by a dramatic increase in the size of domestic fowl assemblages during the Roman period.

### 2.3 Adaptations: new environments and different purposes

Physiological and behavioural changes linked to the process of chicken domestication include reduced flying ability and changes in plumage (Sheppy 201I) as well as a reduced response to stress; sexual changes i.e. precocity and increased fertility; reduced brain weight relative to body weight (Jackson and Diamond 1996); faster muscle growth; and increased body weight. Red Junglefowl naturally have a specialised tropical/sub-tropical habitat and their domesticated descendants have been transformed radically to enable them to thrive in new locations (Pitt et al 2016). Extremes of heat and cold are withstood by sparse or dense feathering and by variation in the size and shape of comb and wattles which play a role in temperature regulation (van Kampen 1971). Successfully adapted landraces and ecotypes can be found in diverse environments including the arid deserts of Egypt, the cold climates of Scandinavia and Russia and the high altitude of the Peruvian Andes and Tibet (Velarde et al I991; Wang et al 2015).

Conscious selection for physical traits during domestication and early chicken husbandry has led to the establishment of certain phenotypes within populations. A perception among classical agronomists that five-toed fowl are superior layers seems
to have justified selection for this trait, resulting in modern breeds including Dorkings, Faverolles and Houdans. Hens with feathered crests were recommended by early modern writers for similar reasons, and large, red combs have been seen consistently as indicators of health and fecundity in both sexes. In some cases, a selected-for physical trait has been found to be genetically linked with economically advantageous traits. For example White Leghorn hens (the foundation of many modern commercial laying flocks) have large combs: the pleiotropic gene responsible for the size of the comb also affects medullary bone allocation during the laying period, increasing the rate at which it is transferred to the bone cavity. This means improved calcium reserves for eggshells resulting in more frequent egg-production and an extended laying cycle (Johnsson et al 2012). It is debatable, however, whether in the case of the Leghorn, comb size or better egg production was the prime consideration during selection and it is likely that both played a part in developing this breed.

Birds kept for purposes other than purely meat or egg production may also have had a part to play in later breed development. Characteristics selected for in cockfighting fowl may have been favourable in chickens bred for meat production: increased androgens for example would have had a positive effect on body size and muscle development. In populations kept for ritual purposes, plumage colour would almost certainly have been significant and if the chickens were consumed as part of the ceremony then meat quality may also have been a factor.

While many of these modifications are not identifiable in archaeological remains, some may be reflected in skeletal morphology. Relative robusticity of bone elements might indicate whether birds were kept for meat production or cockfighting. Conformation, too, may signify types of domestic fowl, even before the development of modern breeds. Junglefowl tend to have a horizontal stance, well adapted to moving through undergrowth in their natural habitat. In domestic chickens, selection has produced extremes, from the exaggerated upright carriage of Asian game fowl, in which the centre of gravity is directly over the legs, to the horizontal stance of the Rhode Island Red in which the centre of gravity is much further forward. If these variations in bone shape and size can be detected and linked to selection processes it may be possible to draw more confident conclusions about poultry-keeping in the past and humanchicken relationships.

### 2.4 Breeds, 'types' and specialisation in husbandry practices

There is no scientifically accepted definition of breed, which is a designation used in animal husbandry and not taxonomy. The term has, however, been usefully defined as "a group of animals that has been selected by man to possess a uniform appearance that is inheritable and distinguishes it from other groups of animals within the same species" (Clutton-Brock 1979). Early stock-keepers understood that mating very closely related animals could result in degeneration and declining fertility and avoided the practice, but pioneers such as Robert Bakewell (1725-95) and John Sebright (17671846) realised that "in and in" breeding - repeated pairings of very closely related individuals - could 'fix' or eliminate certain genetic characteristics to produce increased uniformity. This method had long been used by gamecock breeders. However, it seems likely that, until the fashion for competitive exhibition took off in the nineteenth century, most chicken-keepers would not have exercised this degree of control. The modern concept of chicken breed, with a strict adherence to agreed standards of characteristics including body shape, weight, plumage, leg colour and comb shape, appeared in the mid-I800s and is defined by Hutt as "...a group of fowls related by descent and breeding true for certain characteristics which the breeders agree to recognise as the ones distinguishing the breed." (1949:16).

The Ornithology of the Italian naturalist Aldrovandi (Lind 1963), first published in 1600 AD, makes it clear that a number of different morphotypes were in existence in Mediterranean Europe by the early modern period and although it is unlikely that the poultry-keepers of the time observed the stringent standards of today's exhibitors, a degree of selection may have been employed. At this time and earlier, domestic fowl were often distinguished by their geographical origin and characteristics, with various authors recommending different types depending upon whether they were required for fighting, meat production or egg-laying. That there were physical differences between the types is clear from descriptions given by Classical and early modern authors. These include traits which are not normally preserved in archaeological deposits, for example, plumage (apart from in exceptional cases (MacDonald and Edwards 1993; Hamilton-Dyer 1997)), comb shape and leg colour (although these phenotypes may be identified through analysis of DNA where this survives). However, variations in size and morphology have been detected through biometrical analysis of post-cranial elements (Benecke 1993; Moiseyeva et al 2003; De Cupere et al 2005;

Thomas et al 2013) and may be evidence of landrace breeds which have adapted to the natural environment, the effect of changes associated with specialisation or purely the result of random mutations within the genome.

Documentary evidence for specialisation exists from Classical times, with different husbandry practices developed for the production of poultry meat and eggs. Early references to egg production include the Annals of Thutmose III (18 ${ }^{\text {th }}$ Dynasty 14791425 BC) which describe birds that 'give birth’ - presumably lay - every day: these are usually understood to be chickens (Coltherd 1966). Pliny (Historia Naturalis I0.55), Aristotle (Historia Animalium 6.2.3) and Diodorus Siculus (Bibliotheca Historica I.74) reported methods of artificial incubation developed by the Egyptians carried out on an industrial scale.

Domesticated fowl naturally follow seasonal cycles of laying and moulting. Variations in these cycles may be associated with environmental conditions: warmer climates appear to be favourable but it has long been known that seasonally fluctuating light levels at different latitudes are actually more significant (Hutt 1949:285; Sykes 1956). Efforts appear to have been made to overcome these limitations. Columella proposes a specialised diet of semi-boiled barley and clover to encourage earlier laying in hens kept in colder parts of the country (De Re Rustica 8.5.2) and the act of regular eggcollection would also have induced fowl to continue laying. In this, the physiology of the Red Junglefowl, the ancestral species of all domestic fowl, proved to be advantageous. Red Junglefowl are indeterminate layers which means they will carry on laying for a period after eggs are removed or stop laying if eggs are added to the nest. It may also be significant that when poultry are kept in 'harem conditions' of three to six hens with one cock, this suppresses broodiness and can result in continuous laying for months (unpublished data referred to in Meijer 1995): this is a similar male/female ratio to that recommended by many old poultry manuals. By the late- $13^{\text {th }}$ century, Walter of Henley's treatise on estate management (Lamond 1890) stipulated that each hen could be expected to produce II5 eggs per annum, although this may have been somewhat optimistic. Fourteenth century account rolls, probably more accurate, also record improved egg-production, with some instances of individual hens laying 100 eggs per year (Stone 2006:154): by comparison Brown (1930:247) estimates that pre$20^{\text {th }}$ century non-commercial flocks were typically producing 70 to 80 eggs per annum.

Commercial egg-production on British farms was still described as 'seasonal' as recently as the 1930s, being considered a side-line to the main business and usually a perquisite of the farmer's wife (Godley and Williams 2009).

As egg production was significant in a number of ancient economies, it has been assumed that one of the characteristics selected for early in the domestication process was the change from cyclical mating and egg-laying to year-round egg production. Recent research has found that modern domestic fowl carry a derived recessive thyroid stimulating hormone receptor (TSHR) allele which stimulates the synthesis and release of thyroid hormones and is believed to affect photoperiod control, the absence of strict seasonal reproduction and the loss of incubation behaviour in breeds such as the White Leghorn (Basheer et al 2015; Karlsson et al 2015; Loog et al 2017). Traits associated with this allele may have been selected for during the domestication process: it is also associated with diminished fear of humans and reduced aggressive behaviour and it may be that these were the primary drivers early in the domestication process. Loog et al (2017) identified an increase in TSHR in archaeological material beginning around 920 AD which may relate to wider adoption of Benedictine dietary restrictions and management of flocks for egg production, but it was by no means universally present in a sample of chicken bones dated between ca. 280 BC and the $16^{\text {th }}-18^{\text {th }}$ century AD and the wild-type allele which governs 'normal', unadapted behaviour persisted in some populations until at least the $18^{\text {th }}$ century AD (Girdland Flink et al 2014).

Female birds which have died or been slaughtered during the laying season can be identified through the presence of medullary bone (Rick 1975; Driver I982; Serjeantson 2009). This secondary bone begins to accumulate in the medullary cavity of skeletal elements (primarily the coracoid, humerus, femur, ulna and tibiotarsus) approximately one to two weeks before laying begins and serves as a calcium store for the production of egg shell throughout the laying season. Once laying ceases, the depleted remains are resorbed over the next two to three weeks. If medullary bone is present in archaeological remains, these physical changes can be used to calculate sexratios and seasonality. A significant percentage - 66\% - of the domestic fowl remains from the $3^{\text {rd }}$ to early $5^{\text {th }}$ century AD Red Sea coastal settlement of Berenicke (Lentacker and Van Neer 1996) exhibited a high frequency of medullary bone; this was
interpreted as evidence for strict management of flocks kept primarily for eggproduction, with older or otherwise less productive birds being systematically culled at the end of the laying period, a practice advised by Columella (De Re Rustica 8.5.24). An earlier study used a combination of methods to determine sex ratios within different populations of domestic fowl in Central Europe, including the presence/absence of spurs, medullary bone and sexual dimorphism within types of fowl based on biometrical data of post-cranial bones from known modern breeds (Benecke 1993). The results showed an increase in the ratio of female to male birds in Slavonic areas beginning in the early Middle Ages ( $11^{\text {th }}-13^{\text {th }}$ centuries), interpreted as a move away from meat consumption and towards egg production. It is interesting to note that a $10^{\text {th }}$ century traveller to the area reported that Slavs avoided eating chicken for health reasons (Rapoport 1929), although no mention was made of a preference for eggs.

The specialised but widespread force-feeding of chickens to achieve rapid weight gain and produce birds quickly for the table is known from at least the $I^{\text {st }}$ century BC. Pliny attributes its invention to the inhabitants of the island of Delos although he does not approve of the practice (Historia Naturalis I0.50). Columella (De Re Rustica 8.7) gives details of the method including close confinement and a special diet and this technique does not seem to have changed a great deal by the time Aldrovandi (Lind 1963:13714 I ) and Heresbach (1577) describe it in the $16^{\text {th }}$ century. The chickens were kept in a warm, dark place in very small cages to restrict movement as much as possible. Their heads, wings and tails were plucked free of feathers to keep them clean and deter lice and they were intensively hand-fed for 25 days. Foods included pellets of barley meal soaked in water; alternatively wheat bread soaked in wine and milk could be used and honey water was also advised to sweeten the flesh. The task of fattening the birds could be carried out by the farmer but seems to have frequently been given over to a 'poulterer' (Columella ibid). A similar situation arose in post-medieval Britain when an increasing demand for poultry meat in rapidly expanding urban centres, especially around London, fostered the development of two separate industries. Chicks were hatched and reared before being sold on to professional fatteners and crammers who brought them up to slaughter weight - strictly this is specialisation of methods of production rather than breed development, although improvements were made in this area too. This arrangement reached a peak in the late $19^{\text {th }}$ and early $20^{\text {th }}$ centuries, flourishing particularly in Surrey which had a long history of rearing table fowl (Short
1982). Breeds preferred for fattening included traditional Dorking and Sussex, but by the $19^{\text {th }}$ century increased size was being achieved by cross-breeding with recently introduced heavy Asiatics such as Brahmas and Cochins to produce birds with a very large carcass such as the popular Buff Orpington. Size and weight of the parent stock were the primary criteria when selectively breeding for meat birds and this had been the case since the late Middle Ages (Thomas et al 2013). As body weight is highly heritable, the method was successful in manipulating size and productivity and was used until relatively recently (Hutt 1949:255-6I; Spector 1956): in the latter half of the $20^{\text {th }}$ century, however, food intake and feed conversion ratios became more critical (Emmerson 1997; Godley 2014; Zuidhof et al 2014).

Caponisation of cockerels intended for slaughter is an ancient practice which produces a superior table bird. Several methods have been employed: Columella (De Re Rustica 8.2.3) recommended burning off the spurs with a hot iron and a number of remodelled tarsometatarsi from Roman Colchester may be the result of this procedure (Luff and Brothwell 1993:90). Application of hot irons to the 'loins’ (probably the cloacal area) was also carried out. While this method would not have affected the internal testes, it seems the adverse effect on the papilla situated at the end of the vas deferens achieved similar results to surgical castration, i.e. a fatter bird with tender flesh. By the $16^{\text {th }}$ century these earlier techniques had been abandoned in favour of surgical removal of the testes. Aldrovandi in 1600 (Lind I963:408-4 II ) and Gessner in I555 (Corti and Civardi 2010) both describe the operation in some detail and from their descriptions one can infer that the practice was commonplace and must have been established for some time. In post-medieval England there was a strong tradition of raising capons in Surrey which had continued there into the late $18^{\text {th }}$ century when it had reportedly waned in other parts of the country: "Few Capons are cut now except about Darking (sic) in Surrey..." (Pegge I780). Surgical castration was replaced by chemical castration in the UK but when this was made illegal in 1982, cheap fast-maturing broilers had already replaced the capon as the table-bird of choice. Surgical castration is still in use outside the UK in countries with a tradition of slow-grown poultry.

The age at which it was recommended young cockerels be caponised varied considerably. Modern hybrid sex-linked strains can be sexed at a day old but sexing traditional breeds is difficult and while the distinction can sometimes be made as early
as six weeks it is often not possible until the young birds are three months or even older. Richardson (185I) proposes 3 months, the 1633 edition of Markham's Cheap and Good Husbandry (quoted in Luff and Brothwell 1993) suggests the procedure be carried out very early, between 14 and 21 days, while a later edition of this publication advises waiting considerably longer, "...as soon as the Dam hath left them...or else as soon as they begin to crow" (approximately four to five months) (Markham 1664:115). Practically, there are advantages to early caponisation. At two or three weeks the cockerels' testes are about the size of a cereal grain and an expert can remove them quickly and easily without complications (Calik 2014: 772-3). As the birds reach sexual maturity the testes are much larger and easier to locate but harder to extract without injury. Modern practice seems to be to castrate early, between two to 10 weeks (Lin and Hsu 2003; Chen et al 2006; Mahmud et al 2014; Echols 2015: 252). After the procedure, behavioural changes make the capons easier to manage; vocalisation decreases, they become less active, lose interest in hens and are less inclined to fight among themselves. Inactivity, lipid accumulation in muscle tissue and a slower growth rate mean that the flesh is more tender with a higher fat content. The extended growing period also affects the spurs resulting in a longer and possibly more pointed bone spur core and keratin sheath (Quigley and Juhn I95I; West 1982) although it seems reasonable to assume that the majority of these fattened birds would have been slaughtered long before the spurs fused to the tarsometatarsus, making any differences in shape unrecognisable in archaeological remains. Nevertheless, Aldrovandi's illustration of very long capon spurs and his report of a four year old capon kept as a companion animal indicate that some at least survived beyond the optimum slaughter age (Lind 1963:408-9). Further effects of caponisation on skeletal structure and the difficulty in identifying capons in archaeological material are discussed in Section 2.5.3.

An emphasis towards meat or egg production can be inferred from sex ratios. For a study of domestic fowl remains from 43 Central European sites, ratios were estimated using biometric data to identify sexual dimorphism together with sex-specific traits such as spurs or spur scars (Benecke 1993). This method showed a bias towards male birds in the Iron Age and Roman period, which may mean that meat was favoured over eggs at this time although the possibility that some of these males were game birds kept for cockfighting should not be discounted. Calculation of male-female ratios is problematic, however, as the criteria used may be inconsistent or unreliable. While
elements with medullary bone are undoubtedly from laying hens, tarsometatarsi without spurs or spur scars could be from immature birds of either sex and spurred hens may be more common than previously thought. This was found to be the case in smaller, bantam type birds from the $6^{\text {th }}-7^{\text {th }}$ century AD where a significant proportion of the smaller spurred tarsometatarsi also contained medullary bone (De Cupere et al 2005) and a spurred tarsometatarsus from Lyminge was also found to have medullary bone (Fothergill et al 2017). Nineteenth-century breeders of game fowl preferred to breed from spurred hens (Atkinson 1891:58). Modern examples of spurred hens include a two year old pure bred Oxford Game, a nine year old Spangled Hamburgh, a 2-3 year old Spangled Hamburgh bantam (University of Leicester Skeletal Reference Collection accession nos. R663, R742 and R728) and a number of hybrids including a Rhode Island Red/Light Sussex cross (Sheila Hamilton-Dyer, pers. comm.).

Until the nineteenth century, most flocks in Britain seemed to be developed from European light/Mediterranean types with the females kept for eggs and flock maintenance and the young males and surplus hens fattened for consumption. Specialisation based on breed characteristics and the divergence of meat and egg types did not start in earnest until the nineteenth century when cross-breeding with the newly introduced Asiatics produced a heavier table bird and other imported breeds such as the "Dutch Everyday Layer" (Pencilled Hamburgh) and the non-sitting Leghorn were found to be the most profitable for larger-scale egg production.

Aside from domestic fowl being exploited for meat and eggs, there is a long history of them being bred for cockfighting. The first known documented description of a cockfight occurs in a $4^{\text {th }}$ century BC Chinese text (Cutter 1989:13): other early references to the practice verify its significance in many ancient civilisations including those of India, Persia and Greece (Dundes 1994:242) although there is very little evidence that it had a similar impact on Roman culture (Morgan 1975). The first reference to cockfighting in Britain occurs in fitz Stephen's Life of Thomas Becket (c. II70-I I83), it being at that time a traditional Shrove Tuesday distraction for schoolboys (MacGregor 2012:229). The sport grew in popularity and status during the Middle Ages and by the early modern period it was enjoyed by aristocracy and commoners alike, with enthusiasts such as Edward Smith-Stanley, the $12{ }^{\text {th }}$ Earl of Derby (I752-I834), breeding many hundreds of gamecocks per season. The
gamecocks were clearly distinct from ordinary barn-door cocks and were characterised by a muscular build and powerful legs. By the early $19^{\text {th }}$ century, William Sketchley was able to list twenty varieties of game fowl raised in Britain (Sketchley 18I4) although many of these seem to have been distinguished only by differences in plumage colour and size. Cockfighting was banned in Britain in 1849 but birds of the fighting type continued to be bred for illegal matches or for exhibition.

Finally, while there are no records of shows or exhibitions specifically for poultry until the $18^{\text {th }}$ century, Columella's reference to "propter corporeum speciem" (a description of the breeding of Rhodian and Median chickens "for the beauty of their bodies") strongly suggests an appreciation of form and feather that members of today's 'Fancy' would recognise and gives credence to the assertion that chickens have long been admired for their appearance (De Re Rustica 8.2.12).

### 2.5 Shape variation in bone - causes

Bone is largely composed of the inorganic mineral hydroxyapatite, to give compressive strength, and the fibrous organic protein collagen which gives elasticity and tensile strength. The ultrastructure of avian bone differs from mammalian bone in several respects, mostly associated with adaptation to flight, and is characterised by thin cortical walls, medullary bone in laying females and pneumatisation - the replacement of marrow by air sacs in the cavities of some long bones, notably the humerus (Higgins 1999; Serjeantson 2000:15-21). Mammalian bone is continually being remodelled by two principle cell types - osteoblasts which produce bone and osteoclasts which break it down. By contrast, avian cortical bone retains its primary structure and adaptive remodelling does not occur to the same extent (Currey 1960).

A number of closely-related and overlapping factors may influence the shape of domestic fowl bones, including environmental conditions and husbandry practices as well as genetics and breed development.

### 2.5.I Domestication

One of the most obvious modifications associated with domestication is a change in size. Although exhibition chickens smaller than Junglefowl have recently been developed, notably the tiny $(500 \mathrm{~g})$ Serama from Malaysia, in almost all cases the size
change has been an increase. The largest recorded breed is the Jersey Giant, where mature male birds can reach 6.8 kg . However, the modern domestic chicken is more than simply a scaling up of the Junglefowl and a wide variety of sizes and shapes has been developed, together with an array of phenotypic characteristics affecting comb shape, leg colour, plumage and behaviour. Much of this diversification and morphological change has been brought about through conscious, artificial selection, the effects of which are especially applicable in the chicken which matures quickly and has a rapid breeding cycle: several generations can be produced over a short period.

It is likely that the increased body weight has affected skeletal structure. Campbell and Marcus (1992) identified a high correlation between increased hind limb bone dimensions and heavier body weight in 387 avian species, while Fothergill (2012) noted that domestication and subsequent increased body weight in turkeys bred for meat corresponded with shape changes and increased size in lower limb bones. In the case of the turkey, the effects of heavier body weight may have been compounded by the practice of pinioning, resulting in increased reliance on the lower limbs for locomotion.

### 2.5.2 Husbandry

Environmental conditions have observable effects on skeletal development and the bones of poultry raised under different husbandry regimes differ in shape and structural composition. Significant influences are likely to include variations in exercise, diet and exposure to disease and injury. For example, birds raised in close confinement and fed a restricted or specific diet may have less mineralised bones than scavenging free-range birds. In some cases, however, it may be that those selected for intensive rearing in confined conditions are 'meat-type' chickens of a different type from their free-ranging counterparts and therefore at least some of the morphological differences would be breed/type-related.

Like all Galliformes, chickens are precocial birds; their chicks have open eyes and downy feathers at hatching and are able to run and forage for themselves very quickly. In free-ranging birds, the chicks have a varied diet consisting of a combination of green plants, seeds and protein-rich invertebrates. However, the bone growth and morphology of birds which are closely confined after hatching and fed a restricted diet may be affected. A low protein diet in the first three weeks of life of the common pheasant (Phasianus colchicus L. I758) has been associated with permanent fluctuating
asymmetry in the tibiotarsus (Ohlsson and Smith 200I) and it is not unreasonable to assume that the closely related chicken may be similarly affected by dietary deficiencies. Pratt and McCance found that severe undernutrition in growing cockerels produced a "considerable dwarfing effect" (Pratt and McCance 1960:76) with bone growth slowed but not completely stopped. Narrow bands of calcified tissue resembling Harris lines were observed in all the long bones, although no bent tibiotarsi, enlarged extremities, fractures or other pathologies were recorded in the undernourished birds and growth resumed as soon as a normal diet was reinstated.

Where welfare is an issue, many of the skeletal changes will be due to pathology. The incidence of skeletal disorders in meat and egg flocks has been reviewed comprehensively by Thorp (1994) and copious research into circumstances that may negatively affect the skeleton has been carried out, most of which relates to the economics of modern, intensive broiler-rearing (Riddell 198I; Lilburn 1994; Julian 1998; Paxton et al 2010; Shim et al 2012). Many of these problems stem from the fact that muscle grows and changes much more quickly than bone can adapt to: bone has a limited rate of growth and will always lag behind muscle developmentally (Rath et al 2000). Pelvis and hind limb abnormalities associated with weight-related issues and obligate bipedalism are also seen in other farmed birds, for example ducks (Duggan et al 2015) and turkeys (Duff et al 1987), and bowed tibiotarsi were noted in two reference skeletons of guinea fowl originally obtained from a commercial poultry meat supplier (English Heritage accession numbers 2737 and 2740).

Where they were identified, specimens affected by pathology were excluded as shape variation is due to disease or injury rather than breed or type characteristics.

### 2.5.3 Sex

Red Junglefowl, the wild ancestor of domestic fowl, are strongly sexually dimorphic, with males ( $672-1450 \mathrm{~g}$ ) being considerably larger than females ( $485-1050 \mathrm{~g}$ ) (McGowan 1994). Domesticated chickens have maintained this dimorphism, although to a lesser extent. Remeš and Szekely (2010) determined that cock-fighting breeds are the most sexually dimorphic of the domesticated types, followed by ornamental and then dual-purpose breeds. As well as size difference, the dimorphism manifests as increased robusticity of some elements in the male, especially the tarsometatarsus, which may be associated with increased weight-bearing. There are also morphological
differences in the pelvis which are probably related to egg production (Section 5.6). No biometrical investigations appear to have been carried out on the sexual dimorphism of the domestic fowl pelvis and its potential to inform on the sex ratios of zooarchaeological assemblages, possibly because this element is fragile and seldom recovered undamaged. See Section 3.5.2. Distinction between bones of male and female chickens is complicated not only by the overlap in sizes and the possible presence of different breeds or types within an assemblage but also by differential morphology as a result of surgical castration.

It is well-known that decreased levels of testosterone following early castration delays epiphyseal fusion in mammals, resulting in longer, more gracile long bones. A number of empirical studies have been carried out that quantify the effects (for example, in sheep (Davis 2000; Popkin et al 2012) and cats (Root et al 1997)) but despite significantly more studies in poultry it is not clear how the timing of the procedure affects the skeletons of growing chickens. Hutt's (1929) study of the bone lengths of 105 adult Leghorns included 16 capons and comparison of the tarsometatarsus greatest lengths seemed to show that those of the capons were almost 4 mm longer than those of the cock birds. However, the age of each chicken was not recorded and the sample included both brown and some larger white Leghorns with no indication of how balanced the groups were regarding these differing types. Quigley and Juhn's (195I) conclusion that reduced androgens results in accelerated spur growth in cocks, slips (incompletely castrated) and capons is more persuasive: the study used a sameage population of a single breed (New Hampshire) and the metrical data were collected through radiography. They also remarked that the spur shape of capons is longer and more pointed than that of the cock - 'pointed' presumably meaning slimmer and sharper. Examination of the keratin spurs and bone spur cores of cocks (and hens) of different breeds in the UoL reference collection reveals a wide range of morphologies and suggests that this observation may only be relied upon for the commercial strains routinely used by $20^{\text {th }}$-century poultry scientists. Modern poultrykeepers also report unequal spur-growth rates within groups of same-age cockerels depending upon social hierarchy, with the more docile males' spurs developing more slowly.

As discussed in Section 2.4, throughout history the recommended age of surgical castration for capons has been inconsistent, ranging between a few weeks to three or four months, although one obvious consideration is that the surgeon must be confident of the bird's sex before the operation is undertaken. Modern practice favours early caponisation for reasons of welfare and optimum survival rates as well as better meat quality. Androgens play a significant part in bone development, and modern studies of caponised chickens show a propensity to weaker bones and a higher incidence of pathology. The tibiotarsi of caponised Taiwanese country chickens were found to have reduced weight and biomechanical properties, as well as being slightly shorter than a control group but unfortunately the greatest length was the only measurement taken and no inference can be drawn on shape change (Chen et al 2006). A study of surgically castrated Leghorns ( 5 weeks old) showed that capons were more likely to suffer calcification of the tibiotarsus and tarsometatarsus, including hyperossification of the tibial cartilage, than uncastrated cockerels (Johnson and Rendano 1984).

Despite an abundance of research into the effects of castration on bone morphology and health in modern poultry, consensus remains elusive and some studies have concluded that long bone growth does not seem to be affected at all Jacob and Mather 2000; Mahmud et al 2014). Part of the reason for the inconclusive results must be that the observation periods are often very short with the capons being euthanised before reaching maturity. Previous attempts to produce a spur-fusion/age estimation in cocks and capons have been limited by small sample sizes and breed differences.

All of these factors make identifying capons in archaeological material problematic. A study of capon bone and spur development involving a large number of cockerels and capons of a single breed would provide more reliable comparative reference data. In the absence of such data, if the premise is accepted that capons have longer, more gracile long bones than cocks due to delayed epiphyseal fusion and sharper, possibly earlier-fusing spurs, a large number of tarsometatarsi with spurs or spur scars is currently required in order to attempt identification of capons within an archaeological assemblage.

### 2.5.4 Function

Behaviour and body weight are both reflected in adaptive changes to the avian skeleton. For example, there is a strong correlation of body weight with the least circumference of both femur and tibiotarsus due to the stresses and bending forces these elements are placed under during locomotion (Campbell and Marcus 1992). Bone length ratios may be a useful indicator of locomotion and body weight but a study of a large group of avians with various locomotor classifications found that relative strength ratios of humeri and femora were much more successful predictors (Habib and Ruff 2008). Correlation of wing bone element lengths with locomotion styles is difficult to calculate as the additional lengths of flight feathers are a complicating factor.

Pneumatisation of bird bones is a relatively recent development in the evolutionary sense and may be related to adaptation to flight although there is also a positive correlation with size: smaller species tend to have poorly pneumatised bones irrespective of their flying ability. The onset of pneumatisation in the coracoid has been investigated in two egg-type chicken breeds and found to be considerably variable, occurring later and more infrequently in fast-maturing Golden Comets than in traditional Leghorns (Hogg 1984). In other breeds it may not happen at all: a cursory inspection of the coracoids of modern reference Silkies (a flightless breed) showed that they varied between poor pneumatisation and none. This suggests that flight ability may be a factor, as well as breed and age, although it has been pointed out that flying ability is not consistently related to pneumatisation (Bellairs and Jenkin 1960).

It is likely that the effects of intentional selection have in most cases overwhelmed and obscured any subtler skeletal modifications which may have been due to changes in feeding or activity, and functionality is for the most part not a major factor in bone shape change. However, a study of limb bone length ratios may confirm perceived short-leggedness in table birds or intentional selection for a longer reach in fighting breeds.

### 2.5.5 Breed-related differences

Breed characteristics are certainly identifiable in some individual bone elements: the shortened limb bones of breeds carrying the creeper gene are an obvious example, together with the vaulted skulls of crested fowl like the Poland, the 'shield' that
develops on the spurred tarsometatarsi of some five-toed chickens (Sadler 1991) (but has also been observed on four-toed types) and the very short, thick tarsometatarsi and broad skulls that are intentionally selected for in Indian Game. These examples affect extremities and are often apparent in vivo but it is likely that breed-related differences further occur in skeletal elements which cannot be seen in the living bird.

Darwin observed variation in the skeletons of the different breeds he studied - for example, the smaller sternal crest depth in the Silkie which was measured at $34 \%$ less than the reference Red Junglefowl - which he ascribed to a reduction in the size of the pectoral muscles in this flightless breed (Darwin I868:273). Other variations recorded included the outline of the occipital foramen (circular in a wild 'bankiva' type and almost triangular in a Cochin) (ibid: 26I) and the shape of the furcula, in particular the curvature of the clavicular rami and the shape of the hypocleidium at the symphysis (ibid: 268). It cannot be determined for certain how many specimens of each breed Darwin had available but tables showing relative biometrical differences between breeds show measurements from single elements rather than means (Darwin 1868:27I-273) and it seems likely that in many cases only one specimen had been obtained. In light of this, these and other morphological differences he observed may reflect skeletal variation between individuals rather than consistent breed characteristics. An increased number of both male and female samples from each breed will indicate whether shape variation in skeletal elements occurs consistently depending upon breed or type.

### 2.6 Breeds of domestic fowl most suitable for biometrical analysis

### 2.6.1 Evidence for early 'breeds'

The many breeds of domestic fowl (Gallus gallus f. domestica) can be divided loosely into three groups: game birds bred for fighting; utility breeds developed for meat and/or egg production; and those birds bred mainly for showing purposes. Classical authors notably Varro, (De Re Rustica 3.9.6) Pliny (Historia Naturalis I0.2I) and Columella (De Re Rustica 8.2.4-5) categorised fowl by their characteristics and geographical origin, commending the larger birds from Tanagra, Rhodes and Chalcidice
as superior fighters and the 'native' Italian chickens as suitable for more practical purposes, but it is unlikely that these types conformed to anything resembling a breed standard in the modern sense of the word. The majority of extant breeds have been developed during the last 150 years and many are a product of the 'hen-craze' of the mid-nineteenth century. This phenomenon was characterised by a dramatic increase in the breeding and showing of fancy poultry, with a consequent proliferation of breeds developed often for aesthetic rather than productive qualities (Brown 1906:14). Although claims of great antiquity were made for some of the breeds, many of these cannot be substantiated and ornithologies and texts on poultry husbandry first published prior to the 1850s (for example, Conrad Gessner's Historia Animalium of 1555 (Corti and Civardi 2010), Aldrovandi's Ornithology of 1600 (Lind 1963), Husbandries by Mascall (I58I) and Markham (16|4), John Lawrence (writing as Bonington Moubray)'s Treatise on Poultry (1834, first published I8I3) and Rees's Cyclopaedia (1819)) typically refer to fewer than a dozen breeds including generic types such as 'barn-door fowl' and dunghill fowl'. Very early manuals such as Prudent le Choyselat's Discourse of Housebandrie, first published in France in 1576 and translated into English in 1577 (le Choyselat 1577), do not mention any specific breeds, recommending the best cocks and hens predominantly by colour and size.

The dating of recent archaeological domestic fowl remains can be problematic: the stratigraphy of late post-medieval deposits is often difficult to interpret and modern disturbance can in many cases render the provenance of faunal remains doubtful (Thomas 2009). With the complexity of the lineages of post-1850 breeds in mind, as well as the paucity of securely-dated bone assemblages from the $19^{\text {th }}$ century, evaluation of those chicken breeds suitable for inclusion in the study was limited initially to those mentioned in earlier documents, although a selection of individuals from other breeds was also included as they became available.

### 2.6.2 Old English Game

It is widely proposed that the spread of domestic fowl is closely associated with cockfighting and ritual practices, with meat and egg production being secondary considerations until relatively recently (Simoons 196I; Serjeantson 2000; Serjeantson 2009; Sykes 2012). In the $I^{\text {st }}$ century BC, Caesar observed that the Britons did not eat fowls but kept them "animi voluptatisque causa" - for pleasure and amusement (De Bello

Gallico 5.12), although butchery marks have been identified on chicken remains from Iron Age contexts (Maltby 1987; Ashdown 1979; Armour-Chelu 199I) so perhaps this taboo was not universally observed. It is debatable, however, whether the "pleasure and amusement" did actually refer to cockfighting (Morgan 1975:I20 (footnote I)). By the $18^{\text {th }}$ century, game fowl in Britain had been bred and were classified in a range of different sizes, from large birds known as 'shake-bags' which were popular with the working classes to small and medium sized birds favoured by the more affluent enthusiasts (Scrivener 2009). Following the abolition of cock-fighting in I849, the breed diverged further into a wide variety of types including the Indian Game, the Carlisle, the Modern Game and the Oxford Game. It is generally accepted that the size and conformation of the first three breeds is radically different from the original fighting fowl, the Indian and Carlisle having developed into much broader, stockier birds while breeders of the Modern Game, striving for a show bird with 'reach', have produced a slim, tall bird 'as divergent from the original as the shire horse is from the hackney' (Brown 1906). Only the Oxford now resembles game fowl bred prior to the mid-1850s (Scrivener 2009) and it is this breed which will be focused upon.

### 2.6.3 Five-toed fowl

Five-toed chickens have been reported as early as the $I^{\text {st }}$ century BC, when Varro (De Re Rustica 3.9.4) included 'odd-toes' among a number of desirable characteristics in fowl chosen for breeding stock; this is usually interpreted as an extra, fifth toe (Corti et al 2010). Varro's near contemporaries Columella (De Re Rustica 8.2.8) and Pliny the Elder (Historia Naturalis 10.56) also identified five-toed fowl as superior. The writer and naturalist Aldrovandi, writing in Italy at the end of the sixteenth century, seemed unfamiliar with them (Lind 1963:43-44) even though the illustrations of 'chickens with feathered feet' (which are actually vulture hocks) included in his ornithology depict five toes quite clearly (ibid. 359-60). The breed described by Columella is widely reputed to be the progenitor of the Dorking, being 'very like the now nearly extinct Red Dorking' (Hams 2004:I3) and there seems little doubt that birds closely matching the breed standard have been bred in the area for some considerable time. However, Ferguson's extravagant claim that 'from 1683 to the present time we have ample proofs that the principle fowls of this description have been bred at Dorking...' (Ferguson 1854, cited in Brown 1906:24) does not appear to have further documentary support.

The earliest textual reference to 'Darking' (Dorking) fowl as a specific breed occurs in Bonington Moubray's Treatise on Poultry, first published in 1813 (Moubray 1834). A concentration of breeds with five toes in South-East England and northern France hints at a common ancestry for Dorkings, Houdan and Faverolles, however the occurrence of the characteristic in other breeds from further afield (including the Silkies of China and Japan, the Pavlovskaya from Russia and the Sultan from Turkey) suggests that the mutant trait which causes


Figure 1: Right foot of a Dorking hen, showing the accessory metatarsal, the hallux and the extra fifth toe (pointing upwards) polydactyly may have arisen independently on different occasions in both Asia and Europe, an hypothesis put forward by Corti et al. (2010). The fifth toe that characterises these breeds is not an authentic digit but a duplication of the hallux (Hill and Howes 1892; Hutt 1949:47; Arisawa et al 2006); this form of polydactyly has also been recorded in dwarf chicken populations at a State Breeding Farm in Russia (Corti et al 2010:159). Several variations of polydactyly have been recorded in domestic fowl, with different skeletal forms (Hutt 1949:47-53). Figure I shows the foot of a Dorking hen that adheres to the breed standard, with the genuine hallux and extra toe clearly defined.

### 2.6.4 Crested fowl

Several breeds of chicken, including Poland (Figure 2), Sultan, Houdan, Appenzeller Spitzhauben, Brabanter and Silkie display a crest of elongated feathers which in Silkies has been identified as the result of ectopic expression of cranial skin during embryonic development (Wang et al 20I2). In the large-crested Poland, the condition is associated with abnormal brain growth during gestation resulting in a cerebral hernia and cranial expansion (Tegetmeier I856; Darwin I868; Dunn and Jull 1927; Wang et al

2012; Yoshimura et al 2012). The affected part of the skull, normally the frontal area, characteristically displays large perforations in young crested fowl - incomplete ossification of the juvenile skull is a common characteristic of many avian species - but these perforations reduce over time. It seems likely therefore that the skull from Faccombe Netherton (Figure 2, left) is from an older bird, suggesting that this particular individual may have been valued as much for ornamental purposes as for any utility role. The crest, cerebral hernia and large nostrils and duplex comb form a suite of traits that characterise the Poland although the underlying genetics are complex the vaulting of the skull is not caused by the same gene ( Cr ) as the crest but another ( KfH ) with which it is closely linked (Requate 1960) and the large nostrils are due to a separate gene linked to the duplex comb (Somes 1991). This explains why some of these traits may be found separately in other breeds. It may be that the crest was initially, in some populations at least, a female characteristic which was later transferred to males by selective breeding (Hutt 1949:128). Darwin reported observations that this was formerly the case in Germany (Bechstein 1793 and Blumenbach 1813, cited in Darwin 1868:257), and English authors Mascall (I58I) and Markham (1614) both asserted that although the crest was a desirable feature in a hen, cocks should only have combs. The illustrations of Paduan fowl in Aldrovandi's Ornithology of I600 AD (Lind 1963:356-57) depict both the cock and hen with crests, suggesting that any sexual dimorphism present at this time may have been regional or breed-specific. Crested chickens may have been present in Padova since at least the late $14^{\text {th }}$ century (a fresco by Jacopo da Verona (1397)) depicts a peasant woman feeding a crested hen and chicks) and are widely considered to be the forerunners of the modern Poland breed. They were certainly present in Poland in the latter half of the $17^{\text {th }}$ century when Jacob Haur (1689) particularly commended them as breeding stock. There seems little doubt, however, that the characteristic existed much earlier although its occurrence may have been sporadic. An illustration of a domestic fowl from the I ${ }^{\text {st }}$ century Artemidorus Papyrus (Kinzelbach 2009; Fedi et al 20IO) clearly shows a sizeable crest and is probably the earliest depiction of this trait.

Archaeological evidence of cerebral hernia in chicken skulls is rare and, until the early post-medieval period, generally limited to isolated examples. In Britain, individual skulls have been recovered from a pit dated to AD I50-250 in Canterbury (Allison 2005), a $4^{\text {th }}$ century rubbish deposit at a Romano-British temple complex at West Hill, Uley
(Brothwell 1979) and a Norman pit at a manorial complex in Faccombe Netherton, Hampshire (Figure 2) (Sadler 1990): a more recent specimen was found in an $18^{\text {th }}$ century refuse pit in London (Gordon 2010).


Figure 2: Crested chickens. Left to right: the herniated skull from Faccombe Netherton (Sadler); modern herniated skull from a 4 yr old male Poland bantam with a normal Lakenvelder skull for comparison; a male Silver-laced Poland (flatrock.org.nz)

The earliest evidence for crested fowl from continental Europe is from a single skull of Roman date recovered from a midden at Augusta Treverorum/Trier (Teegen 2008): later examples include one dated to the $16^{\text {th }}$ century from a cesspit of an inn adjacent to the Salzburger Residenz (Pucher 1991) and five more from $16^{\text {th }}-17^{\text {th }}$ century deposits from sites in and around the royal palace at Buda, Hungary (Gál et al 2010). It is debatable whether the earlier specimens provide evidence of systematic selection for crested fowl or isolated spontaneous mutations, although some conscious selection seems likely considering advice on chicken breeding given by classical authors and biometrical evidence for variations in size in archaeological material from Roman and early Byzantine sites (De Cupere et al 2005). An initial contributory factor may have been that the perforations in the skull make crested breeds vulnerable to pecking from other chickens which may have encouraged segregation by their owners, resulting in further refinement of crested varieties, although a recent study of modern Poland chickens suggests that individuals themselves may have an innate preference for breed pairings (Tiemann and Rehkämper 20I2). By the late medieval period, documentary evidence and an increase in archaeological remains strongly indicate intentional breeding (Bél 1984:191, cited in Gál et al 2010:107I; Pucher 1991) and association with high status occupation. Early-modern depictions of chickens resembling modern crested breeds such as Appenzeller Spitzhauben and Brabanter
occur frequently in Dutch art (e.g. d' Hondecoeter c. 1660-95; Steen 1660) and show that, in the Netherlands at least, these breeds were well established at this time. Advertisements in London newspapers confirm that Poland fowl were being offered for sale in the capital during the 1700s (Daily Post I726; Public Advertiser 1757; The World 1790) however the nature of some of these notices, including one in which they and 'Silk fowl' were listed alongside a vulture and a small flemingo (sic), suggests that they were still considered curiosities and crested fowl of any breed were not introduced into Britain on a significant scale until the early $19^{\text {th }}$ century (Scrivener 2009).

### 2.6.5 Hamburghs

Another breed likely to have an ancient lineage is the Hamburgh. The modern name refers to two distinct varieties within the breed, both with different histories, although the origins of each are disputed. Darwin (1868:247) and Tegetmeier (1856:116) noted similarities between the Pencilled Hamburgh and Aldrovandi's illustrated Turkish fowl named ‘Gallina Turcica’ (Lind I963:362-63) but Brown (1906:44) considered that the plumage markings and colour of the Turkish more resembled Spangled Hamburghs, an example of the determination of some commentators to see parallels between modern fowl and historic illustrations to support their theories.

Spangled and Pencilled Hamburghs share a similar morphology, being small and bred for egg production rather than for the table, and both display a rose comb, although Tegetmeier (1856:122) referred to significant differences in skull osteology and in the plumage of the male birds which he claimed betrayed their separate origins. The pencilled fowl were imported from the Netherlands, probably from the early I800s, under the name 'Dutch Everyday Layers', but the progenitors of the spangled and black varieties seem to have been bred in Britain long before that time. These 'Lancashire Mooneys' and 'Yorkshire Pheasants' were popular in the North of England and informal shows for hens, often held at public houses, are believed to have been held as far back as 1700 (Scrivener 2009:82). Baum (I886:I3), Brown (1906:45) and Scrivener (ibid.) all quote a passage from 'A trip to the north of England' by Thomas Sutleif, published in I702, which includes a description of Black Pheasant Fowl as having 'white ears and flat combs'. Darwin (1868:227) considered the Black Hamburgh a product of crossing with the Spanish breed. The wide variety of regional names and
local standards prevalent in Yorkshire and Lancashire prior to the establishment of the Hamburgh breed standard in the late 1840s and the controversy over the amalgamation of British-bred varieties with the superficially similar Dutch fowl has complicated the history of the breed. An attempt was made in the early $20^{\text {th }}$ century to revive the original Yorkshire Pheasants and Lancashire Mooneys under the name ‘Old English Pheasant Fowl' and the breed was relaunched in 1914 (Scrivener 2006:5I; 2009:8I) but individual numbers were never high and the Rare Breeds Survival Trust now considers them 'endangered' (RBST 2008).

### 2.6.6 Silkies

Silkie fowl (Figure 3) are characterised by three distinct traits: the genetic condition fibromelanosis which causes hyperpigmentation and results in dark grey or black flesh, skin and bones (Hutt 1949; Lukanov and Genchev 2013); polydactyly (the breed standard requires five toes on each foot); and fluffy plumage caused by the absence of barbicels on the feathers. In common with many other Asiatic breeds, they also have feathered legs. In the bones, the black pigmentation is restricted to the periosteal layer and it is unlikely that the colour would survive in archaeological specimens. The earliest records of fowl with these traits point to an origin in China - a Chinese text dating to the fourth century AD refers to a chicken with 'whiskers' and five toes, while an eighth-century AD poem mentions black-boned chickens used in a medical capacity and although both of these descriptions are not unambiguous it seems likely that they refer to characteristics displayed by modern Silkies. A 1596 translation of 'The Chinese Encyclopaedia', now identified as Volume 158 of the 'Pen ts'ao kang mu' by Li Shih-chen (Pan 1984), describes seven breeds of chicken including fowl with black feathers, bones and flesh (Darwin I868:247).

Odoric of Pordenone described hens covered with white wool which he saw while travelling in the Chinese province of Fuzhou in the early $14^{\text {th }}$ century (Corti and Civardi 2010) and his near-contemporary Marco Polo reported seeing black chickens with 'hair like cats' during his time in China in the late thirteenth century (Haw 2006:I30). Initial introduction of Silkies to Europe and Britain is not well documented. They were described and illustrated by the Italian naturalist Aldrovandi in his Ornithology of 1600 (Lind 1963:399-400), although his information was drawn from old documents rather than personal experience and it is interesting to note that the
"wool-bearing hen" in the illustration (Figure 3) does not have five toes. The $17^{\text {th }}$ century Cambridge scholar and ornithologist Francis Willughby dismissed them as 'altogether fabulous' and Aldrovandi's illustration as 'fictitious' (Ray 1678). The majority of the show stock brought to the USA, UK and Western Europe in the midnineteenth century were imported directly from China, India and Japan (Scrivener 2009:237). The original Silkies were small - not much larger than most bantam breeds - but in the late $20^{\text {th }}$ century a bantam version was developed in the Netherlands (thought to be crossed with the tiny Belgian Barbu du Watermael) (Scrivener 2009: 240). As the difference between the large fowl and bantams was not well-defined, the large fowl were then increased in size.


Figure 3: Silkie fowl. Left to right: "Wool-bearing hen" (Aldrovandi); Silkie bantam (purelypoultry.com); melanistic chickens on a Chinese market stall (S. Ciencia)

### 2.6.7 Creepers

Documentary and archaeological evidence for short-legged chickens suggests that they have been kept in Europe for hundreds of years. The Dutch naturalist Gisbert Longolius, quoted by Gessner (2010) and Aldrovandi (Lind 1963:30), refers to 'kriel' fowl: 'kriel' is now a Dutch term for bantams but Longolius' much-repeated description of birds that crept over the earth and limped rather than walked certainly brings to mind creeper fowl and has been used to support their presence in Europe at this time. The previously mentioned 'Chinese Encyclopaedia' lists 'a breed that would now be described as a [Burmese] jumper or creeper' (Darwin 1868:247), strongly suggesting that the condition was also known further afield. The dwarfing effect on the legs of creeper fowl, and less obviously to the wings, is determined by a dominant allele which produces the shortened legs when present in a single dose (heterozygous)
but is lethal in a double dose (homozygous). Major skeletal differences can be seen in the limb bones: these are all shortened to varying degrees with the distal-most (the tarsometatarsus and carpometacarpus) being most severely affected. In addition there is a pronounced deformation of the tibiotarsus and the fibula: the tibiotarsus is thickened with the distal shaft usually bent anteriorly and the fibula, instead of being slender and tapering, is sometimes abnormally long and robust and fused to the tibiotarsus at the distal end. Prior to the analysis of the Uley and Lyminge chicken bones for this thesis, these traits had been observed on domestic fowl remains from a number of excavations in Britain including Anglo-Scandinavian and Roman deposits from York and Canterbury respectively (Allison 1985; 2009), a feasting deposit from early-modern Chester (Gordon et al 2015), a single tarsometatarsus from an Iron Age site in Dürrnberg, Austria (Schmitzberger 2012) and, more recently, two tibiotarsi from an excavation in Harfleur, northern France (pers. comm. Tarek Ouselati, Université de Lille).


Figure 4: Scots Dumpy (Feathersite.com)
Extant breeds displaying this characteristic include Scots Dumpies (Figure 4), which were introduced to England from Scotland in 1852 "where they had long been known" (Meall I854:I60). Meall (I854:I6I) suspected a connection with Dorkings as many of them at that time had five claws (although this is not seen in the breed today) and a resemblance to the Dorking was also noted by Tegetmeier (1856:167). The Japanese

Bantam and several European breeds including the French Courtes Pattes, the Luttehøns from Denmark and Krüper fowl from Germany also carry the 'creeper' gene.

### 2.6.8 Dwarf chickens

Research into the genetics of dwarf fowl has found the condition to be predominantly the result of either one of two alleles at the dwarf locus. The $d w^{B}$ (bantam) allele is associated with a $10 \%$ reduction of overall body size while the dw (dwarf) allele results in a more significant $30 \%$ reduction in body size and a disproportional shortening of the shanks (Hutt 1959). Small but normally proportioned domestic fowl appear to have been kept since earliest times. Columella mentions 'dwarf fowl' in his treatise on agriculture (De Re Rustica 8.2.14-I5): this section has occasionally been interpreted as evidence for creepers but the portrayal of the small, characteristically fecund but aggressive chickens is more applicable to 'bantam' type miniatures than creeper fowl. Columella could not recommend them - "unless their very low stature is pleasing to anyone" (De Re Rustica 8.2.14) - which implies that some people were keeping them as curiosities. The depiction of a bantam hen accompanying Aldrovandi's description (Lind 1963:353) appears to have shortened legs, but this is not mentioned in the text and as the illustration of a Persian rooster (ibid:366) also seems short-legged this may be merely the artist's attempt to convey a crouching bird.

Archaeological remains of very small chickens have been identified at sites encompassing a broad chronological and spatial range including an early Roman settlement in Egypt (Hamilton-Dyer 1997); a late Roman village in Portugal (Corona-M 2010); $6^{\text {th }}-7^{\text {th }}$ century deposits from an excavation in Turkey (De Cupere et al 2005) and Central European sites dating from the Iron Age to the Medieval period (Benecke 1993). Kysely's review of domestic fowl remains from the Czech Republic (2010) cites a number of articles which identify a smaller breed or type, however the dating of a very early example from the Balkans (ca. 4500 BC) (Boev 2009, cited in Kysely 2010:24) has recently been revised (Best et al In press). It is unclear whether these early archaeological remains are of a distinct dwarf breed, perpetuated by selection, or simply a reflection of the type of chickens that existed early in the domestication process. Some 'true' bantams - those breeds such as Rosecombs and Japanese Bantams which have no full-size counterpart - are thought to originate from South-

East Asia. It is possible that they were first introduced to Europe through trading routes established by the East India Companies of Britain and the Netherlands, both of which had interests in the Indonesian archipelago including the port of Bantam, Java. A Japanese Bantam appears on Jan Steen's 'The Poultry Yard', painted c. 1600 (Steen 1660), confirming that at least some were known in Western Europe at this time.

### 2.6.9 Asian Game Fowl



Figure 5: Male Shamo, UoL acc. no. R657.

Large game birds with an upright stance, such as the Malay and Asil, have been bred in India and South-East Asia for perhaps thousands of years and are valued there primarily for their fighting qualities, but they are relatively recent arrivals in Britain. Brown (1906) speculated that the first introduction to Britain took place in the early $19^{\text {th }}$ century as the Malay is mentioned by Moubray - here Brown was presumably referring to the first edition of Moubray's treatise published in 1813 (Moubray 1813) however, it is entirely possible that birds of this type had been earlier imported on an informal basis aboard trading vessels such as those belonging to the East India Company (Scrivener 2009). Tegetmeier (1856:65-6) reported a concentration of Malays around Falmouth and the 'Indian Game', bred in Cornwall, certainly seems to have exhibited Malay and Asil characteristics by the time Tegetmeier's contemporary Harrison Weir described them in the 1850s (Scrivener 2009:92). Neither the Malay nor the Asil lays well, and their flesh has been described as gamey and hard, making the pure-bred birds unsuitable for the table, but their large size means they have been used to cross with other varieties for stock improvement (Brown 1906). Japanese Shamo (Figure 5) are of the same type.

### 2.6.10 Rumpless Fowl

Rumpless fowl - those in which the vertebral column is truncated - have been documented since the seventeenth century. The earliest recorded examples seem to
be the 'Persian Fowl' described by Aldrovandi (Lind 1963:365-67), and 'a kinde of poultrie without rumps' noted by British surgeon Nathaniel Highmore (165I). It is likely, however, that these were merely randomly bred farmyard chickens and, as Darwin later says, 'so variable in character that they hardly deserve to be called a breed' (1868:230). Several factors can be responsible for the rumplessness, which is most commonly transmitted as a dominant allele (Dunn and Landauer 1934). An 'accidental' form also occurs, which can be produced by agitation of the eggs or fluctuations in temperature prior to incubation (Landauer and Baumann 1943). Osteological differences exist between the 'accidental' rumpless fowl, which are lacking the free caudal vertebrae, the pygostyle and the uropygial gland, and those carrying the dominant gene in which one or two vertebrae are missing from the centre of the synsacrum and a small, bony protuberance replaces the last two vertebrae of the pygostyle. There are a number of rumpless breeds, including the South American Araucana and the Rumpless Game Bantam (in both Modern and Old English types), but these seem to have been developed relatively recently, with little supporting documentation for intentional selection prior to the nineteenth century.

### 2.6.II Red Junglefowl

It is generally accepted that this species, native to South-East Asia, is the main progenitor of all domestic fowl with a possible contribution from the green junglefowl (Gallus varius Shaw I798), the grey junglefowl (G. sonneratii Temminck I8I3) and the Sri Lankan junglefowl (G. lafayetti Lesson I8I3) (Darwin I868; Hutt I949; Crawford 1990), which genetic research has clarified and confirmed (Akishinonomiya et al 1994; Hillel et al 2003; Liu et al 2006; Sawai et al 20I0). The genetic integrity of modern populations of both wild and captive Red Junglefowl has been compromised by freeranging and feral domestic birds, resulting in large-scale hybridization and introgression (Peterson and Brisbin 1998). An attempt was made to source only museum specimens obtained prior to the mid- $19^{\text {th }}$ century to reduce the effect of the hybridization but very few examples exist and a degree of dilution must be accepted in the specimens accessed for the study. In view of this uncertainty, the specimens used for the study will be referred to as cross-bred Junglefowl.

### 2.7 Chicken breeds: issues with modern reference specimens.

The advent of competitive poultry exhibitions and shows in the mid-I800s resulted in a proliferation of new breeds and increasing complexity of lineages. To counter the effects of these modern developments as much as possible, a substantial proportion of the modern comparative specimens obtained for the study are of traditional breeds documented before I800 AD. However, the degree to which the characteristics and morphology of these reputedly ancient breeds may have altered over the years is, for the most part, unknown. Those raised specifically for meat production, such as Dorkings, have been cross-bred for market-driven traits including white legs, flesh and skin, or simply a larger carcass. Exhibition fowl have been selectively bred to accentuate the desired points stipulated by the breed standard, for example, a larger crest in Poland fowl or a smaller overall size in bantam breeds. The appearance of exhibition versions of utility birds such as Light Sussex fowl now deviates considerably from those kept for practical purposes. Some extremely rare breeds have suffered population bottlenecks, including Scots Dumpies which have been recreated from a few inbred survivors after a dramatic decline in numbers and virtual extinction in the 1970s (Scrivener 2006:178).

Indication of the extent of the change can in some cases be inferred by reference to reliable authorities on poultry including Brown (1906), Tegetmeier (I856) and Wright (1902) and authors of more recent accounts of the history of chicken breeds (Hams 2004; Scrivener 2006; 2009). Evidence from old paintings and illustrations from poultry journals are often useful but should be used with caution as stylistic convention, artistic trends and idealisation may mean the subjects are not accurately represented.

Before the abolition of cockfighting in 1849, the strict rules which governed weight and types of competing birds to ensure a fair fight would have meant that the breeding of game birds was very highly regulated. After I849, the practice continued illegally in many places and it has been claimed that, as exhibition breeds like Carlisle Game and Modern Game were developed for the show ring, the survival of the original 'Oxford' breed was due solely to cock-fighters (Atkinson 1891: 17). Game birds sourced for this research are of the Oxford type and there is little evidence to suggest significant deviation from the pre-I 859 'pit game' birds.

Although the antiquity of the Dorking is generally accepted by breeders and poultry historians, the White and Red varieties are reputedly older and more 'pure'. Silvergrey and Dark Dorkings are large, substantial birds with relatively short legs, a broad breast and a single comb whereas the Red and White are smaller with a more slender body. The White Dorking has a rose comb and showed enough differences in the mid$19^{\text {th }}$ century for Darwin to consider it a 'sub-breed' (Darwin 1868:227) while the Red Dorking "comes the nearest of any to the old description of the 'best' Roman birds by Columella" (Wright 1902:375). It may be that the Dorking's reputation as Columella's five-toed fowl has contributed to a change in body shape as exhibition breeders, influenced by the classical texts, consciously selected for a 'squarer' body shape in an attempt to make their show birds conform to the description. Modifications were also made for more practical purposes; poultry-men in the south-eastern counties, supplying the London market, effected the 'improvement' of the Dark Dorking by cross-breeding with imported Asiatic birds to produce a larger carcass. Lewis Wright records the recollections of breeder John Douglas who used a very large four-toed bird of unknown breed from India to increase the size of his Dorking stock (Wright 1902:370), Wright also refers to breeders in Sussex and Surrey crossing Dorkings with large Spanish fowl (ibid.). These improvements were widely adopted but do not seem to have affected the white variety. It may be, therefore, that White (and possibly Red) Dorkings reflect more closely the original appearance of the breed and efforts were made to obtain specimens of this type for the reference collection.

Crested breeds selected for the study have also undergone recent changes which have altered their skulls and may also have had an effect on the post-cranial skeleton. There is little doubt that the crest of the Poland is now considerably larger than in the past; the illustrations of Paduan fowl in Aldrovandi's ornithology of 1600 (Lind 1963:356-57) and $17^{\text {th }}$-century Dutch paintings (particularly those of Melchior d'Hondecoeter) all show chickens with smaller, looser crests which do not restrict their sight. The Old Polish Crested Fowl which are still bred in Poland may be the descendants of this earlier type. It seems reasonable to assume that the larger crests developed for exhibition have resulted in more serious cases of cerebral hernia, more extreme vaulting and possibly poorer ossification in juveniles. Once skeletonised, two of the donated Silkie fowl were also found to have vaulted, perforated skulls. The Silkie breed standard stipulates a crest but unlike Poland fowl the smaller Silkie crest should
originate from a cushion of fat beneath the skin: this seems to still be the case with birds bred in China and Japan. Anecdotal evidence and conversations with breeders suggests that cerebral hernia in Silkies is a relatively recent but common development in Britain and the U.S.A. caused by crossing with Polands to increase crest size. The introduction of Mediterranean blood to this East Asian breed has the potential to affect the post-cranial bones as well as the skull: this should be taken into consideration whenever cross-breeding is suspected.

Hamburghs seem to resemble those in old illustrations quite closely but, like many other heritage breeds, they are internationally popular. Breed standards vary slightly from country to country, for example, the silver-spangled variety developed in Germany can be considerably larger than its British counterpart. As exhibition fowl and fertilized eggs are traded internationally it is almost certain that today's Hamburghs and Pheasant Fowl will have deviated morphologically as well as genetically from the old regional egg-laying types recorded in the north of England in the 1700s.

Bones of creeper fowl found in York and Canterbury (Allison 1985; 2005; 2009) are often cited as evidence for the longevity of breeds like Scots Dumpies but these and other archaeological creeper bones are often much smaller than those of the large fowl they are supposedly the ancestors of. Although creeper bones are interesting when they turn up in excavations, they are not evidence for a particular breed as the gene may affect a wide variety of types, from tiny Japanese Bantams to the much larger Dumpies.

Modern bantam breeds mostly fall into one of two types: miniature versions of large breeds, most of which have been developed relatively recently for exhibition, and true bantams, such as Japanese Bantams and the European Rosecomb, for which there is no large fowl counterpart. The term 'bantam' is often used loosely by translators of ancient texts as a synonym for a small chicken but this is misleading as the word has only been applied to dwarf fowl since the seventeenth century and originally referred to small, ornamental fowl exported to Europe from Indonesia, some of them through the port of Banten. Although in some cases miniaturisation can be achieved by 'breeding down' from the original large fowl, the aim of exhibitors is to produce a bird that conforms to the breed standard - consequently the genetic make-up of many miniature chicken breeds bears little relation to either their full-size counterparts or
the true bantams (Silk 1949). For example, the small size of the modern Silkie bantam has been achieved by crossing with tiny Belgian bantams. It is questionable therefore how representative the modern exhibition bantams of either type are of the small domestic fowl from Europe prior to the Early Modern period.

Although rumpless fowl were included in several of the lists of chicken breeds in the older manuals, rumplessness is not a breed in itself but a chance mutation that has only recently been selected for and adopted as part of the standard for some breeds. It would therefore not be appropriate to categorise modern rumpless fowl bones as a breed.

The hybridisation and introgression of modern wild Red Junglefowl has been previously alluded to. These problems are compounded in captive populations and have resulted in a variability of form and size not seen in the wild. Bones obtained for the study were from museum specimens but the genetic integrity of most of them cannot be accounted for, hence their classification as 'cross-bred Junglefowl'.

### 2.8 Conclusion

This chapter has covered the development of the chicken from domestication to divergence into the many breeds seen today and discussed evidence for past morphotypes and the beginnings of specialisation. The various causes of variation in bone shape were also considered. The latter half concerned an appraisal of modern breeds together with an evaluation of issues affecting their suitability for the study. From this it can be seen that in most cases, the modern examples of purportedly ancient breeds will have significant differences. Some have changed size, some have been crossed with other breeds to emphasise traits for exhibition purposes, and some which were listed as breeds can be more accurately described as groups sharing one or more characteristics or phenotypes. In short, it is probable that individuals of modern breeds, although bred to conform strictly to an agreed standard, will have evolved considerably from chickens described in old texts. Whether this is reflected in skeletal morphology cannot at this time be determined. What may be able to be proved is whether groups of chickens from these modern breeds or types show morphological similarities.

## 3 Materials

### 3.1 Introduction

This chapter describes the formation of the modern skeletal reference collection. Individuals collected were, wherever possible, obtained from the breeds considered most suitable for morphometrical analysis. Supplementary modern chicken specimens are also listed, together with a smaller collection of non-chicken Galliformes. The rationale behind grouping chickens by type is explained. The sites from which the archaeological assemblages are sourced are described, with particular reference to evidence for the significance of domestic fowl at each. The morphology and function of the bone elements selected for the biometric and geometric morphometric studies are defined. Finally, proposed groupings by breed or type are presented.

### 3.2 Modern Galliform reference specimens

Of the traditional chicken breeds, those documented before 1800 were identified as most useful for biometrical analysis (Section 2.6). The original list of breeds for the study comprised: Dorking, Spangled Hamburgh, Poland, Silkie, Malay, Old English/Oxford Game and Scots Dumpy, as well as Bantams and Rumpless fowl. However, practical difficulties soon became apparent: several of the breeds on the list are very rare, especially the original, large fowl Silkies and Polands which predate the more recently developed and much more popular bantam versions of these breeds. Others, like the equally rare Scots Dumpy, have undergone population crashes or even extinction and been subsequently revived or 'recreated' by enthusiasts. Breeders of Old English and Asian game fowl are reticent and frequently the only way of contacting them was anonymously through second parties. Furthermore, the majority of culled birds available from exhibitors were young cockerels, meaning that the original intention of collecting approximately equal numbers of male and female fully adult birds was compromised to some extent. The original list was re-evaluated and where unavoidable, substitutions and additions were made, for example the inclusion of bantam Poland and some bantam Silkie fowl. The genetic relationship and skeletal resemblance of these miniatures to their large fowl counterparts is questionable.

Details of the chickens obtained for the study as well as those accessed through museums and universities are presented in Appendix A, Section I.I. All biometrical data pertaining to the modern chickens can be found in Appendix B.

### 3.2.1 Sourcing

Information on the research aims of the project was sent to the secretaries of breed clubs together with a request for surplus stock. Awareness was also disseminated through poultry breeding and showing publications (i.e. 'Fancy Fowl'), social media and attendance at various poultry exhibition events. A number of very useful contacts were made through Peter Smith (University of Roehampton), a breeder of Japanese Bantams and qualified poultry show judge.

### 3.2.2 Ethics statement

A strict ethics policy was instituted and adhered to throughout the collection procedure. All of the birds obtained for the University of Leicester modern reference collection were either casualties ('fallen stock') or those which would have been culled as part of normal husbandry practices; they included old or sick birds, hens which had ceased to lay and surplus cockerels. These were euthanized humanely by their owners, all of whom were experienced poultry keepers.

### 3.2.3 Processing method

Prior to processing, samples of feathers were taken from each specimen. These served as reference for plumage colour and type as well as potential DNA samples for other researchers. The complete carcasses were then weighed and photographed (in a number of cases, photographs had also been taken by the donors prior to culling). Preparation of the carcass followed methods adapted from those proposed by Davis and Payne (1992). Each bird was skinned, defleshed and gutted. The shells of developing eggs were recovered from in-lay hens for use as reference specimens by researchers investigating development-related changes in domestic fowl eggshell (Best et al In preparation.). Notes were made and additional photographs taken of breed phenotypes observed during this process (for example, comb type, rumplessness and polydactyly), together with any pathology, such as bumble-foot (pododermatitis) or scaly leg (infestation of the mite Knemidocoptes mutans). Each specimen was then labelled (using 'Tyvek' labels tied around the tarsometatarsus) and simmered to disarticulate the skeleton and remove the remaining soft tissue. The time taken for this
stage was largely dependent upon the age of the bird, with older, mature fowl taking up to three times longer. The disarticulated bones were immersed in Neutrase (a proteolytic enzyme) to clean the last traces of soft tissue followed by soaking in a weak solution of water and household bleach (sodium hypochlorite) for two to three days before being rinsed in tap water and air-dried. A total of 44 chickens were prepared in this way, most being subsequently accessioned into the University of Leicester's vertebrate reference collection.

### 3.2.4 Modern reference material from other sources

Data from a further 58 known-breed chicken skeletons were obtained from reference specimens made accessible through the generosity of the following research institutions and private consultants:

Historic England, Fort Cumberland; Natural History Museum, Tring; Palaeoecology Research Services; University of Sheffield; University of York; Enid Allison (Canterbury Archaeological Trust); Katrina van Grouw; Sheila Hamilton Dyer (independent zooarchaeological consultant); Dr Naomi Sykes (University of Nottingham).

### 3.2.5 Grouping chickens by breed and/or 'type' for statistical analysis

To facilitate easier and consistent classification, and to make use of data from some breeds represented by single individuals, specimens were grouped by type for analysis. These types were constructed using records on breed development from texts including the official Breed Standards of the Poultry Society (Roberts 2008), poultry manuals and poultry club records; by information received from the donors of the specimens and other experienced breeders.

Some breeds were so distinct that they warranted a category by themselves i.e. Silkies. Others were categorised by 'type', for example Hamburghs (Golden Pencilled and Silver Spangled), Old English Pheasant Fowl, Leghorns are all light Mediterranean chickens grouped as 'egg-type'. Of the crested chickens, the majority are Polands but this group also included Sultans and a 'crested, rumpless, Turkish fowl' from the Darwin collection at the NHM (no further information on this individual, including sex, was found in Darwin's correspondence or chicken experiment records). The crossbred Junglefowl and Silkies each form their own groups: Old English (Oxford) Game
fowl also form a single group as they are reputedly ancient and their morphology may reflect their fighting function.

With the exception of one of the Hamburghs, the 'bantams' are a disparate selection which were difficult to group, either with their large-fowl counterparts or by themselves as a group of miniatures. Their inclusion has been useful in initial analyses to show how dissimilar they are and why the term 'bantam' should not be used in a casual way to represent all modern and archaeological small domestic fowl. For this reason they were subsequently excluded from most of the analyses.

### 3.2.6 Non-chicken Galliformes

Concurrent with the primary investigation into variation in bone shape between chickens of different breeds, a parallel study on inter-species osteological identification was also carried out. Bones from three additional species - helmeted guinea fowl (Numida meleagris L. I758); common pheasant (Phasianus colchicus L. I758); and black grouse (Lyrurus tetris L. 1758) were included in the study, almost all of these being accessed through the institutions acknowledged above.

Helmeted guinea-fowl are indigenous to sub-Saharan Africa. It is thought that they had been brought to Greece by the $5^{\text {th }}$ century BC and had spread to Roman Italy by the $I^{\text {st }}$ century AD (MacDonald 1992; Poole 2010) and further into Europe by the Middle Ages although no secure archaeological identifications have been made relating to this period (Serjeantson 2006:145). They may have been present in England by the $13^{\text {th }}$ century (Donkin 1991:43; MacDonald 1992), certainly by the $16^{\text {th }}$ century (Poole 2010:163; Gordon 2015) ; contemporary records are confusing, however, as guineafowl were also frequently referred to as turkeys and vice versa (Donkin 1991:43 and 81). It is highly likely that the historical presence of guinea fowl in Britain is underrecorded to an unknown extent due to this ambiguity and the osteological similarities with chickens.

Common pheasants, native to Central and East Asia, were brought from Colchis (present-day western Georgia) to Greece around the $5^{\text {th }}$ century BC. By the $I^{\text {st }}$ century AD they were valued by the Romans as an exotic food and were imported from Colchis in considerable numbers (Jennison 1937:109-IIO) and transported throughout the rest of the Empire. A few specimens have been identified in Roman
and Saxon bone assemblages in Britain (Yalden and Albarella 2009:107; Poole 2010:163) but they do not appear in significant numbers until the Middle Ages, when find-spots are often high-status sites with evidence for long-distance trade (Poole 2010).

Black Grouse are a wild species which have never been domesticated. In Britain, much of their natural habitat of woodland/moorland fringe has been lost to agriculture and development leading to a decline in population and a reduction in distribution, especially since 1900 (Holloway 1996). Early evidence for Black Grouse includes bones from the late glacial sites at Pinhole Cave, Creswell Crags (Yalden and Albarella 2009) and Ossom's Eyrie (Bramwell et al 1987), and they occur regularly in moderate numbers in faunal assemblages from the Mesolithic to the late post-medieval period (Yalden and Albarella 2009).

Skeletal remains of these similarly-sized and closely-related Galliformes can be very difficult to separate and misidentifications, especially between pheasants and chickens, have led to confusion over early domestication events and the subsequent spread of chickens from South-East Asia. Guinea fowl and other introduced species can end up underrepresented in bone assemblages, reducing their significance.

Identification manuals are a useful resource, and there have been several publications which address the specific problem of Galliform distinction (Lowe 1933; Erbersdobler 1968; MacDonald I992; Bocheński and Tomek 2000; Tomek and Bocheński 2009). However, errors can still occur, a notable example being the recent misidentification of pheasant (Phasianus sp.) bones from a number of Chinese excavations which were initially cited as proof of early chicken domestication events (Eda and Inoué 201I; Xiang et al 2014; Peters et al 2015; Xiang et al 2015; Eda et al 2016).

Some bones are more diagnostic and can be easily distinguished, for example the black grouse tarsometatarsus is considerably shorter than the other three species and too slender to be mistaken for a creeper chicken. The pneumatic foramen in the dorsal side of the coracoid is always absent in helmeted guinea fowl (Numida meleagris) and always present in common pheasant (Phasianus colchicus), however both presence and form are extremely variable in chickens.

Discussion with experienced zooarchaeologists established that, while complete coracoids, scapulae, carpometacarpi and tarsometatarsi of chickens, guinea fowl, black grouse and common pheasant can be relatively easy to separate, humeri, radii, femora and tibiotarsi can be problematic. Fragmentation compounds the issue: for example, a femur with the proximal end present can be identified but isolated distal ends are not quite so distinct (pers. comm. S. Hamilton-Dyer, 30/I/20I7).

Fifty-two guinea fowl, common pheasant and black grouse specimens were included for geometric morphometrical analysis to determine whether this method could provide a reliable means of distinction. Digital images together with biometrical data were collected from the coracoid, humerus, tibiotarsus and tarsometatarsus. The majority of the skeletons were accessed through the Natural History Museum, Historic England and the Universities of Sheffield and York. Details of the individual specimens can be found in Appendix A, Section I.2. The black grouse and pheasant specimens are generally from shot birds or from road casualties. Most of the guinea fowl are from commercial flocks, raised for meat, with just one defined as 'unimproved'. Beyond this, the particular strain of the guinea fowl was not recorded.

### 3.3 Archaeological assemblages

### 3.3.I Introduction

For the comparative archaeological assemblages, three main sites were included. The Romano-British assemblage from West Hill, Uley, Gloucestershire represented domestic fowl relatively soon after their introduction to Britain. Here, chickens seem to have been present primarily as sacrificial offerings. By contrast, the poultry kept at the Saxon 'double monastery' at Lyminge would most likely have been kept for meat and egg production. A $16^{\text {th }}$-century 'feasting pit' discovered during the excavations at the Roman amphitheatre at Chester may yield evidence for specialisation in breeding and rearing birds for the table, with the possibility of caponised fowl among the remains.

Selected coracoids were also included from: Coppergate, York and Flixborough, Lincolnshire. Biometrical and geometric morphometrical data were gathered from these prior to their submission for stable isotope and DNA analysis by other members
of the Project team. The aim was to produce a suite of results for comparison from each individual specimen. Figure 6 shows the locations of the British sites. Details of the individual bones together with biometrical data can be found in Appendix C.


Figure 6: Map of site locations.

### 3.3.2 West Hill, Uley, Gloucestershire: Romano-British temple

This $4^{\text {th }}$-century Romano-Celtic temple complex site (Woodward et al 1993) is located on high ground in the Cotswolds, adjacent to the large hillfort known as Uley Bury. In 1976, a watching brief carried out in advance of a water main installation revealed features and finds indicating a Roman religious site: this was followed by three seasons of investigation sponsored by English Heritage (now Historic England), the British Museum, the Society of Antiquaries of London and the Bristol and Gloucestershire

Archaeological Society. Excavations revealed a multi-phase complex spanning eight centuries, from the Neolithic to the $7^{\text {th }}-8^{\text {th }}$ century AD. The complex was at its height during the early second to the late fourth centuries AD (phases 4 to 5 ), when a stone temple and ancillary buildings were constructed. Inscribed rolled lead tablets, together with fragments of a limestone statue, figurines and altars indicate that the temple was dedicated to the god Mercury - the statuary and figurines include several portrayals of the god accompanied by his cult animals: rams, goats and cocks. Mercury's association with cocks is well-established and acknowledged (Crummy 2007).

The vertebrate remains from the site totalled an estimated quarter of a million fragments, the hand-collected material being augmented by an additional component of smaller bones recovered by sieving (Levitan 1993). The assemblage from in and around the temple complex was dominated by the remains of mature male sheep and goat (mostly goat), with an unusually high percentage of domestic fowl bones, most of which were also identified as from mature males. The location of these bones, both spatially and temporally, their identification as remains of animals sacred to Mercury, the predominance of males and the low incidence of butchery marks were all persuasive evidence for a substantial votive element to the assemblage.

The domestic fowl assemblage was not reported upon separately although an initial assessment was undertaken by Brothwell and incorporated into the vertebrate remains report (Levitan 1993:272). Approximately 3000 domestic fowl bones were retrieved, calculated as $3.79 \%$ of the total number of identified fragments and representing an estimated 500 chickens. Brothwell also carried out separate investigations into the sub-adult component of the assemblage (Brothwell 1997) and evidence for crested fowl at the site (Brothwell 1979). Preliminary examination during biometrical data collection also revealed at least two 'creeper' fowl (including one almost-complete skeleton). Not all of the assemblage was accessible for recording and analysis: the elements included in this study are listed in Appendix C, Section 3.I.

The chickens from the temple at Uley are exceptional in that their sacrifice took place in the context of a large and well-structured ritual complex. Domestic fowl remains have been recovered from other Romano-British sites associated with sacrificial and ceremonial activity (Philpott I991:20I; King 2005), although not in such high individual
numbers and mostly on a smaller scale. Individual Roman inhumations are frequently accompanied by a chicken, sometimes placed in an urn (Fraser and Ryder 1968; Lauwerier I993; Dobney and Jaques 1994; Leary 1994; Barber and Bowsher 2000; Booth et al 2010; Foster 2012) which may be interpreted simply as a gift of food for the deceased: however the cock's association with Mercury, who escorts the souls of the dead to the afterlife, is also significant in this funerary context (Crummy 2007:225).

### 3.3.3 Lyminge, Kent: Anglo-Saxon monastery

The village of Lyminge in south-east Kent is the site of a high-status Anglo-Saxon double monastery, founded in the $7^{\text {th }}$ century AD. These mixed communities of monks and nuns, typically headed by an abbess of royal or high birth, were a short-lived feature of early medieval monasticism and most had disappeared by the middle of the $9^{\text {th }}$ century.

The site was excavated between 2007 and 2014 by a team from the University of Reading in association with Canterbury Archaeological Trust and Kent Archaeological Society (Thomas 2013). The domestic fowl remains analysed for this study relate to the 2008-20I2 seasons and were recovered by a combination of sieving and hand collection. Those included in this study are listed in Appendix C, Section 3.3.

Previous investigations in and around the village had unearthed the $7^{\text {th }}$-century minster church and a pre-Christian cemetery, the latter indicating the importance of the site prior to the foundation of the monastery. The excavations revealed a large complex with evidence for domestic occupation, crafts and economic activities associated with the monastic period, together with sunken-featured buildings and several large timber halls from earlier phases.

Faunal remains were collected by hand-excavation together with a programme of dry sieving, improving the recovery rates of bird bones and other small elements. High concentrations of domestic fowl remains were present in deposits dated to the $5^{\text {th }}-$ $7^{\text {th }}$ centuries, comprising $15.5 \%$ of total NISP, increasing to $37.25 \%$ of total NISP for the $8^{\text {th }}-9^{\text {th }}$ century phase: an increase in sheep remains was also noted in the later phase (preliminary unpublished data from Z. Knapp, University of Reading). An elevated proportion of sheep and chicken bones is characteristic of Middle-Saxon religious houses (Holmes 20II), likely reflecting Benedictine dietary restrictions and
wool-production. Many of the chicken remains from the later phase were chicks and immature birds (Baker 2012), the chicks presumably being natural casualties indicating breeding and therefore a degree of self-sufficiency on site, although these were probably supplemented by birds rendered by tenants as 'food rents' (Stone 2006:I53). The bones of immature individuals represent the choice meat - tender pullets and young cockerels - available to the high-born inhabitants and their guests. Feasting and drinking constituted a part of Saxon monastic life as much as it did in contemporary aristocratic culture (Foot 2006:236), with hospitality also a significant factor (ibid 237) and this pattern is repeated at late-Saxon Eynsham Abbey where, $30 \%-40 \%$ of the chicken bones were immature (Serjeantson 2006:137). Although eggs would have been an important part of the diet, as evidenced by Aelfric's Colloquy (ca. 995) which lists eggs among the foods eaten by the novices and students (Aelfric's Colloquy: line 56), no eggshell was identified from the site despite the favourable preservation conditions and an intensive programme of environmental sampling.

The domestic fowl may have possessed a relatively prominent status in the early medieval period. Contemporary Frankish laws record the penalty for stealing a cock or hen was 120 denarii, as much as for the theft of a sheep, a sparrow-hawk or a herd dog, plus extra penalties for the time it was lost: Drew (2012:71-2) and Welch (2007) assert that the Kentish elite had cultural contacts with continental Frankia at this time.

### 3.3.4 Chester, Cheshire: Early-modern feasting deposit

The Roman amphitheatre at Chester is situated on high ground on the banks of the River Dee, just outside the legionary fortress. By the late-medieval period, the upstanding remains of the amphitheatre had all but disappeared and the area had been redeveloped with high-status buildings including housing for clergy associated with the adjacent collegiate church of St John the Baptist. After the Dissolution (1547), the church continued as the parish church: most of the surrounding high-status buildings seem to have survived the transition (Barrow et al 2005). John Speed's map of 1610 shows the location of the amphitheatre in relation to the church of St John the Baptist.

Excavations in and around the Chester amphitheatre took place in the summers of 2004 and 2005, jointly funded and implemented by Chester City Council and English Heritage (now Historic England). Three main areas were investigated: Area A, the north-western section of the cavea (seating); Area B, the post-Roman archaeology
between the amphitheatre and St John's church; and Area C, the early medieval occupation levels and subsequent accumulation of cultivation soils within the arena (Figure 7).


Figure 7: Location of Area C within the Amphitheatre site. Drawing by R. Gordon (after Wilmott et al, 2006:9)
A large 2.5 m deep rectangular pit, discovered in Area C, contained a huge amount of food waste including well-preserved mammal and bird bone and marine shell. The homogeneous preservation of the remains indicated that they had most likely been dumped over a short period and the deposit was interpreted as the debris from a high-status feast - the pit possibly being dug specifically for this event. Associated finds include late $15^{\text {th }}-16^{\text {th }}$ century glassware and pottery, mostly apparently from drinking vessels, together with a gold ring and a tin-glazed owl cup, also dated to the $16^{\text {th }}$ century (Wilmott et al 2006).

The pit was extensively sampled and much of the fill wet-sieved to 2 mm , improving the recovery rate of juveniles and smaller taxa. Identifications from the animal bone assemblage are consistent with documentary and archaeological evidence for elite consumption at this time (de Worde I508; Maltby 1982; Albarella and Davis 1996 for 1994; Woolgar 200I; Albarella and Thomas 2002; Thomas 2005), providing direct evidence for foods that included beef, veal (particularly calf heads), mutton, lamb and pork (including numerous suckling pigs), chicken, goose, duck, peafowl, venison, hare and rabbit, flatfish, large salmon, oyster and mussel. Among the species identified in the large and varied wild bird assemblage were woodcock (Scolopax rusticola L. I758),
teal/garganey (Anas crecca/querquedula L. I758), lapwing (Vanellus vanellus L. I758), grouse (Tetrao sp.) golden plover (Pluvialis apricaria L. I758), curlew (Numenius arquata L. I758), snipe (Gallinago gallinago L. I758), heron (Ardea sp.) and thrushes (Turdus sp.) (Gordon 2015). Chicken bones are by far the most numerous of the bird remains, the NISP (Number of Identified Specimens) from combined hand-collected and sieved material (659) being approximately a third of the entire bird assemblage (plus 664 from chicken-sized Galliformes not identified to species). During data collection it became clear that the chicken assemblage contained many paired elements and it seems very likely that the remains represent complete but disarticulated skeletons. The bones used for this study are listed in Appendix C, Section 3.6.

The $16^{\text {th }}$-century feasting pit chickens were incorporated into the study as they derive from a period of documented directed breeding. 'Short-legged hens' for the table appear in contemporary literature, being mentioned by both Shakespeare (Henry IV Part 2, Act 5, Scene I) and Jonson (Inviting a Friend to Supper) and possibly refer to square-bodied, fattened Dorking-types rather than creepers. Capons appear regularly in recipes and accounts of the period and were considered a high-status food (Hammond 1993:60; Woolgar 200I) - certainly superior to the ordinary cocks and hens that at that time were 'so common that the poorest widow in the country is able to keep them' (Heresbach 1577) - and it is entirely possible that some of the bones in the pit were of caponised fowl. For a discussion on the problems of identification of capons within archaeological assemblages, see Section 2.5.3.

As well as the bones from Uley, Lyminge and Chester, a number of additional coracoids became available through studies undertaken by members of the Chicken Project (Cultural and Scientific Perceptions of Human-Chicken Interactions). The sites concerned are: Anglo-Scandinavian Coppergate (York); Anglo-Saxon Flixborough (North Lincolnshire); and Fishbourne Roman Palace, Chichester, West Sussex.

### 3.3.5 Coppergate, York

16-22 Coppergate is located within the medieval walled city of York, on sharply sloping ground between the rivers Foss and Ouse. The site was excavated between 1976 to I98I by professional archaeologists from the Ancient Monuments Inspectorate of the Department of the Environment (now Historic England), together with members of the British Academy, personnel from the Manpower Services

Commission and many private individuals. Coppergate, like numerous other sites in York, is notable for well-stratified and excellently preserved sequences of occupation, in this case spanning sixteen centuries from the $I^{\text {st }}$ century AD to the early postmedieval. Most of the vertebrate remains were recovered from deposits associated with four Anglo-Scandinavian tenements dated from mid-9 ${ }^{\text {th }}$ century to mid-II ${ }^{\text {th }}$ centuries (Allison 1985; O'Connor 1989). Extensive sampling and wet-sieving of the Anglo-Scandinavian levels, with residues sorted to 2 mm , ensured that smaller taxa including chickens were well-represented.

Chicken bones dominate the bird assemblage (O'Connor 1989:I94). The total NISP of Anglo-Scandinavian chickens was 1267; approximately half of all the identified bird bones (2484) and $2.35 \%$ of all identified fragments (54020) from Anglo-Scandinavian levels. Of the coracoids selected for the study (Appendix C, Section 3.5), most derived from Phases 4B, 5B and 5C which span the $10^{\text {th }}$ to late $1 I^{\text {th }}$ centuries, with a few from early $13^{\text {th }}$ century features post-dating the tenement development. Concentrations of domestic fowl remains were recovered from backfills of the tenements accumulated during Phase 5B (late-IO $0^{\text {th }}$ to mid-II ${ }^{\text {th }}$ century). It is possible that chickens were kept in the tenement yards, although no bird parasites were identified and no feathers or whole eggs were present (Kenward and Hall 1995:779). It has been suggested, however, that some of the irregular, shallow features in the yards may be the result of chickens scratching and dust-bathing (Kenward and Hall I995:779; Dobney et al 2000).

### 3.3.6 Flixborough, Lincolnshire

The North Lincolnshire parish of Flixborough lies approximately 8 km south of the Humber estuary overlooking the Trent floodplain and delta. Between I989 and I99I, excavations by the Humber Archaeology Unit (now the Humber Archaeology Partnership) funded by English Heritage (now Historic England), revealed the remains of an elite Anglo-Saxon settlement dated from the $7^{\text {th }}$ to the early $1 \mathrm{I}^{\text {th }}$ centuries, with a subsequent phase from the $12^{\text {th }}$ to the $15^{\text {th }}$ centuries (Loveluck 1998; Loveluck and Gaunt 2007). Initial interpretations based on artefactual evidence indicated that the settlement had been a monastic foundation (Yorke 1993; Whitwell I994; Blair I996), although Loveluck favoured a more cautious approach, comparing Flixborough to architecturally similar estate centres for secular or ecclesiastical magnates from the same period (Loveluck 1998).

Seven phases of occupation were identified, with periodic demolition and levelling, the whole area preserved beneath up to two metres of windblown sand. The remains of over 40 buildings were unearthed, together with ovens, haylofts, fences, paths and yards. Refuse had been dumped in huge middens in what appeared to be designated discard zones. The overlying windblown sand provided excellent preservation conditions for the vertebrate assemblage and approximately 200000 fragments of animal bone were hand-collected with thousands more bones recovered from the sieved assemblage. Over 41000 mammal and bird bone fragments from early $7^{\text {th }}$ to late $10^{\text {th }}$ century deposits were identified to taxon.

Material culture and food remains indicate changes in the nature of the settlement over time, with evidence for conspicuous consumption in the $7^{\text {th }}$ to mid- $8^{\text {th }}$ century phases including: large buildings; a species-rich bone assemblage dominated by cattle; and luxury foods such as poultry, hunted animals and exotic small cetaceans. By the $9^{\text {th }}$ century, the status of the site had declined; buildings and artefactual evidence suggested a community of craft-workers, particularly iron-smelters. Cattle consumption decreased and a prevalence of mature animals in the sheep assemblage implied wool-production.

Domestic fowl remains were present in considerable numbers and constituted around half of the hand-collected bird bones identified from the late- $7^{\text {th }}$ to $10^{\text {th }}$ centuries, although there was a gradual decline in chicken bones as a percentage of the total hand-collected NISP across the same period. Bimodal distributions in long bone measurements show principally two groups, probably hens and cocks of the same type but Dobney et al (2007) identified a number of outliers and discussed the possible presence of capons. Eggshell was recovered from $12 \%$ of the wet-sieved samples but this is undoubtedly an underestimate of the actual incidence of eggshell from across the site and from different phases of occupation as environmental sample residues smaller than 4 mm were not checked. Forty-four percent of the deposits where eggshell was recorded were from Phases 4-5b ( $9^{\text {th }}$ century), suggesting that eggproduction was significant at this time (Dobney et al 2007). Details of the coracoids included in the study are given in Appendix C, Section 3.4.

### 3.3.7 Fishbourne Roman Palace, Chichester

The large Roman palace in the village of Fishbourne, Chichester in West Sussex was built in the $I^{\text {st }}$ century AD. It was constructed on the site of an abandoned postinvasion army supply base, with the first phases of the palace dating to around 75 AD. Development continued throughout the $2^{\text {nd }}$ and $3^{\text {rd }}$ centuries, culminating in a rectangular plan surrounded by formal gardens. The palace burnt down during a period of further alterations ca. 270, after which it was abandoned.

Major excavations were carried out throughout the 1960s (Cunliffe 1998). During 2002-2004, Sussex Archaeological Society returned to the site to investigate the earliest phases of the complex (Manley and Rudkin 2002), focusing on the transition from Iron Age to Roman military.

Analysis of the faunal remains from Fishbourne has produced evidence of early ( $1^{\text {st }}$ century) introduction and emparkment of exotic animals including fallow deer and hare (Sykes 2009; Allen and Sykes 201I; Sykes 2014; Miller et al 2016). It is not unreasonable to assume that the flock of palace chickens could have included some considered 'fancy breeds' - unusual plumage or other remarkable physical traits - as well as those kept purely for meat and eggs.

Metrical data for the Fishbourne coracoids was collected by Dr Julia Best (see Appendix C, Section 3.2) but no direct access to the material was possible prior to its destruction for DNA and isotope analysis and no photographs were taken for GMM.

### 3.4 Bone Elements selected for linear biometrical analysis and geometric morphometrics

Measurements from complete domestic fowl bones from both archaeological and modern reference specimens were included in the linear biometrical analysis. Archaeological bones of juveniles, identified by their porous appearance, were excluded, together with those showing evidence of pathology, those damaged by taphonomic processes and, for some analyses, those that could be identified as the remains of creeper chickens. For the geometric morphometrics analysis, five postcranial elements were initially selected (the coracoid, humerus, femur, tibiotarsus and tarsometatarsus) but it soon became apparent that not all of these were suitable for

2D geometric morphometrics. The long, slender shaft of the tibiotarsus makes it vulnerable to damage and mid-shaft breaks are common in archaeological material, therefore the number of archaeological specimens suitable for GMM was much reduced. In addition, the incomplete preparation of some of the historical museum skeletons used for data collection meant that soft tissue was often still attached and fibulae were not disarticulated, making consistent presentation to the camera lens problematic and the subsequent identification and placing of some landmarks impossible. These specimens were necessarily excluded from the GMM dataset, although tibiotarsi which could be confidently refitted could still be used for the linear biometrical analysis. The cylindrical shape of the femur shaft and directional variation in both proximal and distal articulations made consistent placement for image capture impossible and geometric morphometric analysis of this element was discontinued. Limb elements from individuals identified as carrying the 'creeper' gene were excluded from some linear biometrical analyses, for example, for the purpose of estimating sex ratios.

For the non-chicken Galliformes, coracoids, humeri and tibiotarsi and tarsometatarsi were digitised for geometric morphometrics. Although linear metrics were collected from these elements and the femora, time constraints and a narrower research question meant that these data were not analysed or compared with the GMM results.

A more detailed description of each element follows, including information on form and function and references to relevant studies.

### 3.4.1 Coracoid

The coracoid (Figure 8) is an important element of the pectoral girdle, bracing it against the strain of the major flight muscles and forming an important part of the downward stroke mechanism. The hooked process at the proximal end meets with the furcula and scapula to create the triosseal canal through which the supracoracoideus tendon passes. The proximal end of the humerus fits into the shallow glenoid cavity formed by the scapula and coracoid. The distal end is flattened and expanded with a saddle-shaped articular surface which fits rigidly into facets in the sternum. There is considerable morphological variation in this articulatory surface between the modern chicken reference specimens which may be related to functionality or breed but which is very difficult to capture using linear biometrics. At
the dorsal surface at this end there is also an irregular depression for the attachment of the sterno-coracoidal muscle. The foramen for the clavicular air sac (when present) is situated within this depression.


Figure 8: Right coracoid in ventral (A), dorsal (B) and medial (C) views. (Tomek and Bocheński 2009)
The coracoid was included in the morphometrics study for a number of reasons. Its flattened shape made it suitable for 2D geometric morphometrics and although the bone was more stable placed ventral side up, the complexity and morphological variation of the features on the dorsal aspect suggested that this side would be more useful for identifying breed-related variation. Some of this variation may be due to functionality, for example, recent research indicates that the shape and size of the coracoid is correlated with the body mass of extinct and modern volant birds, with the maximum lateral length being the most significant variable in Galliformes (Field et al 2013). Following biometrical data collection and digital image capture, the archaeological coracoids were forwarded to other project members for DNA and stable isotope analysis.

### 3.4.2 Humerus

The humerus, the proximal wing bone (Figure 9), is relatively short and stout with a slightly curved shaft to transfer flight-associated stresses towards the joints. Two large
crests serve as attachment points for the powerful flight muscles (supracoracoideus and pectoralis) - the sizes and locations of the muscle attachments and the overall shape of the humerus vary between taxa and are related to flight style (Kaiser 2007). The brachial index - the ratio of the greatest length of the humerus to the ulna - is also related to flight styles and foraging habits in different families of birds; Nudds et al (2004) found the index in some Galliform species lies close to 1.0 but did not compare different chicken breeds. The proximal articulation of the humerus is broad and flattened and there is a large foramen for the clavicular air sac. The reduced pneumatisation noted in the modern Silkie reference coracoids is not apparent in the humeri from the same individuals.

Despite the round shaft, when laid with the caudal surface uppermost, Galliform humeri lie flat and very stable and this, together with the possibility of breed-related variability, made them ideal for inclusion in the geometric morphometrics study.


Figure 9: Right humerus in anterior (A) and posterior (B) views. (Tomek and Bocheński 2009)

### 3.4.3 Tibiotarsus

The avian tibiotarsus (Figure 10 ) is actually a compound element, formed by the fusion of the tibia with a number of tarsals. The proximal end is characterised by flared crests which form attachment points for the tendons and muscles of the knee. The long and slender shaft terminates at the distal end in two condyles which articulate with the tarsometatarsus. The thin, much reduced fibula runs parallel to the lateral shaft of the tibiotarsus terminating in a fine, normally unattached, distal point. Occasional exceptions include stress-induced enthesophyte formation which fuses the point to the tibiotarsus, and the fibulae of some chickens carrying the creeper gene in which the fibula is thickened and ankylosed to the tibiotarsus (Gordon et al 2015).


Figure 10: Right tibiotarsus in proximal (A) and anterior (B) views. (Tomek and Bocheński 2009)
The tibiotarsus dataset was considerably smaller than those for the humerus, coracoid and tarsometatarsus. Very few archaeological specimens were undamaged and suitable for GMM. Of the modern reference bones, several were excluded from the GMM
study, although biometrical data could sometimes be taken: problems included bowed shafts, enthesophyte formation and other pathologies, together with incomplete processing of some historical specimens.

### 3.4.4 Tarsometatarsus

The tarsometatarsus (Figure II) consists of three bones, the $2^{\text {nd }}, 3^{\text {rd }}$ and $4^{\text {th }}$ metatarsals, fused together. At the proximal end, two approximately equal concavities articulate with the tibiotarsus. On the plantar surface there is a perforated structure the hypotarsus - through which the flexor tendons, which control the foot, pass: the shape and number of passages in the hypotarsus is variable and can be used for classification (Mayr 2016) but it is fragile and subject to breakage and erosion in


Figure 11: Right tarsometatarsus in dorsal (A) and plantar (B) views. (Tomek and Bocheński 2009)
archaeological specimens. At the distal end, three trochlea articulate with the $2^{\text {nd }}, 3^{\text {rd }}$ and $4^{\text {th }}$ digits: a small depression on the distal posterior shaft marks the attachment point for the ligament which connects the accessory metatarsal for the $I^{\text {st }}$ digit (hallux) and any supernumerary toes. This accessory metatarsal may occasionally fuse to the
shaft in pathological and polydactylous specimens. A large foramen slightly off-centre on the distal shaft marks the line of fusion between the $3^{\text {rd }}$ and $4^{\text {th }}$ metatarsi. Male (and occasionally female) chickens and pheasants develop spurs but these are absent on grouse and helmeted guinea fowl.

Similar to the bones of the wing, the relative lengths of the lower limb bones are related to evolutionary and behavioural characteristics, for example, a lengthened leg is an evolutionary development in cursorial birds which gives extra leverage and improves efficiency in walking and running. The maximum adaptation occurs in the distalmost elements, therefore there is a greater degree of elongation in the tarsometatarsus when compared to the femur. An extreme example of this is the roadrunner (Geococcyx sp.) (Engels 1938). Many chicken breeds, especially game birds, 'bankiva' types and light Mediterranean breeds appear long-legged when compared to heavier breeds such as Dorkings and comparison of bone element ratios may be able to identify these differences.

The tarsometatarsus has been used previously to distinguish between breeds/types and sexes (West 1985; Sadler 1991) and is significant in evolutionary and functionality studies (Zeffer et al 2003). Although both the spurs and hypotarsus pose problems when positioning the bone flat for 2D image capture the research potential makes the attempt worthwhile.

### 3.5 Additional elements

### 3.5.I Furcula

The $v$-shaped furcula, or wishbone, is part of the appendicular skeleton. It is formed from two clavicles, the ventral ends of which are fused and attached to the sternum by a ligament. The terminals are attached to the coracoids: flexion of the furcula during flight or other activity therefore reflects movement in the coracosternal joint. The role of the furcula is still not fully understood (Bailey and Demont 199I; Nesbitt et al 2009). Jenkins et al (1988) proposed that the expansion and contraction of the starling furcula during flight acts as a kind of bellows to compress the interclavicular air sacs and aid respiration. Certain shapes seem to correlate with flight requirements or locomotion in some avian groups (Hui 2002; Close and Rayfield 2012) but in some volant birds, for example a number of owl and parrot species, the symphysis remains
unossified without affecting flight ability. The furculae of magpies (Pica pica L. I758) and starlings (Sturnus vulgaris L. I758) spread laterally from the midline during the downstroke of the wings and recoil on the upstroke (Jenkins et al 1988; Boggs et al 1997) but this dynamic is not universal to all birds: the opposite is true for chukar partridges (Alectoris chukar Gray I830) in flight (Baier et al 2013) and the furculae of hawks are robust and do not flex at all.

Although Hui (2002) concluded that furcula morphology is influenced more by function than phylogeny, it seems possible that some shape differences, for example variation in the angle of the fused clavicles, might be associated with body weight or size, sex, breed or wider genetic groups. Differences in the curvature of the clavicular rami and in the outline of the hypocleidium (the projection at the symphysis) of chicken furculae were interpreted by Darwin as breed-related (I868: 268), although he does not disclose how many specimens of each breed his observations were taken from. Inspection of furcula morphology during preparation of modern chicken skeletons for the present study also revealed considerable variability and suggested morphological similarities within some groups and breeds. For example the clavicles of some Asian game breeds, notably the Shamo and Asil (UoL accession nos. R657, R658 and R662), had a much-reduced curve giving them a 'flattened' appearance which, together with a wide angle at the symphysis gave the furcula a triangular outline. The modern broiler chicken furculae also had a wide angle at the symphysis, possibly associated with overdeveloped pectoral muscles.

A study was undertaken to investigate the relationship between the shape of the furcula, body weight and flying ability. A set of novel measurements are detailed in Section 4.2.4: results are in Section 5.5.

### 3.5.2 Pelvis

The avian pelvis comprises the ilium, ischium and pubis which are separate at hatching but fuse, first with each other and subsequently with the synsacrum, creating in the mature bird a rigid protective vault for the abdominal organs including the reproductive system. Fusion times for avian bone elements, including the pelvis, vary according to breed, sex and nutrition (Latimer 1927; Harrison 1970; Harrison 1975; Habermehl 1975; Hogg 1980; Hogg 1982; Thomas et al 2016). Although several of these studies include fusion data for the pelvis these refer to young birds and do not
include times for fusion to the synsacrum. As noted in Section 2.5.3, there do not appear to have been any previous investigations into the potential of the avian pelvis for sex determination in archaeological material, possibly because this element is often recovered unfused or fragmented, but it seems reasonable to assume a correlation between egg-laying capability and pelvis shape. The egg-to-body ratio of birds is far larger than for other egg-laying animals such as reptiles and the wide abdominal cavity extends far to the rear of the hip joint to facilitate the accommodation and passage of the fully-formed egg. Working on the assumption that the caudal end of the female pelvis would likely be a different shape from the male, two new metrics were designed to describe this variation.

The standard measurement (von den Driesch 1976) which captures the widest breadth of the pelvis is the distance across the two antitrochanter (BA). These are the articulations of the acetabulum which brace the femoral trochanter and limit abduction. However, this measures the pelvis in the middle and does not effectively describe the variation at the caudal end which may relate to the extra capacity in the female pelvis for the development and passage of an egg. Both the spinae dorsolateralis ilii and the processus terminalis ischii are caudal features of the pelvis and measurements of the width between them may be a more useful indicator of egg-production but neither is included in the standard suite of measurements established by von den Driesch. These measurements are defined in the methods section (4.2.4) and a small study was carried out to test their potential (Section 5.6).

## 4 Methods

## 4.I Geometric Morphometrics

This section is intended to be an introduction to geometric morphometrics and comprises an explanation of the underlying theory and past applications as well as the description of the method employed for data collection. The introduction presents a general overview of GMM, including some of its advantages over ordinary linear biometrics. Past applications are reviewed and present potential assessed. Technical issues relating to the selection and placement of landmarks are listed. Finally, a detailed description is given of the landmark configurations designed for each of the four elements chosen for the study.

## 4.I.I Introduction to Landmark-based Geometric morphometrics:

Traditional biometrical methods measure linear distances, typically length, breadth and depth. The main advantages with these methods are that they are very simple; they are normally taken to an accepted standard (for example, that proposed by von den Driesch (1976)) and require minimal specialist equipment. However, linear distance is highly correlated with size and shape may not be reflected in size variables, which can make shape analysis difficult. Another disadvantage is that measurements from two different specimens can produce identical results if their location in relation to each other is not included. For example, the smallest breadth of the corpus measurement on bone shafts (designated 'SC' by von den Driesch (1976)) may occur in significantly different places on various specimens of the same element. The advantage of landmark-based geometric morphometrics is that, because it uses a suite of Cartesian coordinates instead of linear measurements, it records both size and shape (although size per se is discounted during analysis) and allows the quantification and comparison of complex features which are difficult or impossible to measure using traditional biometrical methods. Graphical representations of the specimen can also be reconstructed from the recorded measurements, especially when three-dimensional coordinates are taken. On a practical level, digitally captured images are easier to store, transfer and share than the physical archive.

For landmark-based geometric morphometrics, individual photographs or scans are taken of every specimen included in the study. To obtain reliable data each specimen must be of a high quality, for example, each element must be complete, of good preservation and free from mineralised concretions or other material which may obscure features. Bones displaying pathological conditions should also be discounted. Photographs must show contrast and be sharply focused and orientation of the selected specimen must be consistent across all of the images used; consistency of distance and lighting is also desirable. Such an approach enables easier recognition of landmarks and reduces the need for compensatory procedures such as enhancement of the photographs using image processing software.

There are a number of advantages to the landmark-based method, the most significant of which is that size can be mathematically removed so that shape alone can be concentrated upon. Providing that the quality of the photographs/scans is good, data are easily collected. Both 2D and 3D coordinates can be presented visually as a shape rather than tables of numbers, aiding interpretation. One of the disadvantages of landmarks is that they do not convey information on the spaces between the points and changes occurring in these areas cannot be included in the analysis, although the use of semi-landmarks can go some way towards resolving this problem.

For landmark based geometric morphometrics, corresponding (biologically homologous) anatomical points are marked on the photographs. There are three main types of points: landmarks which relate to a feature of biological significance (for example, the point at which sutures meet); those which are used to describe maxima or minima of curvature; and constructed landmarks which are defined by their position in relation to other landmarks and are often used when there are insufficient identifiable features. These categories are more fully described in Section 4.I.3.6. These variables are represented by Cartesian coordinates, which can be recorded either two- or three-dimensionally. Three dimensional coordinates are more suitable for elements with considerable depth and complexity such as skulls, while the simpler 2D method (in which all the landmarks should ideally lie in the same geometric plane) is adequate for 'flatter' bones like bird coracoids.

For the analysis of landmark-based data, differences of size, location and orientation are removed by the application of a three-step process known as Procrustes
superimposition. The centroid (centre of gravity) of each coordinate configuration is calculated and each configuration is then superimposed onto a common centroid. The configurations are rescaled to an equal size and rotated until the sum of the squared distances between corresponding landmarks is minimised. The Procrustes coordinates now describe shape per se. Figure 12 illustrates this procedure in a simplified way, and Section 4.3.I explains the process more fully. The shape-changes identified can be visualised in a number of ways including deformation grids and wireframe diagrams.


Figure 12: The Procrustes fit sequence simplified.
Principal Component Analysis (PCA) can then be carried out on the configuration points generated to obtain principal component scores (also called relative warp scores) for each configuration of points. Statistical methods can be applied to the principal component scores, for example, comparison of different groups using discriminant function analysis.

Several issues need consideration when using landmark-based geometric morphometrics. The choice of the landmarks themselves is important, to ensure that they are applicable to the research questions and reflect most effectively the changes in bone morphology due to, for example, selective breeding. Occasionally, landmarks may be difficult to identify, perhaps due to inferior quality images, poor preservation of specimens or actual reduction in the size of diagnostic features and in these cases, a decision must be made to either exclude those specimens or estimate the location of the landmark. When capturing images for 2D geometric morphometrics, consistent planarity of a specimen is crucial as any variation will have a detrimental effect on the relative position of the landmarks. Flat elements such as mandibles which split at the symphysis (such as those of bovids and rodents) present few problems but crania and long bones are more problematic and means must be found of positioning each
specimen consistently so that it presents the same aspect to the camera lens. Measurement error, which can amplify the amount of variance within a sample, can never be totally eliminated and has been acknowledged by several authors (Arnqvist and Mårtensson 1998; Fruciano 2016; Webster and Sheets 2010; Zelditch et al 2012) as a potentially serious problem. Various strategies have been proposed to estimate the extent of any errors and make compensation. For example, a measurement error assessment can be carried out prior to taking the images which will be used for the study. The methods, results and implications of a pilot study to test for measurement error are presented in Section 6.2.

## 4.I. 2 Past applications and future potential

Geometric morphometrics, described as "the empirical fusion of biology and geometry" (Bookstein 1982:45I), has been used widely to address zoological research questions, in particular those concerning inter- and intra-species variation. Recent studies have included investigations into adaptive bone remodelling (Anderson et al 2014), dispersal of commensal species (Valenzuela-Lamas et al 2011), identification of closely related species (Cordeiro-Estrela et al 2008) and morphological differences relating to domestication (Drake and Klingenberg 2008; Devillard et al 2014). The technique has been extensively applied to pig remains, most recently to identify differences between crania from wild and domestic individuals and to attempt to distinguish between modern pigs of traditional breeds (Owen et al 2014). Studies in which geometric morphometrics has been used in a direct comparison with traditional biometrical analysis include an investigation into dimorphism of the cranium and mandible of a species of South American lizard (Fabre et al 2014): here the authors concluded that while both techniques produced similar results for the mandible, geometric morphometrics was better at identifying shape differences in muscle insertion areas of the cranium.

Geometric morphometrics has not been applied to archaeological domestic fowl assemblages with the aim of breed or type distinction, although a biometrical analysis of chicken bones which attempted to identify breeds or types in a large assemblage from a $6^{\text {th }}-7^{\text {th }}$ century Turkish site showed encouraging results (De Cupere et al 2005). Here, a combination of linear measurements of long bones and observations of medullary bone present enabled recognition of three breeds of varying size, including a
small 'bantam' type. Similarly, wide variation in the sizes of tarsometatarsi from Roman Colchester revealed at least two different sizes of fowl within the spurred fraction suggesting different breeds or types, although the presence of capons was also considered (Luff and Brothwell 1993:97). These findings show that breeds/types can be identified using size-variance but it is possible that shape-variation of similarly-sized elements, identified using GMM, may also reveal breed-related differences.

## 4.I. 3 Choosing and placing landmarks

When selecting landmarks for a new project it is often recommended that previous studies are consulted to find conventions appropriate to the subjects being researched. In the case of the present study, however, no prior work has been carried out on avian post-cranial bones, necessitating the development of a new protocol. The criteria which must be considered when choosing landmarks for a geometric morphometric study are listed below.

### 4.1.3.1 Homology/correspondence

Landmarks must be homologous or correspond across all the specimens in the study. Correspondence is often equivalent to homology, but not always. For example, the juncture of specific skull sutures in mammals of the same family, genus or species would be homologous landmarks but the wingtips of unrelated flying animals would be described as corresponding.

### 4.1.3.2 Coverage

Fullest possible coverage of the specimen is preferred but may be more important in some cases than others. For example, a study involving shape change linked to evolutionary development requires maximum coverage of the specimen, whereas for a biomechanical study it would be more important to identify and landmark functionally relevant parts of the structure.

### 4.1.3.3 Repeatability

Issues with repeatability are closely related to homology/correspondence. To reduce the risk of measurement error, landmarks must be able to be located reliably and placed on all specimens multiple times. Problems with repeatability are often associated with Type II landmarks which are defined as maximum/minimum curvature; these often require extra care when identifying the point at which the curve changes
direction. Other problems may be due to pronounced morphological variation within individuals in a population, especially where domestication is a factor. Repeatability can vary considerably between various types of structure. Well-defined anatomical features, such as the intersections of veins in fly wings (Klingenberg et al 1998; Gidaszewski et al 2009), are conducive to reliable and consistent landmark placement whereas some anatomical features on mammal and bird bones may appear indistinct and ambiguous. In archaeological material, taphonomic processes can compound these problems.

### 4.1.3.4 Consistency of Relative Position

Occasionally, landmarks can switch position relative to each other. This is a rare occurrence and is usually related to migrating foramina or anomalous patterns of sutures. Where landmarks are switched, either the specimens or the landmarks themselves must be excluded.

### 4.1.3.5 Coplanarity of landmarks

This is an important point to consider in studies that use 2D images of 3D objects specimens must be consistently orientated under the camera lens and a single plane chosen to reduce distortion. This becomes more of an issue in images of complex objects with greater depth, such as skulls, where 3D digitising would have been more appropriate.

### 4.1.3.6 Typology of Landmarks

Bookstein's influential system of landmark classification (I991) categorises potential points into three types of decreasing value.

- Type I: Discrete juxtaposition of tissues
'Juxtaposition of tissues' describes locally defined points at which adjacent tissues meet, for example the juncture of veins in a fly wing or the sutures of a skull: it also encompasses small, discrete features such as foramina. The points at which teeth and alveolar bone meet may also be used although the dynamic nature of alveolar bone should be considered when choosing these as landmarks. Type I landmarks are widely considered to be optimal as they are independent of each other and biologically easier to interpret. They are especially significant in evolutionary development studies.

However, there are often very few true Type I landmarks on a specimen and other, less ideal, types must be employed to achieve adequate coverage.

- Type II: maxima of curvature or other local morphogenetic processes

These landmarks include points of teeth and the tips of tubercles and processes which may relate to muscle attachments: many are correlated with biomechanical forces. In the present study, the majority of landmarks are of this type. Although shape is of primary significance, functionality may be also a factor, for example, some chickens may be more active than others due to husbandry practices or breed characteristics and this may be apparent in individual features such as muscle attachments or the more general morphology of the bones as a whole. The homological basis of Type II landmarks may have weaker grounds.

- Type III: extremal points

These are also called 'constructed landmarks'. They are often used in cases where smooth, continuous surfaces without definite features (such as the shaft of a long bone or the ventral margin of a mandible) prevent the identification of Type I and II landmarks. Type III landmarks can correspond to existing landmarks, centroids or intersections between inter-landmark segments and can, for example, be placed at the midpoint of a line between two others or at a remote point orthogonal to that midpoint. Because of their interdependence, the direction of their displacement is often constrained to a single direction and results can be difficult to interpret or be of limited value, depending upon the type of study. However, they can be useful for visualisation purposes.

Finally, there are features that are assumed to be homologous between specimens but that have no clear boundaries. These can be rounded structures like bulges on the flat surfaces of bone or voids such as the foramen vasculare distale on the distal tarsometatarsus. in these cases, landmarks can only be placed approximately in the centre. These have been named 'fuzzy landmarks' (Valeri et al 1998).

### 4.1.3.7 Identifiers

When using MorphoJ, each landmark configuration has an individual identifier composed of coded information in a sequence of characters. In this way, classifiers,
which provide information on the properties of each specimen, can be extracted. These can then be used to subdivide data sets or define groups for analyses. The classifiers for the digital images used for the study are: origin of bone element: archaeological excavation or modern/historical reference collection (Table I); the accession number or bone id number; the breed or species (Table 2); sex, if known; age in months, if known; left/right side of the skeleton; the bone element.

| Code | Source |
| :--- | :--- |
| $r$ | University of Leicester |
| t | Natural History Museum, Tring |
| s | Dr Naomi Sykes |
| j | Dr James Barrett |
| k | Enid Allison |
| a | Alison Foster |
| f | Flixborough |
| c | Chester |
| u | Uley |
| l | Lyminge |
| e | Heritage England |
| h | Sheila Hamilton-Dyer |
| y | Coppergate |
| w | University of York |
| $z$ | University of Sheffield |

Table 1: Code letters for excavations, institution and private collections.
A three digit code was used to identify individual specimens/elements where possible. In the case of modern reference material from the University of Leicester, this was derived directly from the accession number allocated to that specimen. Where the institution accession number was longer than three digits, a separate reference number was allocated to each specimen, fully referenced to the original. For archaeological elements, the Bone ID number allocated during the recording of linear biometrical data has been retained making cross-referencing possible. The only exception was Lyminge, where it was not possible to confidently link the elements to the images as Bone IDs were given after the photographs were taken.

Where the sex of the reference specimen was known, the codes ' $m$ ' for male and ' $f$ for female were employed. Where the sex was unknown, as in the case of the archaeological material and some museum specimens, the letter ' $x$ ' was used.

| Code | Breed |
| :---: | :---: |
| ab | Araucana bantam |
| as | Asil |
| bg | Black grouse (Tetrao tetrix) |
| bo | Buff Orpington |
| bs | Black Sussex |
| br | Brahma |
| CO | Cochin |
| cr | Turkish Crested Rumpless |
| dk | Dorking |
| fb | Friesian bantam |
| gf | Guinea Fowl (Numida meleagris) |
| gp | Gold-pencilled Hamburgh |
| hb | Silver-spangled Hamburgh bantam |
| hm | Silver-spangled Hamburgh, full-size |
| ho | Houdan |
| ig | Indian Game |
| jb | Japanese bantam |
| kr | Krüper |
| ku | Kulm |
| la | Lakenvelder |
| Ih | Leghorn |
| Is | Light Sussex |
| ma | Maran |
| ml | Malay |
| og | Oxford Game fowl |
| pb | Poland bantam |
| pf | Old English Pheasant Fowl |
| ph | Common Pheasant (Phasianus colchicus) |
| ra | Rumpless Araucana |
| rb | Ross 308 broiler |
| rc | Rosecomb bantam |
| rj | Cross-bred Junglefowl |
| rr | Rhode Island Red |
| sg | Scots Grey (misidentified - a creeper, probably a Scots Dumpy) |
| sh | Shamo |
| si | Silkie |
| sp | Spanish |
| ss | Speckled Sussex |
| su | Sultan |
| vw | Vorwerk |
| ws | Welsummer |

Most of the modern reference specimens were of known age: ages given by the donors range from accurate (hatching and culling dates given) to approximate (for example $2-3$ years). The ages given by the donors were translated into months and, where ages were approximate, a date was chosen from the middle of the range (2-3 years would be 2.5 years, or 30 months). Only two characters of the identifier were used to record age and where individuals were very old they were recorded as 99 months rather than extending the code to three characters.

Bone elements were recorded as either 'l' for left or 'r' for right. The left side was used preferentially but where this was not possible, for example because of absence, pathology, damage or identifier rings on the tarsometatarsi, the right element was used and the photograph digitally reflected using image manipulating software (Microsoft Picture Manager) to enable it to be landmarked as a left element. Although this resulted in a 'left' sided element for the purposes of landmark placement and analysis, it was still identified as a right element in the identifier string. A copy of the original image was retained.

Abbreviations for elements are given in Table 3.

| Code | Element |
| :--- | :--- |
| cor | coracoid |
| hum | humerus |
| fem | femur |
| tbt | tibiotarsus |
| tmt | tarsometatarsus |

Table 3: Abbreviations for bone elements.

### 4.1.3.8 Photography

One camera and lens was used throughout the data collection process to negate/minimise introduced error as a result of inter and intra-lens variation (Janin 2015). Proximal and distal elements of the bones were in the same horizontal level and care was taken that all parts were in focus. Parallax effect is a known problem when capturing images for geometric morphometrics, the resulting distortion at the periphery of the image can introduce error. It can be overcome by standardising the image capture process, keeping the camera lens at the same angle for every image and placing the specimen in the same place every time (Mullin and Taylor 2002). These requirements were adopted during the photography: in addition, to check for the
parallax effect, a sheet of graph paper was photographed and distortion was found to be very close to zero. Digital images were acquired with a Nikon D60 digital SLR camera equipped with a Nikon AF-S DX Zoom-Nikkor 18-55mm f 3.5-5.6G lens. The camera was mounted upon a tripod with the lens directed orthogonally to, and 37 cm from, the surface the bones were placed upon. Two studio lamps with diffusers were used to create a natural light and reduce highlights and sharp shadows on the images. All photographs were taken with a 100 mm photographic scale for setting scales when digitising the landmarks.

### 4.1.3.9 Data Gathering and Statistical Analysis Software

The software used for creating files and digitising the landmarks is freely available from the Department of Ecology and Evolution, State University of New York, Stony Brook, NY (Morphometrics at SUNY Stony Brook, 2016). Files of images were compiled using tpsUtil (Rohlf 2013) and the configurations of landmarks were digitised using tpsDig2 (Rohlf 2013). Measurement error checks (Section 6.2) and statistical analyses were undertaken using tpsSmall (Rohlf 2015) MorphoJ (Klingenberg 20II) and Past 3.14 (Hammer et al 2001).

## 4.I. 4 Landmarking

For preference, the left elements from reference and archaeological specimens were used but where this was not possible due to absence, breakage, pathology or any other reason, the right element was photographed but then digitally flipped to achieve a reflected image. Coded information in the identifier strings (Section 4.I.3.7) for each bone meant that these reflected images were still identifiable as right-side elements. Anatomical terminology for all elements follows Baumel and Witmer (1993), Proctor and Lynch (1998) and Tomek and Bocheński (2009).

### 4.1.4.1 Coracoid

All the coracoids were photographed from the dorsal aspect. There was a great deal of variability in the morphology of the coracoids from the modern reference chickens, probably related to domestication and breed development. This presented some problems when choosing and defining landmarks. For example, the shape of the lateral process of the basal end (marked by landmark 4, Figure I3) varied from a barely discernible bump to two or even three projections. After some experimentation it was decided that this feature was too significant to omit and the landmark was defined
as the maximum curvature of the cranial-most projection, even though on occasion this meant that one or more other projections had to be ignored. An attempt was made to capture the shape of the pneumatic foramen but this was abandoned as, again, the feature was too variable and sometimes completely absent.

Ultimately, I4 landmarks were chosen. The locations are illustrated in Figure I3 and a full description of each is given in Table 4.


Figure 13: The completed landmark configuration for the coracoid

| Coracoid landmarks |  |  | Number |
| :--- | :--- | :--- | :--- |
| Name | Type | Description/guide to landmark <br> placement |  |
| Angulus medialis | I | II | Point of maximum curvature of the medial <br> angle |
| Angulis lateralis | 2 | II | Extreme point of the lateral angle: depending <br> on anatomy this can be positioned on the <br> lateral extremity of the sternal articular <br> surface |
| Facies articularis sternalis | 3 | II | Minimum curvature of the sternal articular <br> surface |
| Processus lateralis | 4 | II | Lateral process: extremely variable especially <br> in domestic fowl. Landmark should be <br> positioned on the maximum curvature of the <br> cranial-most projection of the process, <br> regardless of the size and number of other <br> projections. |


| Coracoid landmarks |  |  | Number |
| :--- | :--- | :--- | :--- |
| Name | Type | Description/guide to landmark <br> placement |  |
| Cotyla scapularis, lateral | 5 | II? | Point at which the articular surface of the <br> scapular cotyle meets the lateral margin of <br> the corpus |
| Mid-corpus, lateral edge | 6 | III | Mid-point of ventral edge of the corpus, equal <br> to the mid-point of the measured distance <br> between landmarks 4 and 5 |
| Minimum curvature <br> between cotylus scapularis <br> and facies articularis <br> humeralis | 7 | II | Minimum curvature between the scapular <br> cotyle and the humeral articular surface |
| Maximum curvature of <br> facies articularis humeralis | 8 | II | Maximum curvature of the humeral articular <br> surface, at the mid-point |
| Extreme point of cranial <br> end of coracoid | 9 | II | Cranial-most point of the coracoid - the <br> point at which callipers would touch when <br> taking a GL measurement |
| Medial extent of impressio <br> ligamenti <br> acrocoracohumeralis | IO | II | Extreme medial point of the impression of <br> the acrocoracohumeralis ligament - the point <br> at which the depression terminates |
| Medial edge of processus <br> acrocoracoideus | II | II | Medial-most edge of the acrocoracoidal <br> process |
| Point of processus <br> acrocoracoideus | I2 | II | Point of the acrocoracoidal process - the <br> extreme tip of the 'hook' |
| Processus procoracoideus | I3 | II | Maximum curvature of the procoracoidal <br> process |
| Mid-corpus, medial edge | I4 | III | Mid-point of the medial edge of the corpus, <br> equal to the mid-point of the measured <br> distance between landmarks 4 and 5 |
| Table 4: Ladre |  |  |  |

Table 4: Landmarks for domestic fowl coracoid, dorsal aspect

### 4.1.4.2 Humerus

All the humeri were photographed from the caudal aspect. Several landmarks which seemed to be useful were subsequently excluded. These included two placed at the proximal and distal ends of the attachment scar for the musculus latissimus dorsi which connects the humerus to the axial skeleton and elevates the wing. The attachment
point is positioned slightly proximal of mid-shaft on the caudal aspect of the humerus. Although this feature was clearly defined on some specimens, on others it was shallow and difficult to see to the point of being invisible. Similarly, the edge of the depression immediately distal of the articular surface of the caput (caudal aspect) was sharply demarcated on some humeri but amorphous and indistinct on others. Ultimately, twenty-two landmarks were chosen, illustrated in Figure 14 and fully described in Table 5.


Figure 14: The completed landmark configuration for the humerus.

| Humerus landmarks |  |  | Number |
| :--- | :--- | :--- | :--- |
| Name | Type | Description/guide to landmark placement |  |
| Tuberculum dorsale | I | II | Point of maximum curvature of the dorsal <br> tubercle |
| Ventral edge of caput <br> humeri | 2 | II | Juncture of the articular surface and incisura <br> (groove) of the humeral caput at the <br> proximal/ventral edge |
| Mid-point of caput <br> humeri | 3 | III | Mid-point of measured periphery of articular <br> surface of humeral caput (between landmarks 2 <br> and 21) |
| Incisura capitis humeri | 4 | I | Most distal point of v-shaped groove of the <br> humeral caput |
| Tuberculum ventrale I | 5 | II | Point of maximum curvature of small projection <br> at proximal margin of incisura capitis humeri. N.B. <br> This landmark can be difficult to place in some <br> specimens due to the relative smoothness of the <br> curve |


| Humerus landmarks |  |  |  |
| :---: | :---: | :---: | :---: |
| Name | Number | Type | Description/guide to landmark placement |
| Crista coracoidea | 6 | II | Mid-point of proximal edge of the crista coracoidea |
| Tuberculum ventrale II | 7 | II | Proximal edge of small muscle attachment on the ventral tubercle |
| Tuberculum ventrale III | 8 | II | Distal edge of small muscle attachment on the ventral tubercle |
| Foramen pneumaticum | 9 | II | Most distal point of the preumatic foramen |
| Mid-shaft, ventral edge | 10 | III | Mid-point of ventral edge of shaft, a point perpendicular to the mid-point of the measured distance between landmarks 3 and 15 |
| Tuberculum supracondylare ventralis | 11 | II | Point of maximum curvature of the ventral supracondylar tubercle |
| Margin of epicondylus ventralis | 12 | II | Point of the extreme edge of the ventral epicondyle. N.B. In some specimens, the ventral margin of the epicondyle is well-defined and can be easily located but in many others the feature is more rounded and location may be problematic |
| Maximum curvature of epicondylus ventralis | 13 | II | Point of maximum curvature of the ventral epicondyle |
| Minimum curvature between condylus ventralis and epicondylus ventralis | 14 | II | Point of minimum curvature between landmarks 13 and 15 |
| Maximum curvature of condylus ventralis | 15 | II | Point of maximum curvature of the ventral condyle |
| Minimum curvature of condylus ventralis and condylus dorsalis | 16 | II | Point of minimum curvature between landmarks 15 and 17 . This is often relatively sharply defined, resembling a ' $v$ ' more than a curve |
| Maximum curvature of condylus dorsalis | 17 | II | Point of maximum curvature of the dorsal condyle |
| Margin of condylus dorsalis | 18 | II | Point of the extreme edge of the dorsal condyle |
| Tuberculum supracondylare dorsalis | 19 | II | Point of maximum curvature of the dorsal supracondylar tubercle |
| Mid-shaft, dorsal edge | 20 | III | Mid-point of dorsal edge of shaft, a point perpendicular to the mid-point of the measured distance between landmarks 3 and 15 |


| Humerus landmarks |  |  |  |
| :--- | :--- | :--- | :--- |
| Name | Number | Type | Description/guide to landmark placement |
| Dorsal edge of caput <br> humeri | 21 | II | Minimum curvature of the juncture of the <br> articular surface of the humeral caput and the <br> dorsal tubercle |
| Musculus pectoralis <br> profundi attachment <br> scar | 22 | II | Most distal point of the pectoral muscle scar. N.B. <br> In the majority of cases this point occurs central <br> to the edge of the bone and does not define the <br> dorsal edge |

Table 5: Landmarks for domestic fowl humerus, caudal aspect

### 4.1.4.3 Tibiotarsus

Modern and archaeological tibiotarsi were photographed from the anterior (cranial) aspect. An attempt was made to capture the most distal extent of the crista cnemialis cranialis but this feature was often indistinct at this point. Similarly, experimental landmarks placed to define the medial and lateral condyles more accurately were not possible as these were morphologically too variable. Eleven landmarks were chosen (Figure I5) and fully described in Table 6.


Figure 15: The completed landmark configuration for the tibiotarsus, cranial aspect.

| Tibiotarsus landmarks |  |  |  |
| :--- | :--- | :--- | :--- |
| Name | Number | Type | Description/guide to landmark <br> placement |
| Proximal <br> articulation: medial <br> margin | I | II | Medial-most point of proximal articulation |
| Crista cnemialis <br> cranialis | 2 | II | Most proximal point of the crista cnemialis <br> cranialis |
| Crista cnemialis <br> lateralis | 3 | II | Most lateral point of the crista cnemialis lateralis |


| Tibiotarsus landmarks |  |  |  |
| :--- | :--- | :--- | :--- |
| Name | Number | Type | Description/guide to landmark <br> placement |
| Crista fibularis | 4 | II | Proximal extent of crista fibularis - the <br> prominent edge marking the point of fusion <br> with the fibula |
| Condylus lateralis I | 5 | II | Indentation at proximal extent of the lateral <br> condyle |
| Condylus lateralis II | 6 | II | Maximum curvature of distal end of the lateral <br> condyle |
| Incisura intercondylaris | 7 | II | Minimum curvature of the intercondylar <br> incisura |
| Condylus medialis I | 8 | II | Maximum curvature of distal end of the medial <br> condyle |
| Condylus medialis II | 9 | II | Indentation at proximal extent of the medial <br> condyle |
| Pons supratendinus | I0 | II | Distal extent of margin of the supratendinal <br> bridge |
| Canalis extensorius | II | II | Distal opening of canalis extensorius: landmark is <br> placed on the distalmost point |
| Table 6: Landmarks for the domestic fowl tibiotarsus, cranial aspect |  |  |  |

Table 6: Landmarks for the domestic fowl tibiotarsus, cranial aspect

### 4.1.4.4 Tarsometatarsus

The tarsometatarsi were all photographed from the dorsal aspect. Several landmarks which were potentially useful were problematic: for example the incisura between trochleas II and III was frequently indistinct and could not be located on all specimens, and the margins of the foramen vasculare distale could not be clearly defined. Rather than leave this foramen unmarked, a 'fuzzy' landmark was placed in the exact centre of the hole, so not actually located on the bone at all. Figure 16 shows the final configuration of 18 landmarks for the tarsometatarsus and Table 7 lists the definitions.


Figure 16: Landmarks for domestic fowl tarsometatarsus, dorsal aspect.
Table 7 lists the final sequence of 18 landmarks for the tarsometatarsus.

| Name | Number | Type | Description/guide to landmark placement |
| :--- | :--- | :--- | :--- |
| Proximal <br> tuberculum, medial <br> edge | I | II | Maximum curvature of small tuberculum just distal <br> of the cotyla medialis |
| Cotyla medialis | 2 | II | Medial-most point of the cotyla medialis |
| Eminentia <br> intercondylaris | 3 | II | Tip of the eminentia intercondylaris |
| Cotyla lateralis | 4 | II | Lateral-most point of the cotyla lateralis |
| Proximal <br> tuberculum, lateral <br> edge | 5 | II | Maximum curvature of small tuberculum just distal <br> of the cotyla lateralis |
| Lateral foramen <br> vascularia | 6 | II | Distal-most extent of the lateral foramen vascularia |
| Medial foramen <br> vascularia | 7 | II | Distal-most extent of the medial foramen vascularia |
| Mid-shaft, lateral <br> edge | 8 | III | Orthogonal to the mid-point between landmarks 3 <br> and I2, placed on the lateral margin |
| Trochlea <br> metatarsus IV, edge <br> of articulation | 9 | II | The most proximal edge of the articulatory surface <br> of the trochlea metatarsus IV. There is often, but <br> not always, an associated depression on the lateral <br> margin at this point |
| Trochlea <br> metatarsus IV | I0 | II | Minimum curvature of the central groove of the <br> trochlea metatarsus IV |
| Incisura <br> intertrochlearis <br> lateralis | II | The most proximal extent of the incisura <br> intertrochlearis lateralis |  |


| Name | Number | Type | Description/guide to landmark placement |
| :--- | :--- | :--- | :--- |
| Trochlea <br> metatarsus III, <br> maximum lateral <br> side | I2 | II | Maximum curvature of the lateral side of the <br> articular surface |
| Trochlea <br> metatarsus III, <br> minimum | I3 | II | Minimum curvature of the central groove of the <br> trochlea metatarsus III |
| Trochlea <br> metatarsus III, <br> maximum medial <br> side | I4 | II | Maximum curvature of the medial side of the <br> articular surface |
| Trochlea <br> metatarsus II, distal <br> point | I5 | II | Distal-most point of trochlea metatarsus II |
| Trochlea <br> metatarsus II, <br> medial point | I6 | II | Medial-most point of trochlea metatarsus II |
| Foramen vasculare <br> distale | I7 | II | Exact centre of the foramen vasculare distale |
| Mid-shaft, medial <br> edge | I8 | III | Orthogonal to the mid-point between landmarks 3 <br> and I2, placed on the medial margin. If spur is <br> present, ignore spur shield and place landmark on <br> shaft |

Table 7: Landmarks for domestic fowl tarsometatarsus, dorsal aspect

### 4.2 Methods: Linear biometrical analysis

### 4.2.1 Introduction

This section explains the protocol followed when collecting linear metrics data, describes steps taken to ensure consistency within the dataset and defines new metrics designed to capture the shape of the furcula and the caudal end of the pelvis. The analytical methods applied to the data are outlined and previous applications of each technique noted where relevant.

### 4.2.2 Measurements: standard

With the exception of the Lyminge, Flixborough and Fishbourne assemblages, all biometrical data was collected by the author. Cranial and post-cranial measurements were taken according to the standards established by von den Driesch (1976). For the
majority of the bones, measurements were taken with MIB Messzeuge electronic digital callipers DIN 862 to two decimal places, although for a few specimens approaching and greater than 150 mm (for example, the tibiotarsi of Asian Game fowl), less accurate callipers were used which measured to one decimal place. Where paired elements were identified in archaeological assemblages (including associated bone groups), measurements from only one bone were included: after consideration for irregularities due to pathology and taphonomic processes, left-sided elements were preferentially selected.

Short descriptions of the measurements for the coracoid, humerus, femur, tibiotarsus and tarsometatarsus are given in Table 8, but see von den Driesch (1976) for a full description and diagrams.

| Abbreviation | Description |
| :--- | :--- |
| Bb | Basal breadth (coracoid) |
| Bd | Breadth of distal end |
| Bf | Breadth of articular surface (coracoid) |
| Bp | Breadth of proximal end |
| Dd | Depth of distal end |
| Dip | Diagonal of proximal end |
| Dp | Depth of proximal end |
| GL | Greatest length |
| La | Axial length (tibiotarsus) |
| Lm | Medial length (femur) |
| SC | Smallest breadth of the shaft |

Table 8: Standard measurements abbreviations and descriptions.
Several of the measurements in von den Driesch's manual are highlighted as being difficult to take, for example, the breadth of the proximal end of both the humerus and femur. To maintain consistency and increase confidence in the data, wherever possible the measuring was carried out by one person. The breadth of the proximal end of the humerus $(\mathrm{Bp})$ was consistently taken with the callipers flat against the lateral edge, as illustrated by von den Driesch (1976: II6, Fig 54a). When recording the smallest breadth of the corpus of the tibiotarsus (SC), this was measured in the same plane as the greatest breadth of the distal articulation (Bd), as specified by von den Driesch (ibid. I26-7, Figure 62c). Clarification is necessary as there can be some inconsistency in the way this metric is taken depending upon the manual followed: for example, the diagram illustrating the SC in Cohen and Serjeantson's identification manual (1996) is
depicted from the lateral aspect. Consistent methodology is important when secondary data is incorporated.

The Lyminge biometrics were collected by a team at an early stage in the project using the measurements illustrated in Cohen and Serjeantson's manual (1996). As well as the noted inconsistency with the SC measurement of the tibiotarsus, this manual also omits the distal breadth ( Bd ) of the tibiotarsus and the consequent loss of this data has limited comparisons in a number of analyses.

As well as these standard biometrics, additional measurements were devised to capture variation in the furcula and pelvis, as discussed in Sections 3.5.I and 3.5.2.

### 4.2.3 Furcula measurements

Measuring the internal angle of the symphysis required the assembly of a file of digital photographs (including a scale) of the individual furculae. TpsDig2 (Rohlf 2013) software was used to set the scale and measure three separate angles (Figure 17). ' $A$ ' is the angle at the symphysis, measured from the terminals of the rami; ' $B$ ' is the angle at the symphysis at $50 \%$ of the length of the rami; ' C ' is the angle at the symphysis at $10 \%$ of the length of the rami.


Figure 17: Furcula symphysis. Angles A, B and C.
These angles could only be calculated on complete elements where the length of the rami could be measured and, as archaeological furculae rarely survive undamaged, an alternative metric was designed to enable angles to be measured on broken furculae the angle between 10 mm from the midline of the symphysis on each ramus (Figure 18).


Figure 18: Measuring the internal angle of the furcula from 10 mm from the central fusion line of the symphysis.
These measurements were applied to modern reference chicken furculae: the results are in Section 5.5.

### 4.2.4 Pelvis measurements

Additional measurements for the pelvis comprised the breadth between the spinae dorsolateralis ilii (termed 'Bsdi') and the breadth between the processus terminalis ischii ('Bpti') (Figure 19). The points of the callipers should be placed at the very tips of the processes, not to either side.


Figure 19: Pelvis (Gallus gallus, after von den Driesch) showing additional metrics.

### 4.2.5 Log transformed values, log ratios and kernel density estimation

 Where required, biometrical data were log-transformed (log 10 ) to reduce skew and normalise distribution. Log-transformation makes patterns in the data clearer and helps to meet the assumptions of some statistical methods. To compare metrics across sites, measurements were log-scaled against corresponding values from a 'standard chicken', in this case a modern Warren-Ranger hybrid dual-purpose hen from the University of Leicester comparative skeletal reference collection (Accession no. RI59: GL measurements can be found in Appendix B, Section 2.8). A log-ratio of zero means that the measurement is the same as that of the standard; a positive ratio is larger than the standard and a negative ratio is smaller. This method has the advantage of enabling comparison between individuals in cases where the number of samples is small (O'Connor 2007).Kernel density estimates were used to investigate size differences within the log-scaled datasets and identify multiple-density clusters which might indicate the presence of more than one breed/type. Kernel density estimation is a data-smoothing technique that offers an alternative to histograms when presenting continuous variables. A kernel is placed at the position of each data point on the x axis and the contributions from all are added to obtain a smooth curve. This avoids the problem of fluctuating densities in histograms depending on the number of bins chosen.

### 4.2.6 Measurement ratios

Measurement ratios have long been used to capture and compare more of the shape of a bone than is possible with single measurements. The technique has been used for species separation: Armitage used ratios of mandible measurements (diastema index $v$ the height of the mandible) to distinguish between black and brown rats (Armitage et al I984) and Albarella (1997) employed a similar method using ratio indices of metapodial measurements to investigate the introduction of different breeds of cattle, concluding that morphological differences between breeds can mask differences between sexes. Salvagno and Albarella (2017) have more recently combined the technique using standard and novel metrics of several elements from sheep and goats to successfully separate the two species. Kysely (20I0) employed ratio indices in his paper on early domestic chickens in Central Europe, in this case looking at the humerus length divided by the femur length. Cross-bred Junglefowl were found to
have longer humeri than femora, which was interpreted as a consequence of their relatively longer wing. However, the length of the humerus, or any other forelimb bone, is not necessarily a good indicator of total wing length or locomotion in the living chicken as the length of the primary feathers varies from breed to breed.

Ratios are calculated by dividing one metric by another: for example, the ratio $\mathrm{Bd} / \mathrm{Lm}$ is calculated by dividing the breadth of the distal end of a bone by the medial length. If the quotient is then multiplied by 100 this gives the first metric as a percentage of the second. For the current study, the smallest metric of the two is always the dividend and the larger is the divisor. If a calculated ratio/percentage is plotted against a raw metric, for example GL (the greatest length), the resulting data are influenced by size but plotting against another ratio factors out size and the result reflects only shape differences.

### 4.2.7 Limb bone proportional lengths

Different chicken breeds can appear to have proportionally long or short legs, with relative lengths of the tarsometatarsus especially seeming to show breed-related variation. For example, Dorking fowl are large, meaty birds with a short-legged appearance while Old English Game have an upright posture and apparently longer legs. It is debatable whether these differences are real or largely an illusion contingent upon other physiological characteristics such as stance and plumage length and density.

Ratio indices can be used to draw comparisons between two or more elements from the same individual. This has less potential than the measurement ratio method described above as it is only calculable for whole or partial chicken skeletons. There are no previous examples of the technique being used to investigate variation in breeds or types of chicken, either in modern or archaeological domestic fowl bones; however, a study from the early days of poultry science used a similar method to investigate sex dimorphism in Leghorn chickens (Hutt 1929).

Metrical parameters for breeds can be investigated using chicken skeletons from modern reference collections but these can only be compared with archaeological material in cases where it can be confidently established that all the elements from an associated bone group are definitely part of the same skeleton: it is also necessary that the same elements are present from each individual. Despite these constraints, a
preliminary study of limb bone proportions was carried out using measurements from five modern chicken breeds/types and four archaeological skeletons.

The proportional lengths of the limb bones were established using a technique similar to the brachial index. This method calculates ratios between proximal wing bone lengths and has been used to investigate wing proportions, locomotion and phylogeny in a number of biological and paleontological studies (Verheyen I96I; Nudds et al 2004; Nudds et al 2007). The greatest length (GL) of the humerus is divided by the ulna GL. A score of one indicates parity; >I means a longer ulna; <l means a longer humerus. The hind limb study used the GL measurements from three elements: the femur, tibiotarsus and tarsometatarsus. For each skeleton these measurements were summed and the individual GLs for each bone were calculated as a percentage of the total length. For example, the GL metrics (in mm) for the female Dorking (acc. no. R723) were 85.66 (femur); I 16.65 (tibiotarsus); and 77.88 (tarsometatarsus): total length $=280.19$. The three element greatest lengths were therefore 30.57; 41.63 and 27.80 percent of this total respectively. Results were tested using Permanova (nonparametric MANOVA).

### 4.3 Data Exploration and Analysis Methods

The extent and complexity of the data means that, rather than the hypothesis-testing method of data investigation a multivariate approach is a more appropriate starting point. This can show up relationships between groups or individuals which may in turn suggest which hypotheses are worth further consideration. In geometric morphometrics, this process begins with Generalised Procrustes Analysis (GPA), or Procrustes Superimposition. Tests for normal distribution do not necessarily have to be carried out prior to investigation of shape using geometric morphometrics as normal distribution is not a realistic expectation. For example, MorphoJ (Klingenberg 201 I) has no test for normal distribution but does include a facility to check for outliers which can be excluded or amended as required.

### 4.3.I Generalised Procrustes Analysis

First proposed by Gower (1975) and further developed by Rohlf and Slice (1990), Generalised Procrustes Analysis allows the comparison of configurations of landmarks
by superimposition, performing an alignment that minimizes the square distance between homologous landmarks and thus removes differences of size, location and orientation. The algebraic procedure is known as the Generalized Least Squares fitting (Gower 1975). To remove the size difference, the configurations are rescaled by standardising all their centroid sizes to one. The centroid is the geometric centre of the landmark configuration for each specimen. Centroid size is a measure of the configuration, calculated as the square root of sum of the squared distances among all the landmarks in each configuration from the centroid (Figure 20). This process is analogous to calculating the standard deviation.


Figure 20: Centroid size (Klingenberg 2014).
Next, the configurations are translated by relocating the centroid for each configuration onto a single point. Finally, to obtain a full Procrustes superimposition, the configurations are rotated into an optimal least-squares alignment so that the spread of landmarks around the average location of each landmark is minimised, resulting in minimal dispersal of corresponding points. This achieves a 'best fit' and gives a standard orientation. The procedure is illustrated in Figure 21 using fly wings.


Figure 21: The process of Generalised Procrustes Analysis (Klingenberg 2014).
Shape is thus the residual information that remains after scale, location and rotational effects have been filtered out of form: shape differences are expressed as the
mismatch between homologous landmarks across the sample. This measure of shape difference between the configurations is called the Procrustes Distance, which is equal to the square root of the sum of squared distances between corresponding landmarks in two shapes after a Procrustes fit. The equation is given below.

$$
D_{12}=\sqrt{\sum_{i=1}^{k}\left(x_{1 i}-x_{2 i}\right)^{2}+\left(y_{1 i}-y_{2 i}\right)^{2}}
$$

Procrustes Distance provides a measure of biological distance and can be used to calculate the degree of fit between individual specimens.

After standardisation, the resulting Procrustes shape-space is curved. However, to perform standard statistical tests, the configurations need to be projected into a flat space, called tangent space, where Euclidean geometry applies. The circle in Figure 22 represents a cross-section of Kendall's shape space. Point $K$ is the position of a shape in Kendall's shape space. Point $A$ is its corresponding position after superimposition and scaling to centroid size. Point $P$ is the orthogonal projection of Point $A$ onto tangent space. Point T is the sample mean shape. Angle $\rho$ is the Procrustes Distance.


Figure 22: Tangent space (Klingenberg 2014).

The difference among the options is not expected to be as large as is suggested by the diagram: in most datasets it is not great and will make negligible difference to the analysis and results (Adams et al 2004). The difference between Procrustes distance and tangent distance can be calculated to check whether the projection of shape coordinates in tangent space has a significant effect on the results. This test is carried out in Section 6.2 as part of the measurement error assessment.

### 4.3.2 Shape-change visualisation

Another advantage of geometric morphometrics is that shape change variables following Procrustes superimposition can be visualised as illustrations or computer graphics (Klingenberg 2013). When considering any shape change diagram it should be remembered that displacement of the landmarks is a consequence of change in the tissues between, not at, landmarks and a shift in a landmark's position is relative to all other landmarks in that configuration.

A simple method depicts the relative shifts of landmark positions by 'lollipop’ graphs: the one in Figure 23 shows the shift of one configuration from the sample mean. Because there is no representation of the object, these minimal graphs require familiarity with the landmarks and the specimens in the study and are not easy to interpret. Another drawback is the lack of information about the shape between the landmarks and the underlying anatomical structure. Overlying wireframes or outline grids (Figure 23) representing the starting and target shapes can help, but these also cannot portray the actual anatomy between the landmarks and should be seen purely as an aid to visualisation.


Figure 23: From left to right: lollipop, wireframe and outline graphs depicting the same relative shift of landmark configurations in a study of fly wings (Klingenberg 2014).

Transformation grids pioneered by D'Arcy Thompson (1917) are also commonly used. In Figure 24, the deformation of a regular grid with landmarks superimposed is used to show the same transformation from one fly wing shape to another.


Figure 24: Transformation grid. The same shape change in the fly wings visualised using a deformed grid (Klingenberg 2014).

Transformation grids show the shape change as a deformation of a rectangular grid using the analogy of the thin-plate spline: an infinitely thin sheet of metal. The more the shape change is localised in one or a few small areas, the more energy it takes to deform the metal sheet. When there is no change, or uniform change, to the flat plate there is zero bending energy. Low bending energy refers to generalised change spread out over a large area and high bending energy to localised abrupt changes. High or low bending energy does not reflect the magnitude of the shape change, just the localisation. Like the wireframes and outline graphs, the intermediate areas between landmarks do not depict a biological reality and when areas of the object are far away from any landmarks, transformation grids should be interpreted with caution.

The Morphoj software includes a facility for importing an outline diagram of the object under investigation and this method of visualisation, while subject to the caveats described above, is an intuitive and simple way of presenting shape change and has been used for the visualisations in this thesis.

### 4.3.3 Principal Components Analysis

The multivariate data sets generated by Generalised Procrustes Analysis (PCA) are large and extremely complex. Principal Component Analysis (Hotelling 1933; Pearson 1901) is a useful way of initially investigating variation in a complex data set by synthesising the data from a mass of variables into a set of compound axes. Principal Component Analysis is sometimes called Relative Warp Analysis in geometric morphometrics studies - the term relative warp is more often used when the principal components are being visualised with vectors or deformation grids (Bookstein 1989).

There are a number of advantages of the technique:

- It reduces the dimensionality of multivariate data by reducing a large set of variables to a more manageable few - the 'principal components' - which summarise multidimensional variation while preserving as much of the relevant data as possible;
- Most of the variation in a dataset can usually be explained by the first few principal components;
- Presentation of results is simplified and clusters of individual specimens are more easily identified in plots of principal component scores;
- Scores of different principal components are not correlated, which means they can by analysed separately from each other.

PCA is an indirect ordination method used for exploratory investigation of the data rather than statistical analysis. Assumptions about the data - that it should be continuous and normally distributed - do not have to be strictly adhered to if the purpose of the test is to generate rather than test hypotheses. As PCA is a descriptive method without statistical significance, p -values are not relevant at this stage.


Figure 25: Transitioning the data to a new coordinate system (Klingenberg 2014).

After Generalised Procrustes Analysis (Section 4.3.I), the shape variables of each configuration are plotted onto a 2-D scatterplot (Figure 25/I) and the average of all the variables calculated and used as the origin of a new coordinate system (Figure $25 / 2$ ). A line through the data points $\left(y_{1}\right)$ describing the most variance is the first principal component: a second line orthogonal to it (y2) describes the second principal component (Figure 25/3). The data are then rotated making a new coordinate system which is aligned with the variation in the dataset (Figure 25/4).

For principal component analysis, a statistical software package can typically be expected to produce:

- A list of coefficients describing the principal components. This can be tabulated PC scores (eigenvectors) or graphical output, or both;
- The variance of each component (eigenvalues). This shows the percentages of total variance in descending order often presented as a histogram or scree plot;
- Loadings - the higher the component loadings (either positive or negative), the more important that variable is to the component;
- Principal component scores presented as scatterplots (preferably with equal axes for ease of interpretation). The range of scores on each axis reflects the amount of variance for that component.


### 4.3.4 Multivariate Regression

Generalised Procrustes Analysis does not completely negate the effects of size and a degree of allometry - morphological changes that are size-related - may still remain. Identifying allometry is important in ontogenetic studies, where the dataset includes a range of ages, or where there is a wide range of sizes within a species (Drake and Klingenberg 2008). In a geometric morphometrics study, regression analysis can be used to test for the presence of allometry and determine whether shape changes are related to size variation, or whether organisms are growing isometrically, in proportion.

The result of a multivariate regression of the dependent variable (shape described by Procrustes coordinates) on the independent variable (in this case centroid size or log
centroid size) explains the shape change per unit of increase in size. The null hypothesis is that of independence: that shape is unrelated to size and growth is isometric. If the study is not concerned with the effect of allometry, this can be removed by using the residuals from the regression for further analysis, for example a principal components analysis, as they are uncorrelated with centroid size.

### 4.3.5 MANOVA and Permanova

MANOVA (multivariate analysis of variance) is used to test whether several groups have the same multivariate mean by comparing sample variance estimated from mean values. It requires one independent variable with categorical data and two or more dependent variables with continuous data. It assumes multivariate normal distribution in each group and is sensitive to outliers. The null hypothesis is that the group means are equal. Observations must be independent so it is not suitable for nested data. MANOVA works better with larger sample sizes and there needs to be more cases in each group than the number of dependent variables. The data in the study do not always meet these assumptions: many of the sample sizes are small and data are not always normal. In these cases Permaonova (or NPMANOVA) was used. This is a nonparametric method of statistical analysis also used for determining differences between groups. It can be used as an alternative to MANOVA when the number of cases is close to or less than the number of variables, for example, when a sample has few specimens but many landmarks. A further advantage is that, unlike MANOVA, it does not assume normal distribution and can be used on unequal sample sizes and when nothing is known about the parameters of the variable of interest.

### 4.3.6 Discriminant Function Analysis

Discriminant Function Analysis (DFA) is a combination of predictors that distinguish two or more a priori known groups which have normal distribution by calculating the maximal separation between them. Unknown individuals can also be assigned group membership from a set of variables by assigning each point depending on minimal Mahalanobis distance between individuals and group means; the smaller the distance from an individual to a group centroid, the more likely it is that the individual will be classified in that group. The predictor variables are the independent variables and the known groups are the dependent variables.

The first stage of the process is similar to a MANOVA and the same assumptions about the data apply. If the data are not normal the resultant significance tests are still reliable as long as non-normality is caused by skew and not outliers. Extreme outliers which have an impact on the mean will increase variability and affect statistical significance tests based on pooled variances across all groups. Potential bias can also be introduced if the comparative groups contain unequal numbers of specimens. A leave-one-out cross-validation procedure is used to test group assignment. The results of the cross-validation should always be used in preference to initial classification rates.

When applying DFA in GMM studies, problems of overfitting often occur because of the amount of variables compared to the number of specimens. In a recent reevaluation of this phenomenon, Bookstein (2017) recommends at least four specimens per variable to reduce the risk of errors. The problem can be overcome to some extent by running the DFA on a reduced set of principal components rather than the original full set of Procrustes coordinates, although caution should still be exercised when interpreting the results.

### 4.3.7 Canonical Variate Analysis and Between Groups Principal Component Analysis

Canonical Variate Analysis (CVA) simplifies a multivariate dataset by reducing dimensionality and maximising separation between three or more pre-defined groups. It can allocate specimens to correct groups by measuring their distance (usually Mahalanobis distance) to the group means. It can be seen as the equivalent of discriminant function analysis for more than two groups and can assign specimens to multiple groups in the same way that discriminant analysis can for pairs of groups. There are several restrictions when using the technique:

- Groups must be mutually exclusive, so it is not suitable for nested, overlapping or intersecting sets;
- Variables must be categorical, non-sequential, without order or numerical value;
- The best results are obtained when there is normal distribution within each group and equal variance-covariance matrices;
- There must be at least as many specimens as variables (landmarks) because when the number of variables is close to the number of specimens, CVA will
always find perfect separation of the groups even if they have the same means (Mitteroecker and Gunz 2009; Mitteroecker and Bookstein 201I).

Because of this, CVA can be unsuitable for geometric morphometrics and is in some cases best avoided. As an alternative, Mitteroecker and Bookstein (20II) advocate the use of Between-Groups Principal Component Analysis (BGPCA), which solves some of the problems associated with CVA. It does not depend on normal distribution and can be used with small sample groups in which the variables are equal to or exceed the number of specimens. The group means are used to determine the orientations of a set of eigenvector axes and the data comprising the sample projected into this group mean-determined PCA ordination space, thus it can be simply described as a PCA of the means of groups. It also preserves correspondence to the true Euclidean and Procrustes distances more faithfully than a typical CVA.

### 4.3.8 Procrustes ANOVA

Procrustes ANOVA (analysis of variance) is a method for assessing the relative amounts of variation among individuals and has been used in studies of left-right asymmetry (Klingenberg and McIntyre 1998) to calculate the amount of measurement error relative to biological variation. It can also be used to assess the extent and significance of nested levels of measurement error from repeat measurements to ascertain the reliability of image capture and digitisation in a geometric morphometrics study.

The results output from a Procrustes ANOVA in Morphoj consists of separate ANOVA tables for centroid size and for shape. The tables present sums of squares (SS, which is the sum of squared effects of variance across all coordinates); degrees of freedom (df, which is calculated based on the number of specimens); and mean squares (MS). Mean squares describe the variance associated with each effect and an estimate of its relative contribution to the total variation. Mean squares are calculated by dividing the total sum of squares by the relevant degrees of freedom for that effect (Klingenberg and McIntyre 1998). There are more degrees of freedom in Procrustes ANOVA than ordinary ANOVA because the squared deviations are summed over all the landmark coordinates (instead of a single sum of squares in conventional ANOVA). Therefore the number of degrees of freedom for Procrustes ANOVA is equal to the number for ordinary ANOVA multiplied by the shape dimension. For two-dimensional
coordinate data, the shape dimension is equal to twice the number of landmarks (the total number of coordinates) minus four degrees of freedom (two for translating, one for scaling and one for rotating). Also produced are Goodall's F-statistic (Goodall 1991) (the ratio of mean squares between the different levels of error) and parametric p -values.

### 4.3.9 Cross validation

Cross-validation assesses the reliability of classifications resulting from Discriminant Function Analysis (DFA) and Canonical Variate Analysis (CVA). It is necessary to reduce the effects of overfitting which happens in complex models, for example when sample sizes are equal to, or smaller than, the number of variables (Kovarovic et al 201I). The leave-one-out cross-validation technique randomly removes a specimen of a known group from a dataset and recalculates the discriminant function. The specimen is then treated as an unknown and reclassified depending upon the distance of its discriminant function from the group mean. This process is carried out for each specimen in turn for a specified number of times (in MorphoJ the default setting for the permutation test is 10000 times). By using specimens from known groups, it can be calculated how accurately discriminant function analysis assigns specimens to the correct group and by extension the level of confidence in subsequent placings of specimens from unknown groups. Initial results from analyses like DFA should always be cross-validated.

## 5 Linear biometrics results

## 5.I Introduction

This chapter gives the results of a number of investigations using the metrical data from the modern and archaeological assemblages. First, for each element, kernel density estimates (Section 5.2 ) were applied to greatest length (GL) measurements of archaeological bones to investigate the modality of the data. Bimodal density is most likely to mean both males and females in the sample but multimodality could indicate more than one breed/type of chicken. In the next section (5.3), newly developed measurement ratios were used to examine different shapes in modern chicken bones and ascertain whether these are breed-related. The results were compared to those from archaeological bones to see if Roman, Saxon and Early modern chickens show any shape-similarities to modern breeds and, if so, which ones. Changes through time and between sites were also examined. In Section 5.4, measurement ratios of limb bone elements from modern chickens were analysed to investigate whether the proportional lengths of the wing and lower limb elements are consistent across breeds or if there is breed-related variation. Data from a small number of archaeological associated bone groups was included for comparison. Finally, results are presented from analyses of two elements that were not included in the GMM study: the furcula was examined to investigate association of shape-variation with weight or flight ability; and two new metrics devised for the domestic fowl pelvis were analysed to evaluate their use as a sex-discrimination tool in intact archaeological material.

### 5.2 Kernel density estimates

### 5.2.I Introduction

Kernel density estimation (see section 4.2.5) was applied to the archaeological assemblages to compare intra- and inter-site densities and investigate the possibility of different breeds/types at six different sites. The datasets comprised GL (greatest length) metrics of six elements using only skeletally mature bones. Known outliers such as the creeper elements from Uley were removed before analysis. The GL measurements were log-transformed and, because the numbers of measurable
elements from Uley, Fishbourne and Chester were small, these were then scaled against a log-transformed suite of measurements from a standard chicken, in this case a modern Warren-Ranger hybrid hen from the University of Leicester collection. The measurements for the standard chicken can be found in Appendix B, Section 2.8 and the GL raw data and the log-scaled measurements are in Appendix C, Section 3.7. Past does not currently offer a facility for overlaying several kernel density estimates graphs so these were produced using R, an open-source software package for statistical analysis and data visualisation (an example of the code to produce the graphs can be found in the Appendix C, Section 3.7.5). On the individual element plots that follow, zero on the x -axis represents the value of the standard chicken metric with the values to left and right being log-scaled archaeological values representing shorter and longer elements respectively. The $y$-axis reflects the relative densities, with the higher peaks indicating clusters of similar values.

| Period | Site | Bone element |  |  |  |  |  |
| :--- | :--- | :--- | :---: | :---: | :---: | :---: | :---: |
|  |  | Coracoid | Humerus | Ulna | Femur | TBT | TMT |
| Roman | Uley | 36 | 24 | 16 | 19 | 4 | 11 |
|  | Fishbourne | 14 |  |  |  |  |  |
| Anglo-Saxon/ <br> Scandinavian | Lyminge | 67 | 73 | 37 | 69 | 43 | 105 |
|  | Flixborough | 31 |  |  |  |  |  |
|  | Coppergate | 87 |  |  |  |  |  |
| Early-modern | Chester | 13 | 12 | 13 | 11 | 12 | 9 |
| Total | $\mathbf{2 4 8}$ | $\mathbf{1 0 9}$ | $\mathbf{6 6}$ | $\mathbf{9 9}$ | $\mathbf{5 9}$ | $\mathbf{1 2 5}$ |  |

Table 9: Number of greatest length measurements per element by site.
Table 9 gives the numbers of specimens from each site. Comparisons were made between the same elements from different sites and periods. As there were coracoids from two Roman and three Saxon sites it was possible to carry out inter-site comparisons for these periods. For the remaining elements, comparisons were made between the Roman, Saxon and Early Modern assemblages. The plots from all elements from each site were then overlaid to check if the profiles were consistent.

### 5.2.2 Within-period comparisons - coracoids

The distribution of the Fishbourne coracoids (Figure 26) comprises two densities, probably representing male and female chickens with slightly more hens than cocks, while the distribution underlying the Uley profile suggests that most if not all of the individuals there were male.


Figure 26: Kernel density estimates for log-scaled coracoid GL measurements from two Roman sites.


Figure 27: Kernel density estimates for log-scaled coracoid GL measurements from three Saxon sites.
The size range between the three Saxon-period sites (Figure 27) is very similar and bimodal distributions are clearly defined for each site but the individual curves are slightly different. Lyminge shows two densities with a notably higher concentration in the smaller group indicating an adult population dominated by females and Flixborough
follows this pattern to a lesser extent. The Coppergate profile, however, suggests more males were present: the high number of specimens in this set (87) makes it unlikely that this result is an artefact of an unequal dataset.

### 5.2.3 Between-period comparisons

Figure 28 compares the profiles of the Uley, Lyminge and Chester coracoids. The Chester curve is near-normal with the mean only a little smaller than the modern standard. If the premise that the Chester assemblage consists of complete but disarticulated skeletons is correct, this would suggest that the coracoid is not, for this population at least, a strongly sexually dimorphic element. It may also be a reflection of the small sample size (just I3 specimens).


Figure 28: Kernel density estimates for log-scaled coracoid GL measurements from Roman, Saxon and Earlymodern sites.

Results for the humeri (Figure 29) are similar to those for the coracoids, with the Uley and Lyminge profiles clearly depicting the proportions of males and females from each site. Size differences in the Chester humeri are more defined than in the coracoids from this site.


Figure 29: Kernel density estimates for log-scaled humerus GL measurements from Roman, Saxon and Earlymodern sites.

The ulna, femur, tibiotarsus and tarsometatarsus plots (Figures 30 to 33 ) all show similar profiles and proportions to the humerus, with the exceptions of a trimodal distribution in the 37 Lyminge ulnae (Figure 30). This suggests that more than one breed/type may be represented: the possibility of the presence of larger capons should not be discounted although the small sample size means this and the presence of multiple breeds can only be speculation. The three densities in the Lyminge femur curve (Figure 3I) were due to a single particularly short femur (GL 57.63 mm ). This femur was confirmed as adult during data collection, presumed at the time to be a bantam and removed as an outlier from the datasets constructed for the measurement ratio study in Section 5.3. However, further investigation of relative metrics using measurement ratios revealed a disproportionate morphology, strongly suggesting that the bone was derived from a chicken affected by the creeper gene. For further details of a comparative study including modern and archaeological creeper chickens, see Section 5.3.5.


Figure 30: Kernel density estimates for log-scaled ulna GL from Roman, Saxon and Early-modern sites.


Figure 31: Kernel density estimates for log-scaled femur GL measurements from Roman, Saxon and Earlymodern sites.


Figure 32: Kernel density estimates for log-scaled tibiotarsus GL measurements from Roman, Saxon and Earlymodern sites.


Figure 33: Kernel density estimates for log-scaled tarsometatarsus GL measurements from Roman, Saxon and Early-modern sites.

The tibiotarsus graph (Figure 32) includes a profile for Uley but the strongly bimodal distribution should be viewed with caution as the curve represents only four specimens. The curves for Lyminge and Chester reveal greater densities of tibiotarsi with shorter lengths and are interpreted as having proportionally higher female populations.

All the Uley tarsometatarsi (Figure 33) have fully fused spurs and are assumed to be male. Most of them plot to the right of the modern, female, standard whereas the few longer specimens from Lyminge are nearer the standard. The Chester tarsometatarsi profile suggests bimodality but this is relatively indistinct. The Uley and Lyminge spurred tarsometatarsi are examined further in Section 5.2.4.

### 5.2.4 Spurred tarsometatarsi



Figure 34: Kernel density estimates for log-scaled tarsometatarsi GL measurements: Uley and Lyminge. In datasets which comprise known-sex individuals, multi-modal densities can indicate the presence of different breeds and possibly castrates. Analysis was carried out on tarsometatarsi with fused spurs - assumed to be from mature male birds - from Uley and Lyminge (the few that were present in the Chester assemblage were not sufficient for meaningful analysis). Figure 34 shows bimodality in the Lyminge curve with two smaller tarsometatarsi indicating at least two populations of 'normal' sized fowl and proportional dwarfs. The greatest length measurements of these Lyminge 'bantam'
tarsometatarsi are 63.19 mm and 63.17 mm : both of them are significantly shorter than either a modern male Friesian bantam (e008) 77.73 mm or a male Spangled Hamburgh bantam (r73I) 70.97 mm . The weights of the Friesian and Hamburgh were recorded as 1500 g and 1020 g respectively, which suggests that the Lyminge dwarfs may have been very small, possibly under I kg.

### 5.2.5 All elements

For the following graphs, the zero on the x -axis is the standard chicken reference for each of the overlaid elements. The distributions show the size of the elements relative to the standard. Profiles which are generally of the same shape mean that the elements are from similar populations. Chester (Figure 37) exhibits a range of different size profiles, some less distinct than others but most are bimodally distributed. It was speculated that the Chester bones recovered represented at least 13 disarticulated chicken skeletons but while for most of the elements there are greater densities of shorter lengths, the femur profile shows slightly more of longer lengths, so the deposition and/or recovery of these remains cannot be explained so neatly. It may be that different morphotypes are represented by variation in different elements. This incongruity highlights the issue of treating single context assemblages as homogeneous. The Lyminge profiles (Figure 36) consistently follow a pattern of dominance by shorter lengths for every element and look more like a single assemblage. However, a significant difference is seen on the Uley plot (Figure 35). While the coracoid, humerus and especially femur metrics are, on the whole, shorter than the standard chicken, the tarsometatarsi are almost all longer. Results in the leg-length indices section (section 5.4.3.I) reveal that, of the modern breeds, Old English Game were found to have the longest tarsometatarsi and shortest femora proportional to total leg length. Calculations of the Warren-Ranger femur and tarsometatarsus greatest lengths as a percentage of total leg length compared to the mean percentages of male and female Old English Game are presented in Table IO:

| Breed |  | Femur | Tmt |
| :--- | :--- | :---: | :---: |
| Old English <br> Game | Male (mean) | $29.5 \%$ | $29.5 \%$ |
|  | Female (mean) | $29.8 \%$ | $28.25 \%$ |
|  | Female | $30.6 \%$ | $27.6 \%$ |

Table 10: Mean lengths of Old English Game femora and tarsometatarsi compared to the standard chicken.
The length of the standard chicken's tarsometatarsus relative to total leg length is therefore shorter than that of the Old English Game. If the lower limb bones of the

Uley chickens were similarly proportioned to those of the Old English Game, this would explain why the tarsometatarsi plot to the right of the standard chicken and the femora to the left. This pattern is not seen in the Lyminge and Chester element profiles suggesting that, proportionally, they are more akin to the standard.


Figure 35: Kernel density estimates for log-scaled GL: six elements from Uley.


Figure 36: Kernel density estimates for log-scaled GL: six elements from Lyminge.


Figure 37: Kernel density estimates for $\log$-scaled GL: six elements from Chester.

### 5.2.6 Conclusions

Investigation of the archaeological assemblages using kernel density plots and logscaled measurements has informed on the relative sizes of the remains and the modality of the data which in turn has indicated the possibility of different breeds. It has also hinted at differences in conformation between the lower limbs of the Uley chickens and those from Lyminge and Chester.

Unsurprisingly, most of the bones in the study were smaller than those of the WarrenRanger hen used as the standard. The exceptions were the Uley tarsometatarsi, which were almost all longer than the standard. Further exploration of the data using leg element indices suggested that the Uley chickens may have been a more rangy, longlegged type proportionally similar to modern strains of Old English Game.

For the most part, the Lyminge values were bimodally distributed with greater densities of shorter measurements indicating a probable dominance of hens. This emphasis on egg-production reflects the dietary restrictions typical of an ecclesiastical site and supports the interpretation of Lyminge as a monastic foundation. The profile of the coracoids from Flixborough, another large estate with a possible ecclesiastic connection, also reveals a dominance by hens although this was significantly less pronounced. Those from Coppergate show the opposite bias, with a greater density of
longer measurements indicating a higher proportion of larger, probably male, chickens at this site.

The exceptions to the bimodal profiles of the Lyminge data were the ulnae, which had three densities, an outlying femur and two small spurred tarsometatarsi. The extra density in the ulna profile suggested two different sizes of male bird, possibly reflecting the small numbers of specimens in these larger groups but also hinting at the presence of castrated males. There is no reliable documentary evidence for surgical castration of chickens during this period: the reference to capons in contemporaneous Irish texts (Kelly 1997:102) does not specify the method used. The outlying femur proved to be disproportionately short and stout and is considered to be from a 'creeper' chicken. The discovery of creeper remains at Lyminge means that all three of the main archaeological assemblages included in the study produced bones from at least one creeper. The short tarsometatarsi from Lyminge were judged to be from proportionally dwarfed male chickens although the possibility of spurred hens should not be discounted. A broken spurred tarsometatarsus too damaged to be included in this study contained medullary bone and so was certainly from a laying hen, and small spurred hens were identified in a $6^{\text {th }}-7^{\text {th }}$-century assemblage from Sagalassos, Turkey (De Cupere et al 2005). It is not impossible, therefore, that these two small spurred tarsometatarsi were also from female birds.

For Chester, it is suspected that most of the bones recovered are of disarticulated skeletons from a single context and represent I3 or so individuals. However, while most of the element profiles showed a slight increased density of females, the femur curve showed the opposite, this imbalance suggested the presence of more male individuals.

### 5.3 Measurement ratios

### 5.3.1 Introduction

The measurement ratio method offers a different approach to data, being used to identify changes in bone shape rather than size. It has been previously employed to distinguish species and breeds and to investigate changes relating to domestication. An explanation of the technique and reference to previous applications are covered in section 4.2.6.

### 5.3.2 Method

For this study, the dataset consisted of breeds or 'types' represented by six or more individuals. Some of these categories consist of one breed, others are a combination of closely-related breeds (see section 3.2.5 for an explanation of breed/type groups). Initial exploration of the data revealed that although the groups comprising Polands/crested fowl and Sussex each contained a relatively large number of specimens, results for both were too variable to be useful: they were therefore excluded to reduce confusion. Reasons for this variability can only be speculated upon but the Sussex sample comprised mainly utility birds which did not have to conform to a strict breed standard.

The remaining 49 individuals were categorised into six groups to represent a range of morphologies (Table II).

| Modern elements by breed and sex |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Modern breeds |  | Coracoid | Humerus | Femur | Tibiotarsus | Tarsometatarsus |
| Dorking | Male | 3 | 3 | 3 | 3 | 3 |
|  | Female | 6 | 6 | 6 | 6 | 6 |
| Hamburgh | Male | 6 | 6 | 6 | 6 | 5 |
|  | Female | 2 | 3 | 3 | 2 | 3 |
| X-B Junglefowl | Male | 4 | 4 | 4 | 4 | 4 |
|  | Female | 3 | 4 | 4 | 4 | 4 |
| Old English Game | Male | 5 | 6 | 6 | 6 | 6 |
|  | Female | 4 | 4 | 4 | 4 | 4 |
| Silkie | Male | 3 | 3 | 3 | 3 | 3 |
|  | Female | 4 | 4 | 4 | 4 | 4 |
| Asian Game | Male | 5 | 5 | 5 | 5 | 5 |
|  | Female | 1 | I | I | I | I |
| Archaeological elements by site |  |  |  |  |  |  |
| Site |  | Coracoid | Humerus | Femur | Tibiotarsus | Tarsometatarsus |
| Uley |  | 22 | 24 | 17 | 4 | 8 |
| Fishbourne |  | 14 |  |  |  |  |
| Lyminge |  | 60 | 63 | 39 | 32 | 48 |
| Flixborough |  | 31 |  |  |  |  |
| Coppergate |  | 87 |  |  |  |  |
| Chester |  | 13 | 12 | 11 | 12 | 9 |

Table 11: Numbers of specimens used in the measurement ratio study.
Table II lists the specimens by breed, sex and element: the Hamburgh group includes other egg-type breeds closely related to Hamburghs such as Old English Pheasant fowl and Leghorn; 'Asian Game’ comprises Malay, Shamo, Asil and ‘Kulm’ fowl.

Short descriptions of the standard measurements for the coracoid, humerus, femur, tibiotarsus and tarsometatarsus are given in Table 8, Section 4.2.2, but see von den Driesch (1976) for a full description and diagrams. Further details of each dataset including occasional omissions due to missing/damaged elements are provided in Appendices $B$ and $C$, together with the ratios between the individual measurements for each element for both modern and archaeological bones.

|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| :--- | :--- | :---: | :---: | :---: | :---: | :---: |
| Coracoid Lm/GL |  | 0.0192 |  |  |  |  |
| Coracoid Bf/Bb |  |  |  |  | 0.0490 |  |
| Coracoid Bb/GL |  |  |  |  |  | 0.0497 |
| Humerus Bp/GL |  | 0.0417 |  |  |  |  |
| Humerus SC/Bp |  |  | 0.0101 |  |  |  |
| Humerus Bd/Bp |  |  |  | 0.0360 |  |  |
| Femur Bd/GL |  | 0.0039 |  |  |  |  |
| Femur Bd/Lm |  | 0.0001 |  |  |  |  |
| Femur Dd/Bd |  |  | 0.0255 |  |  |  |
| Femur SC/GL |  |  |  | 0.0067 |  |  |
| Femur SC/Lm |  |  |  | 0.0094 |  |  |
| Tbt - SC/Dip | 0.0317 |  |  |  |  |  |
| Tbt Bd/GL |  |  |  |  | 0.0118 |  |
| Tbt Bd/Dip |  | 0.0348 |  |  |  |  |
| Tbt Dd/GL |  | 0.0014 |  |  |  |  |
| Tbt SC/GL |  | 0.0115 |  |  |  |  |
| Tbt Dd/La |  | 0.0046 |  |  |  |  |
| Tbt SC/La |  | 0.0243 |  |  |  |  |
| Tbt Dd/Dip |  |  | 0.0189 |  |  |  |
| Tmt SC/GL | 0.0217 |  |  |  |  |  |
| Tmt Bd/GL | 0.0043 |  |  |  |  |  |

Table 12: Modern chicken breeds/types: measurement ratio datasets with non-normal distribution.
Tests were run on the ratios from the modern breeds to check that the data were normally distributed. As the sample sizes were small, the Shapiro-Wilks test was used. All of the ratio combination values for each breed and bone element were found to be normal with the exception of those listed in Table 12. Complete results of the normality tests are provided in Appendix D, Section 4.I.2.

Illustrating every possible permutation of measurement ratios is impractical, especially for the femur and tibiotarsus, which have more standard measurements and therefore significantly increased numbers of combinations. To assess the most successful combinations, non-parametric Permanova tests were carried out on all paired ratio combinations for each element using the breeds as a grouping variable, the null hypothesis being that the centroids (group means) and dispersion of the groups are equivalent for all groups. This test is more suitable for sample sets which are small, of uneven sizes, or which are not normally distributed. The summarised results are presented in Tables 13, 18, 22, 27 and 32. Values in these tables show the numbers of paired chicken breed groups (out of a possible 15 combinations) which can be distinguished by the different ratio combinations (statistical significance: Hotelling's test p -values with alpha level of <0.05). The most effective combinations are coloured red; the least successful are blue. The most effective were calculated by the simple means of totalling the numbers of pairs in each column - the columns with the highest scores were selected for further investigation and analysis.

Colour-coded scatterplots follow, illustrating a selection of ratio combinations. For reasons of brevity those most effective at separating the groups were chosen although others may also give information on the relational differences and similarities between the breeds/types. Convex hulls, which show the smallest convex polygon containing all points of one group, have been added to aid interpretation. All group means were calculated for each ratio and these can be found in Appendix D, Section 4.I.3. (When generating scatterplots, Past will often position the first letter of each group name at the approximate group mean but this is not consistent and the group means tables should be referred to.) A short explanation identifies and interprets most relevant features of each plot. Results of the Permanova tests for the ratio pairs discussed in the text can be found in Appendix D, Section 4.I.4, with significant p-values in bold type.

To mitigate some of the negative effects caused by unequal sample sizes and occasional non-normality, Between-Groups Principal Component Analysis (BGPCA) (Section 4.3.7) was used to investigate relationships between all of the ratio combinations for each element. A scatterplot of scores for the first two components shows the relationship between the groups and, for the coracoids, humeri and tarsometatarsi,
superimposed biplots indicate the measurement ratios which are most significant in separating them. Biplots for the femora and tibiotarsi are not included as the large number of ratios for these elements confuse the plot but loadings for all the measurement ratios from this analysis are included in the Appendix D, Section 4.I.8 and 4.I.9. Permanova tests were carried out on the first two principal components for each element to test the statistical significance between groups.

Discriminant Function Analysis (DFA) was applied to all of the ratio combinations for all five elements, using the breed groups as grouping variables and the measurement ratios as independent variables. Cross-validation was carried out on initial results but bearing in mind the caveats relating to over-estimation of the maximal differences when using small and uneven sample sizes, the results should be interpreted with caution. Data from the archaeological assemblages do not have these problems to the same extent - outliers were identified and removed prior to analysis and the sample sizes are generally much larger. Scatterplots of specimens along the first two canonical axes are presented to illustrate maximal and second-maximal separation between groups. Confusion matrices show the given and estimated group assignments for each point, together with group assignation after cross validation by leave-one-out jackknifing (Section 4.3.9). Classification tables for the DFA can be found in Appendix D, sections 4.I. 5 and 4.I.6.

For the modern specimens, sex is indicated by square datapoints for males and filled dots for females. The archaeological points are triangles to indicate unknown sex with the exception of tarsometatarsi with spurs or spur scars which are assumed to be from male birds and are represented by squares. During data collection, medullary bone was recorded when it occurred but these elements could not be included in the biometrical analyses as they were, for the most part, fragmentary.

Comparisons were made between the modern groups and the archaeological datasets using ratio combinations which were the most effective at separating the modern groups followed by BGPCA and DFA. For the coracoid, it was possible to compare two Roman and three Anglo-Saxon sites, fully described in Section 3.3. For the remaining elements, comparisons were made between Roman, Saxon and Early Modern assemblages.

### 5.3.3 Coracoid

### 5.3.3.1 Modern

Table 13 shows that the most effective combination of measurement ratios for the coracoid are $\mathrm{Lm} / \mathrm{GL} \vee \mathrm{Bb} / \mathrm{GL}, \mathrm{Lm} / \mathrm{GL} v \mathrm{Bb} / \mathrm{Lm}$ (which gave almost identical results) and $\mathrm{Bb} / \mathrm{GL} v \mathrm{Bb} / \mathrm{Lm}$. All of these separated cross-bred Junglefowl and Asian Game from the other groups. The weakest combination was $\mathrm{Bf} / \mathrm{Bb} v \mathrm{Lm} / \mathrm{GL}$.

| Coracoid | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | 5 | 13 | 13 | 11 | 11 |
| $\mathrm{Lm} / \mathrm{GL}$ | 5 |  | 8 | 9 | 7 | 8 |
| $\mathrm{Bf} / \mathrm{Bb}$ | 13 | 8 |  | 13 | 9 | 10 |
| $\mathrm{Bb} / \mathrm{GL}$ | 13 | 9 | 13 |  | 11 | 11 |
| $\mathrm{Bb} / \mathrm{Lm}$ | 13 | 71 | 7 | 9 | 11 |  |
| $\mathrm{Bf} / \mathrm{GL}$ | 11 | 8 | 10 | 11 | 7 |  |
| $\mathrm{Bf} / \mathrm{Lm}$ | 11 |  |  |  |  |  |

Table 13: Modern chicken breeds/types - coracoid. Numbers of paired groups (out of a possible 15) distinguishable according to Permanova tests.

Figure 38 illustrates the shape similarities and differences between the coracoids from six types of modern chicken when the ratio between the medial length (Lm) and the greatest length (GL) is plotted against the ratio between the basal breadth (Bb) and GL. There is some overlap between the groups but, generally, breeds with a robust morphology plot to the top-left of the graph while the more gracile types plot towards the bottom-right. The medial length relative to the greatest length gives an indication of how far the lateral angle projects sternally compared to the medial angle, although the metrics can be complicated by idiosyncratic development of the medial angle, not uncommon in domestic chickens. The lower the score, the more pointed the lateral angle. On the whole, the Asian breeds (Asian Game and Silkies) have a relatively shorter Lm while the Hamburgh/egg-types have the longest with one specimen (Old English Pheasant Fowl e004) having a ratio of 99.73, indicating near-parity of both measurements. The ratio between Bb and GL reflects the total basal breadth of this approximately triangular bone, relative to the greatest length. The graph shows that the coracoids of the lighter cross-bred Junglefowl and Hamburghs are narrower at the basal end which contrasts with heavier breeds like Asian Game and Dorkings.

Although all of the Silkie coracoids in the sample are likely to be from birds weighing
less than 2 kg , they also group with the heavy breeds, suggesting that factors other than weight may be influencing bone shape.


Figure 38: Modern chicken breeds/types - coracoid. Ratio between Lm and GL plotted against the ratio between Bb and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.
$\mathrm{Bf} / \mathrm{Bb}$ identifies the breadth of the basal articular surface relative to the overall basal breadth. Although this ratio was less effective at separating the groups, the scatterplot (Figure 39) gives an interesting insight into a potentially significant difference between types. The group means show that the shortest facets, by a considerable margin, were seen on the Dorkings and the longest on the Old English Game and Hamburghs with the cross-bred Junglefowl and Asian Game plotting mid-range and the Silkies being more variable.


Figure 39: Modern chicken breeds/types - coracoid. Ratio between Bf and Bb plotted against the ratio between Bb and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

## Between-Groups Principal Component Analysis (BGPCA)

Figure 40 shows a BGPCA scatterplot of scores for the first two principal components which together account for almost $95 \%$ of the variance. The graph illustrates the relationship between the six groups and the measurement ratios which are most influential in separating them, showing that the most important ratios for the lighter types are $\mathrm{Bf} / \mathrm{Bb}$ and $\mathrm{Lm} / \mathrm{GL}$ while for the heavier breeds, $\mathrm{Bb} / \mathrm{Lm}$ and $\mathrm{Bb} / \mathrm{GL}$ are the most significant. Results of a Permanova test of the scores from these two components is included (Table I4).


Figure 40: Modern chicken breeds/types - coracoid. BGPCA. $1^{\text {st }} \mathrm{PC}=69.46 \%$ of the variance; $2^{\text {nd }} P \mathrm{PC}=25.02 \%$ of the variance. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian Game |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
| Dorking |  | $\mathbf{0 . 0 0 3 1}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 2 1}$ | 0.2038 | $\mathbf{0 . 0 2 7 0}$ |
| Hamburgh | $\mathbf{0 . 0 0 3 1}$ |  | $\mathbf{0 . 0 0 8 6}$ | 0.9550 | $\mathbf{0 . 0 4 1 2}$ | $\mathbf{0 . 0 0 0 3}$ |
| X-B JF | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 8 6}$ |  | $\mathbf{0 . 0 1 0 3}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 7}$ |
| O E Game | $\mathbf{0 . 0 0 2 1}$ | 0.9550 | $\mathbf{0 . 0 1 0 3}$ |  | 0.0611 | $\mathbf{0 . 0 0 0 9}$ |
| Silkie | 0.2038 | $\mathbf{0 . 0 4 1 2}$ | $\mathbf{0 . 0 0 0 4}$ | 0.0611 |  | 0.2176 |
| Asian Game | $\mathbf{0 . 0 2 7 0}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 9}$ | 0.2176 |  |

Table 14: Modern breeds/types - coracoid: p-values from Permanova of PC1 and PC2 scores.

## Discriminant Function Analysis (DFA)

Discriminant function analysis was carried out on all the ratio combinations using the breeds as the pre-determined groups. The scatterplot of the first two axes (Figure 4I) confirms the relationship of the bone shapes to each other, although it also shows the effects of overfitting. Classification was initially $69.57 \%$, reduced to $50 \%$ after leave-
one-out cross-validation (Table I5) (see Appendix D, Section 4.I.5.I for classification table).


Figure 41: Modern chicken breeds/types - coracoid. Discriminant function analysis plot of all ratios. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue -cross-bred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | Cross-bred <br> Junglefowl | Old English <br> Game | Silkie | Asian <br> Game | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $7 / 4$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $1 / 2$ | $1 / 3$ | 9 |
| Hamburgh | $1 / 1$ | $4 / 4$ | $1 / 1$ | $2 / 2$ | $0 / 0$ | $0 / 0$ | 8 |
| X-B J-fowl | $0 / 0$ | $0 / 0$ | $6 / 5$ | $1 / 2$ | $0 / 0$ | $0 / 0$ | 7 |
| Old Eng. <br> Game | $0 / 0$ | $1 / 3$ | $2 / 2$ | $6 / 4$ | $0 / 0$ | $0 / 0$ | 9 |
| Silkie | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $6 / 3$ | $1 / 2$ | 7 |
| Asian <br> Game | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $2 / 2$ | $3 / 3$ | 6 |
| Total | $9 / 7$ | $5 / 7$ | $9 / 8$ | $9 / 9$ | $9 / 7$ | $5 / 8$ | 46 |

Table 15: Confusion matrix for all coracoid ratios before/after cross-validation.

### 5.3.3.2 Archaeological

The coracoids from six archaeological sites were compared on an individual basis with the modern breeds and with each other using a combination of $x-y$ plots, between groups principal component analysis and discriminant function analysis.

## Roman

All the ratio combinations showed differences between the coracoids from the two Roman sites, Uley and Fishbourne: these were most obvious in the ratio combination $\mathrm{Bf} / \mathrm{Bb} v \mathrm{Bb} / \mathrm{GL}$, illustrated in Figure 42. A Mann-Whitney U-test on the $\mathrm{Bb} / \mathrm{GL}$ values produced a statistically significant $p$-value of 0.0001 with a less significant $p$-value of 0.0186 for the $\mathrm{Bf} / \mathrm{Bb}$ values. Full test results are given in Appendix D , Section 4.I.7.I.


Figure 42: Uley and Fishbourne - coracoids. Ratio between Bf and Bb plotted against ratio between Bb and GL. Colour key: blue - Fishbourne; red - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.

The x -axis shows that several of the Fishbourne coracoids have proportionally longer basal facets, while on the $y$-axis, more of the Uley points extend towards the top of
the graph, suggesting that a broader basal breadth relative to the greatest length characterised this population.


Figure 43: BGPCA of measurement ratios - coracoids. Modern chicken breeds with two Roman assemblages: Uley (above) and Fishbourne (below). Colour key: yellow - Asian Game; brown - Dorking; green -Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley (top), Fishbourne (bottom).

Figure 43 shows individual BGPCA plots for each Roman assemblage compared with the modern breeds. Most of the Fishbourne coracoids plot more negatively than the modern specimens on the PCI axis (which accounts for $78 \%$ of the variation). A biplot (not illustrated), which indicates the importance of each ratio relative to the groups, confirms that $\mathrm{Bf} / \mathrm{Bb}$, and $\mathrm{Bf} / \mathrm{GL}$ are the most significant for the Fishbourne coracoids. By contrast, the Uley coracoids share similarities with more of the modern breeds, overlapping with Old English Game and Dorkings as well as the lighter Hamburghs and cross-bred Junglefowl. This suggests that the Uley chickens were more 'developed' and probably more robust that the Fishbourne chickens.

The confusion matrix from a discriminant function analysis of the two groups shows a high success rate for correct classification, $83.33 \%$, which falls slightly to a respectable $77.78 \%$ after cross-validation (Table 16). The detailed classification table is in Appendix D, Section 4.I.6.I.

|  | Fishbourne | Uley | Total |
| :--- | :---: | :---: | :---: |
| Fishbourne | $10 / 10$ | $4 / 4$ | 14 |
| Uley | $2 / 4$ | $20 / 18$ | 22 |
| Total | $12 / 14$ | $24 / 22$ | 36 |

Table 16: Confusion matrix for Roman coracoids before/after cross-validation.

## Anglo-Saxon/Scandinavian

The three assemblages from the Saxon period were less distinct from each other but in every ratio combination examined (not illustrated) it was apparent that the Coppergate coracoids were less variable than those from the other two sites, even though they were the largest sample numerically. As an example, Figure 44 shows the ratios $\mathrm{Lm} / \mathrm{GL}$ and $\mathrm{Bf} / \mathrm{Bb}$ plotted against each other. Comparison of the group means (Appendix D, Section 4.I.3.I) for the $\mathrm{Bf} / \mathrm{Bb}$ ratio reveals that the Lyminge basal facets are the shortest relative to the basal breadth while Flixborough are the longest but it is interesting to note that the Roman Uley and Fishbourne group means are lower and higher than the Saxon means respectively.


Figure 44: Anglo-Saxon/Scandinavian coracoids. Ratio between Lm and GL plotted against ratio between Bf and Bb. Colour key: red - Coppergate; black - Flixborough; green - Lyminge. Refer to tables in Appendix 4.1.3 for accurate group means.

Figure 45 shows individual BGPCA graphs of the three Saxon/Anglo-Scandinavian sites compared with the modern breeds. While there is not a great deal of difference between the group means, with all three tending to plot near the Hamburghs, the Coppergate scatter is more directly positioned over the modern breeds while the Flixborough and Lyminge scatters both contain more specimens which plot significantly to the left. The shape-variability of all three is considerably wider than the modern groups but this may be a reflection of the phenotypic uniformity in the modern birds which is the product of generations of strictly controlled, selective breeding: a standardised diet may also be a contributory factor.


Figure 45: BGPCA of measurement ratios - coracoids. Modern chicken breeds with Anglo-Scandinavian Coppergate, Anglo-Saxon Flixborough and Lyminge. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black Coppergate (top), Flixborough (middle) and Lyminge (bottom).

A DFA of the three sites (plot not illustrated) confirms this similarity with just 55.32\% of all specimens initially correctly classified, further reduced after cross-validation to 48.94\% (Table 17). See Appendix D, Section 4.I.6.I for the classification table. Results for Coppergate were marginally better than for Lyminge and Flixborough.

|  | Coppergate | Flixborough | Lyminge | Total |
| :--- | :---: | :---: | :---: | :---: |
| Coppergate | $28 / 26$ | $12 / 12$ | $13 / 15$ | 53 |
| Flixborough | $6 / 8$ | $13 / 11$ | $9 / 9$ | 28 |
| Lyminge | $12 / 14$ | $11 / 14$ | $37 / 32$ | 60 |
| Total | $46 / 48$ | $36 / 37$ | $59 / 56$ | 141 |

Table 17: Confusion matrix for coracoids ratios from three Saxon sites before/after cross-validation.

## Early-modern



Figure 46: Modern chicken breeds/types and Chester - coracoids. Ratio between Lm and GL plotted against ratio between Bb and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Chester. Refer to tables in Appendix 4.1.3 for accurate group means.

Initial investigation of the paired ratio combinations for $16^{\text {th }}$-century Chester and the modern breeds revealed that the archaeological specimens showed a wide distribution but, on the whole, plotted with the cross-bred Junglefowl, Hamburghs and Old English Game although a few consistently plotted with the Dorkings and Silkies. The combination which gave the best separation between Chester and the modern types (16 out of a possible 21 pairs) was Lm/GL plotted against $\mathrm{Bb} / \mathrm{Lm}$, shown in Figure 46.


Figure 47: BGPCA of measurement ratios - coracoids. Modern chicken breeds with early-modern Chester. PC1 $=70.61 \%$ of the variance; PC2 = 24.24\% of the variance. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black Chester.

Between-Groups Principal Component Analysis of all of the modern and $16^{\text {th }}$-century Chester ratio results confirmed that the Chester coracoids were far more akin to the modern specimens than the Roman and Saxon coracoids. Figure 47 shows virtually all of the $16^{\text {th }}$-century coracoids from Chester plotting directly over the modern specimens. The group means indicate that the Chester assemblage as a whole is more similar to the Hamburghs and Old English Game.

### 5.3.4 Humerus

### 5.3.4.1 Modern

Table 18 shows that the most effective ratio combination for the humerus was $\mathrm{Bp} / \mathrm{GL}$ v SC/Bd which distinguished 12 group pairs from a possible I5, while combinations of $\mathrm{Bd} / \mathrm{GL}, \mathrm{Bp} / \mathrm{GL}$ and SC/Bp distinguished II group pairs. None of the combinations were successful at separating Dorkings, Silkies and Asian Game from each other. The weakest combination was $S C / G L$ with $B d / B p$, which only separated three pairs.

| Humerus |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |
| $\mathrm{Bd} / \mathrm{Bp}$ |  | 3 | 8 | 7 | 8 | 9 |
| $\mathrm{SC} / \mathrm{GL}$ | 3 |  | 9 | 10 | 7 | 9 |
| $\mathrm{Bp} / \mathrm{GL}$ | 8 | 9 |  | 11 | 11 | 12 |
| $\mathrm{Bd} / \mathrm{GL}$ | 7 | 10 | 11 |  | 11 | 10 |
| $\mathrm{SC} / \mathrm{Bp}$ | 8 | 7 | 11 | 11 |  | 9 |
| $\mathrm{SC} / \mathrm{Bd}$ | 9 | 9 | 12 | 10 | 9 |  |

Table 18: Modern chicken breeds/types - humerus. Numbers of paired groups (out of a possible 15) distinguishable according to Permanova tests.

Figure 48 shows a scatterplot for $\mathrm{Bp} / \mathrm{GL} v \mathrm{SC} / \mathrm{Bd}$ which was the most effective ratio combination identified by the Permanova tests. On the x-axis, cross-bred Junglefowl and Hamburghs plotted to the left indicating a narrower proximal end relative to total length while Dorkings, Silkies and Asian Game were broader. The SC/Bd results show similar results (although there is much more overlap between the groups): a relatively broader distal end for the heavier breeds and Silkies while in the lighter fowl it is narrower. Scores for Old English Game were quite variable but their group mean for the SC/Bd ratio reflects an even narrower average distal end relative to the shaft breadth than that of the cross-bred Junglefowl which is unexpected.

Figure 49 examines the breadth of the distal end relative to the greatest length and the breadth of the shaft relative to the proximal end and gives a similar distribution of points to the previous graph, although the group means show that this time the Old English Game plot on average a little closer to the Hamburghs and cross-bred Junglefowl.


Figure 48: Modern chicken breeds/types - humerus. Ratio between Bp and GL plotted against ratio between SC and Bd. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 49: Modern chicken breeds/types - humerus. Ratio between Bd and GL plotted against ratio between SC and Bp. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

## Between-Groups Principal Component Analysis (BGPCA)

Figure 50 shows a BGPCA scatterplot of scores for the first two components which together account for almost $94 \%$ of the variance. For the first PC, almost all of the heavy breeds and the Silkies plot to the left of the mean, while the English Game and the lighter breeds trend towards the right. The biplot indicates that the most significant ratios for the heavier types are the breadth of the proximal and distal ends relative to the greatest length while for the Mediterranean types, the breadth of the shaft relative to both distal and proximal breadths are more influential.


Figure 50: Modern chicken breeds/types - humerus. BGPCA. Ist PC $=72.96 \%$ of the variance; $2^{\text {nd }} \mathbf{P C} 20.89 \%$ of the variance. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian Game |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
| Dorking |  | $\mathbf{0 . 0 2 3 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 3 1}$ | 0.1932 | 0.4613 |
| Hamburgh | $\mathbf{0 . 0 2 3 2}$ |  | $\mathbf{0 . 0 0 9 7}$ | $\mathbf{0 . 0 1 2 4}$ | 0.0651 | $\mathbf{0 . 0 0 6 5}$ |
| X-B Junglefowl | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 9 7}$ |  | $\mathbf{0 . 0 0 8 0}$ | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | $\mathbf{0 . 0 0 3 1}$ | $\mathbf{0 . 0 1 2 4}$ | $\mathbf{0 . 0 0 8 0}$ |  | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 1 4}$ |
| Silkie | 0.1932 | 0.0651 | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 0 0 9}$ |  | 0.4554 |
| Asian Game | 0.4613 | $\mathbf{0 . 0 0 6 5}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1 4}$ | 0.4554 |  |

Table 19: Modern breeds/types - humerus: p-values from Permanova of PC1 and PC2 scores.
A Permanova test of scores from the first two components (Table 19) shows the groups that are statistically distinct from each other. Significant p-values confirm that cross-bred Junglefowl and Old English Game have the most distinct humeri, while Dorkings, Silkies and Asian Game are morphologically similar.

## Discriminant Function Analysis



Figure 51: Modern chicken breeds/types - humerus. Discriminant function analysis plot of all ratios. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue -cross-bred Junglefowl; pink - Silkie.

The discriminant function analysis scatterplot (Figure 5I) separates light breeds from heavier types clearly; however, there is a considerable overlap between Dorkings, Silkies and Asian Game, and between cross-bred Junglefowl and Hamburghs which results in poor classification rates. Correct classification was initially $55.1 \%$ of the
specimens, which fell to $40.82 \%$ after cross-validation (Table 20). Details of individual classifications are in the Appendix D, Section 4.I.5.2.

|  | Dorking | Hamburgh | Cross-bred <br> Junglefowl | Old English <br> Game | Silkie | Asian <br> Game | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $3 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 2$ | $4 / 4$ | $2 / 2$ | 9 |
| Hamburgh | $0 / 0$ | $6 / 5$ | $2 / 2$ | $1 / 1$ | $0 / 1$ | $0 / 0$ | 9 |
| X-B J-fowl | $0 / 0$ | $1 / 1$ | $6 / 6$ | $1 / 1$ | $0 / 0$ | $0 / 0$ | 8 |
| Old Eng. <br> Game | $0 / 2$ | $2 / 2$ | $1 / 1$ | $6 / 4$ | $1 / 1$ | $0 / 0$ | 10 |
| Silkie | $2 / 3$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $3 / 1$ | $2 / 2$ | 7 |
| Asian <br> Game | $0 / 0$ | $1 / 1$ | $0 / 0$ | $0 / 0$ | $2 / 2$ | $3 / 3$ | 6 |
| Total | $5 / 6$ | $10 / 9$ | $9 / 9$ | $8 / 9$ | $1 / 9$ | $7 / 7$ | 49 |

Table 20: Confusion matrix for all humerus ratios before/after cross-validation.

### 5.3.4.2 Archaeological

Humeri from Uley, Lyminge and Chester were initially compared individually with the modern breeds/types using the ratio combination which the initial Permanova tests found to be most effective at separating the modern groups: the $\mathrm{Bp} / \mathrm{GL}$ ratio between the breadth of the proximal end and the greatest length with SC/Bd, the shaft breadth relative to the distal breadth. Initial inspection of the scatterplots suggests a change over time with the Roman humeri (Figure 52) showing more similarities with the cross-bred Junglefowl, Hamburghs and Old English Game, Lyminge (Figure 53) most closely resembling the Old English Game and the Early-Modern Chester (Figure 54) specimens trending more towards the heavier Dorkings. The group means (Appendix D, Section 4.I.2.2) indicate that the archaeological humeri from Lyminge and Chester have broader proximal ends relative to the greatest lengths than do those from Uley; humeri from Chester have the most slender shaft relative to distal breadth.


Figure 52: Modern chicken breeds/types and Uley - humerus. Ratio between Bp and GL plotted against ratio between SC and Bd. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 53: Mod chicken breeds/types and Lyminge - humerus. Ratio between Bp and GL plotted against ratio between SC and Bd. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 54: Mod chicken breeds/types and Chester - humerus. Ratio between Bp and GL plotted against ratio between SC and Bd. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Chester. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 55: Archaeological humeri. Ratio between Bp and GL plotted against ratio between SC and Bd. Colour key: red - Chester; green - Lyminge; purple - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.

Figure 55 plots the variability and distribution of the three archaeological assemblages using the $\mathrm{Bp} / \mathrm{GL}$ ratio plotted against the $\mathrm{SC} / \mathrm{Bd}$ ratio and shows that, while the Chester humeri are the least variable, the between-group variance for the humerus is much less than in other elements.

The relationships between groups depicted in the BGPCA graphs (Figure 56) are similar to those plotted using the measurement ratios. These graphs also show a small but perceptible shift through time with more of the Uley chickens points plotting closely with the cross-bred Junglefowl, English Game and Hamburgh/egg-types and the Chester scores shifted slightly towards the stockier Dorkings.


Figure 56: BGPCA of measurement ratios - humeri. Modern chicken breeds with (from top to bottom) Roman Uley, Saxon Lyminge and Early-modern Chester.

Discriminant Function Analysis

|  | Chester | Lyminge | Uley | Total |
| :--- | :---: | :---: | :---: | :---: |
| Chester | $7 / 1$ | $3 / 7$ | $2 / 4$ | 12 |
| Lyminge | $13 / 13$ | $36 / 34$ | $14 / 16$ | 63 |
| Uley | $7 / 8$ | $4 / 6$ | $13 / 10$ | 24 |
| Total | $27 / 22$ | $43 / 47$ | $29 / 30$ | 99 |

Table 21: Confusion matrix for archaeological humeri before/after cross-validation.
Results of discriminant function analysis of the three archaeological datasets (plot not illustrated) did not distinguish between the three sites effectively (Table 21 ) with only $56.57 \%$ of the specimens initially classified to the correct groups, reduced to $45.45 \%$ after cross-validation. Classifications can be found in Appendix D, Section 4.I.6.2.

### 5.3.5 Femur

### 5.3.5.1 Modern

There are seven standard measurements for the avian femur which can be formulated into 21 different ratios. Combinations of the most reliable of these measurements were used to make 15 ratios which were tested using non-parametric Permanova tests. The tests showed a wide range of results, from some that produced no separation at all to others that separated up to 11 or 12 of the group pairs. Table 22 below illustrates the results from the combinations attempted and shows the numbers of group pairs successfully separated according to $p$-value $<0.05$. The most successful ratio combinations are those which used the breadth of the distal end relative to medial length (Bd/Lm) in conjunction with Dd/Lm, SC/GL, Bd/GL, Bp/GL, SC/Lm and Dd/GL. P-values of Permanova tests of these combinations are in the Appendix D, Section 4.I.4.2. Silkies and Asian Gamefowl were consistently impossible to separate using any of the ratio combinations except Dd/Lm v Bd/Lm, and Hamburghs were frequently confused with Old English Game. The weakest ratios were Dd/Bd, Dd/Bp and Dp/Dd: those ratios that used the SC measurement were also often unsuccessful unless plotted against more effective ratios.

| Femur |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Dd/Bd |  | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| SC/Bd | 1 |  | 3 | 9 | 7 | 10 | 8 | 3 | 1 | 0 | 3 | 8 | 9 | 3 |
| SC/GL | 0 | 3 |  | 10 | 8 | 11 | 10 | 4 | 0 | 0 | 3 | 9 | 10 | 1 |
| Bd/GL | 0 | 9 | 10 |  | 10 | 11 | 10 | 9 | 5 | 0 | 3 | 11 | 11 | 3 |
| Bp/GL | 0 | 7 | 8 | 10 |  | 11 | 10 | 8 | 1 | 0 | 3 | 10 | 10 | 3 |
| Bd/Lm | 0 | 10 | 11 | 11 | 11 |  | 10 | 11 | 7 | 3 | 3 | 11 | 12 | 4 |
| Bp/Lm | 0 | 8 | 10 | 10 | 10 | 10 |  | 10 | 4 | 0 | 3 | 10 | 10 | 3 |
| SC/Lm | 0 | 3 | 4 | 9 | 8 | 11 | 10 |  | 0 | 0 | 3 | 10 | 10 | 1 |
| SC/Bp | 0 | 1 | 0 | 5 | 1 | 7 | 4 | 0 |  | 0 | 3 | 3 | 6 | 1 |
| Dd/Bp | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |  | 1 | 0 | 0 | 0 |
| Dp/Dd | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 |  | 3 | 3 | 1 |
| Dd/GL | 0 | 8 | 9 | 11 | 10 | 11 | 10 | 10 | 3 | 0 | 3 |  | 10 | 3 |
| Dd/Lm | 0 | 9 | 10 | 11 | 10 | 12 | 10 | 10 | 6 | 0 | 3 | 10 |  | 4 |
| SC/Dd | 0 | 3 | 1 | 3 | 3 | 4 | 3 | 1 | 1 | 0 | 1 | 3 | 4 |  |

Table 22: Modern chicken breeds/types - femur. Numbers of paired groups (out of a possible 15) distinguishable according to Permanova tests.


Figure 57: Modern chicken breeds/types - femur. Ratio between Bd and Lm plotted against ratio between Dd and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

The scatterplot in Figure 57 is of the most successful ratio combination for the femur measurements and shows that the cross-bred Junglefowl and lighter Hamburghs have a smaller distal breadth and depth relative to the medial length than the Dorkings and Asian Game. The group means increase from the bottom left to the top right of the graph indicating that, generally, the tendency is towards a relatively broader and deeper distal articulation as the breeds get larger and heavier. (The small Silkie bantams are again an exception, plotting with the larger fowl.)

This trend was observed in the $x-y$ plots of all the combinations of effective ratios listed above (not illustrated), with the light breeds consistently plotting bottom left of the graph and the heavier types towards the top right. The trend is not always so welldefined nor the groups so distinct, however. In Figure 58 the progressively increasing group means show that the relationship between the breadth of the shaft and the greatest length (SC/GL) broadly follows this pattern but on an individual basis there is far more variability and overlapping within and between all of the breeds except for the cross-bred Junglefowl.


Figure 58: Modern chicken breeds/types - femur. Ratio between SC and GL plotted against ratio between Bd and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 59: Modern chicken breeds/types - femur. BGPCA of all ratio combinations. $1^{\text {st }} P=75.30 \%$ of the variance; $2^{\text {nd }} \mathbf{P C}=15.16 \%$ of the variance. Colour key: yellow - Asian Game; brown - Dorking; green -Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

## Between-Groups Principal Component Analysis (BGPCA)

Figure 59 plots the scores from a BGPCA using all of the ratio combinations. As the large number of combinations would confuse the graph, a biplot of the loadings has not been superimposed but the loadings table (Appendix D, Section 4.I.8.3) shows that the most significant ratios for the first principal component are SC/Dd and SC/Bd (separating the cross-bred Junglefowl and egg-types) and $\mathrm{Dd} / \mathrm{Bp}$ and $\mathrm{Bd} / \mathrm{Lm}$ (significant for the Dorkings and Asian Game).

A Permanova of the scores from the first 2 components (which together account for $90 \%$ of the variance) confirms that the differences between some of the groups are statistically significant and the cross-bred Junglefowl are the most distinct (Table 23).

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian Game |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
| Dorking |  | $\mathbf{0 . 0 2 7 4}$ | $\mathbf{0 . 0 0 2 0}$ | $\mathbf{0 . 0 4 7 6}$ | 0.0542 | 0.3061 |
| Hamburgh | $\mathbf{0 . 0 2 7 4}$ |  | 0.1867 | 0.5815 | $\mathbf{0 . 0 0 6 8}$ | $\mathbf{0 . 0 1 4 2}$ |
| X-B JF | $\mathbf{0 . 0 0 2 0}$ | 0.1867 |  | $\mathbf{0 . 0 4 1 9}$ | $\mathbf{0 . 0 0 4 6}$ | $\mathbf{0 . 0 0 5 0}$ |
| O E Game | $\mathbf{0 . 0 4 7 6}$ | 0.5815 | $\mathbf{0 . 0 4 1 9}$ |  | $\mathbf{0 . 0 1 5 3}$ | $\mathbf{0 . 0 2 8 8}$ |
| Silkie | 0.0542 | $\mathbf{0 . 0 0 6 8}$ | $\mathbf{0 . 0 0 4 6}$ | $\mathbf{0 . 0 1 5 3}$ |  | 0.2724 |
| Asian Game | 0.3061 | $\mathbf{0 . 0 1 4 2}$ | $\mathbf{0 . 0 0 5 0}$ | $\mathbf{0 . 0 2 8 8}$ | 0.2724 |  |

Table 23: Modern breeds/types - femur: p-values from Permanova of PC1 and PC2 scores.

## Discriminant function analysis

The discriminant function analysis of all ratios plot (Figure 60) suggests significant differences between groups and the initial test correctly classified $79.59 \%$ of the specimens, but this fell sharply to $32.65 \%$ after cross-validation (Table 24). The analysis was repeated using only the eight most effective ratios but this reduced correct classification to $67.35 \%$ and the cross-validated result remained at $32.65 \%$. Individual classifications are in Appendix D, Section 4.I.5.3.


Figure 60: Modern chicken breeds/types - femur. Discriminant function analysis plot of all ratios. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - crossbred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | Cross-bred <br> Junglefowl | Old English <br> Game | Silkie | Asian <br> Game | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $8 / 3$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $0 / 2$ | $1 / 3$ | 9 |
| Hamburgh | $1 / 1$ | $6 / 2$ | $1 / 2$ | $1 / 3$ | $0 / 1$ | $0 / 0$ | 9 |
| X-B J-fowl | $0 / 0$ | $1 / 4$ | $7 / 3$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 8 |
| Old Eng. <br> Game | $0 / 1$ | $2 / 7$ | $0 / 1$ | $7 / 2$ | $1 / 3$ | $0 / 0$ | 10 |
| Silkie | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $7 / 5$ | $0 / 1$ | 7 |
| Asian <br> Game | $1 / 2$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | $0 / 2$ | $4 / 1$ | 6 |
| Total | $10 / 7$ | $9 / 10$ | $8 / 6$ | $9 / 8$ | $8 / 13$ | $5 / 5$ | 49 |

Table 24: Confusion matrix for all femur ratios before/after cross-validation.

### 5.3.5.2 Archaeological

Figures 61, 62 and 63 show femora from Uley, Lyminge and Chester compared with those from the modern chicken breeds using the ratio found to be the most effective in separating the modern breeds/types ( $\mathrm{Bd} / \mathrm{Lm} \vee \mathrm{Dd} / \mathrm{Lm}$ ). The trend from bottom left to top right shows an increasingly broader, deeper distal articulation relative to the medial length. Roman Uley chickens (Figure 6I) plot with the lighter cross-bred Junglefowl and Hamburghs. The group means indicate that Saxon Lyminge (Figure 62)
and Early-modern Chester (Figure 63) have on average slightly more robust distal ends than Uley but the Lyminge distribution is very variable with some individuals plotting with the cross-bred Junglefowl, most with the Old English Game and a few with the heavier Dorkings.


Figure 61: Modern chicken breeds/types and Uley - femur. Ratio between Bd and Lm plotted against ratio between Dd and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 62: Modern chicken breeds/types and Lyminge - femur. Ratio between Bd and Lm plotted against ratio between Dd and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge.


Figure 63: Modern chicken breeds/types and Chester - femur. Ratio between Bd and Lm plotted against ratio between Dd and Lm. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Chester. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 64: Archaeological femora. Ratio between Bd and Lm plotted against ratio between Dd and Lm. Colour key: red - Chester; green - Lyminge; purple - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.

The variability and distribution between the three archaeological assemblages is easier to see in Figure 64. The main difference between Roman Uley and Saxon Lyminge is that the depth of the distal articulation is increased in some of the Lyminge femora. The pattern of distribution shows that the Chester femora have the least variability. However, the degree of overlap for this and the remaining ratio combinations (not shown) means that the sites are difficult to distinguish using discriminant function analysis.

## Between Groups PCA

BGPCA plots of the individual assemblages (Figure 65) give broadly similar results although incorporating all the measurement ratios helps define the relationships of the archaeological specimens with those of the modern breeds more accurately. Uley plot nearer the cross-bred Junglefowl and Hamburghs; Chester are more narrowly distributed and overlap mostly with the Dorkings while the Lyminge assemblage is again characterised by a broader scatter overlying the distributions of several of the modern types.


Figure 65: BGPCA of measurement ratios - femora. Modern chicken breeds with (from top to bottom) Roman Uley, Saxon Lyminge and Early-modern Chester. Colour key: yellow - Asian Game; brown - Dorking; green -Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley (top), Lyminge (middle), Chester (bottom).

## Discriminant Function Analysis

Discriminant function analysis of the three archaeological assemblages was ineffective at assigning the specimens to the correct category, probably related to the degree of overlap which occurs between all the ratio combinations.

|  | Uley | Lyminge | Chester | Total |
| :--- | :---: | :---: | :---: | :---: |
| Uley | $13 / 8$ | $2 / 5$ | $2 / 4$ | 17 |
| Lyminge | $7 / 12$ | $25 / 14$ | $7 / 13$ | 39 |
| Chester | $1 / 3$ | $3 / 6$ | $7 / 2$ | 11 |
| Total | $21 / 23$ | $30 / 25$ | $16 / 19$ | 67 |

Table 25: Confusion matrix for DFA of all three archaeological sites: femur.
Initial classification was $67.16 \%$, but, as in the DFA of the modern breeds/types, the cross-validated result was very low at $35.82 \%$ (Table 25). Individual classifications are in Appendix D, Section 4.I.6.3.

## A femur from a 'creeper' chicken

During analysis of the kernel density profiles of log-scaled metrics from Lyminge, femur L66I was identified as an outlier (Section 5.2.2: Figure 31). This specimen was omitted from the measurement ratio dataset after normality tests and consequently excluded from the analyses above. As the effect of the creeper gene is less pronounced on the proximal long bones, a confident identification of a creeper femur and not simply a chicken exhibiting proportional dwarfism was difficult to determine by observation. A small comparative study was carried out using the Lyminge femur together with those from known-breed modern creepers and the creeper ABG from Uley. 'Normal' femora from Uley, Lyminge and two traditional breeds from the modern reference collection were also included: the selected archaeological femora had the nearest $G L$ to the mean of the combined femora GLs from each site, excluding the creepers (Table 26). Measurement ratios were calculated from diagnostic metrics $(\mathrm{Bd} / \mathrm{GL}$ and $\mathrm{Bp} / \mathrm{GL})$ and an $x-y$ scatterplot of these ratios is presented in Figure 66.

The separation between the 'normal' femora and the creepers is unambiguous. The modern Old English Game and Hamburgh (dark green) cluster with the average femora from Lyminge and Uley (light green). The modern creepers (purple) are quite variable, with the most distinct morphologies being those of the Japanese Bantam (R652) and Krüper (KRMI). The Lyminge femur under investigation (L66I) plots
closely with the Uley femur from the creeper ABG (U065) and the modern Scots Dumpy (EOO5) and can be confidently identified as from a creeper chicken.

| Site/Collection | Bone ID/context/ <br> accession number | Bd | Bp | GL | Bd/GL | Bp/GL |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Lyminge | L661 | 12.87 | 12.93 | 57.63 | 22.28 | 22.44 |
| Uley | U065 | 15.14 | 14.47 | 65.32 | 23.18 | 22.15 |
| Japanese Bantam | R652 | 13.25 | 12.34 | 47.47 | 27.91 | 26.00 |
| Scots Dumpy | E005 | 15.29 | 15.71 | 68.19 | 22.42 | 23.04 |
| Krüper | KRM1 | 19.57 | 19.37 | 79.49 | 24.61 | 24.36 |
| Old English Game | R735 | 17.08 | 17.58 | 88.59 | 19.28 | 19.84 |
| Hamburgh | R736 | 18.60 | 19.86 | 96.49 | 19.28 | 20.58 |
| Lyminge mean | L857 | 13.68 | 14.00 | 71.32 | 19.18 | 19.63 |
| Uley mean | U048 | 15.86 | 15.79 | 81.13 | 19.55 | 19.46 |

Table 26: Metrics and measurement ratios for femur L661 and known creeper/non-creeper femora.


Figure 66: Lyminge femur L661 with modern and archaeological creeper chickens. Ratio between Bd and GL plotted against the ratio between Bp and GL. Colour key: light green - archaeological 'normal'; dark green modern 'normal'; red - archaeological creepers; purple - modern creepers.

### 5.3.6 Tibiotarsus

| Tibiotarsus |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Bd/Dip |  | 11 | 11 | 9 | 11 | 11 | 10 | 10 | 8 | 11 | 12 | 11 | 11 | 11 | 12 |
| Bd/GL | 11 |  | 11 | 4 | 12 | 10 | 11 | 12 | 7 | 9 | 14 | 11 | 11 | 11 | 9 |
| Dd/GL | 11 | 11 |  | 4 | 12 | 11 | 10 | 11 | 7 | 7 | 13 | 7 | 13 | 10 | 7 |
| SC/Bd | 9 | 4 | 4 |  | 4 | 4 | 4 | 4 | 7 | 7 | 5 | 5 | 5 | 4 | 6 |
| SC/GL | 11 | 12 | 12 | 4 |  | 12 | 11 | 10 | 7 | 6 | 12 | 7 | 12 | 10 | 7 |
| Bd/La | 11 | 10 | 11 | 4 | 12 |  | 11 | 11 | 7 | 10 | 13 | 10 | 14 | 11 | 8 |
| Dd/La | 10 | 11 | 10 | 4 | 11 | 11 |  | 10 | 7 | 6 | 11 | 7 | 13 | 10 | 7 |
| SC/La | 10 | 12 | 11 | 4 | 10 | 11 | 10 |  | 7 | 7 | 11 | 6 | 12 | 10 | 7 |
| Bd/Dd | 8 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |  | 8 | 7 | 8 | 7 | 7 | 8 |
| Dd/Dip | 11 | 9 | 7 | 7 | 6 | 10 | 6 | 7 | 8 |  | 7 | 8 | 9 | 6 | 8 |
| Dip/GL | 12 | 14 | 13 | 5 | 12 | 13 | 11 | 11 | 7 | 7 |  | 12 | 11 | 11 | 9 |
| SC/Dip | 11 | 11 | 7 | 5 | 7 | 10 | 7 | 6 | 8 | 8 | 12 |  | 12 | 6 | 7 |
| Dip/La | 11 | 11 | 13 | 5 | 12 | 14 | 13 | 12 | 7 | 9 | 11 | 12 |  | 11 | 9 |
| La/GL | 11 | 11 | 10 | 4 | 10 | 11 | 10 | 10 | 7 | 6 | 11 | 6 | 11 |  | 7 |
| SC/Dd | 12 | 9 | 7 | 6 | 7 | 8 | 7 | 7 | 8 | 8 | 9 | 7 | 9 | 7 |  |

Table 27: Modern chicken breeds/types - tibiotarsus. Numbers of paired groups (out of a possible 15) distinguishable according to Permanova tests

Initial assessment of the ratio pairs using Permanova (Table 27) showed that the most successful ratios were $\mathrm{Dip} / \mathrm{La}, \mathrm{Bd} / \mathrm{Dip}, \mathrm{Dip} / \mathrm{GL}, \mathrm{Bd} / \mathrm{GL}$ and $\mathrm{Bd} / \mathrm{La}$. The most effective combinations of these ratios were those between the diameter of the proximal end and the breadth of the distal end relative to the greatest length and the lateral length ( $\mathrm{Dip} / \mathrm{GL} v \mathrm{Bd} / \mathrm{GL}$ and $\mathrm{Dip} / \mathrm{La} \mathrm{v} \mathrm{Bd} / \mathrm{La}$ ) which both separated I 4 pairs from a possible 15. The least successful ratio was $\mathrm{SC} / \mathrm{Bd}: \mathrm{Bd} / \mathrm{Dd}$ and $\mathrm{SC} / \mathrm{Dd}$ were also of limited value.

### 5.3.6.1 Modern



Figure 67: Modern chicken breeds/types - tibiotarsus. Ratio between Bd and La plotted against ratio between Dip and La. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

Figure 67 plots the values for the breadth of the distal articulation and the diameter of the proximal end relative to the lateral length of the tibiotarsus ( $\mathrm{Bd} / \mathrm{La} \vee \mathrm{Dip} / \mathrm{La}$ ). The combination Dip/GL v Bd/GL was marginally more effective at separating the groups and produced an almost identical graph (not illustrated) but the La measurement is arguably more useful in archaeological assemblages as frequently damage to the cnemial crest means the greatest length cannot be measured. Figure 67 shows the trend from narrow articulation at the bottom left to broader at the top right. The most obvious feature of this graph is that the separation between the types, shown by the convex hulls, is much more distinct than for the other four elements in this study. For the $\mathrm{Bd} /$ La ratio, the general inclination is for bigger birds to have broader distal ends but the position of the large Asian Game is unexpected as their distal ends are shown to be narrower than the Silkies and most of the Dorkings. Group means for the Hamburgh/egg-types and the cross-bred Junglefowl are similar but the Old English Game span a wide range. The general pattern is repeated for the Dip/La values,
although the proximal ends of the cross-bred Junglefowl tibiotarsi are relatively more slender than the Hamburghs and this time the Asian Game plot with the heavy Dorkings.


Figure 68: Modern chicken breeds/types - tibiotarsus. Ratio between Bd and Dip plotted against ratio between SC and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

Alternative ratio combinations were examined to explore other shape differences.
Figure 68 corroborates the result from the previous graph - that the distal tibiotarsi of Asian Game are surprisingly narrow. Here the distal breadth is shown relative to the proximal diameter on the x-axis: the Asian Game plot towards the left of the scale with most of the Hamburghs and Old English Game. The group means show that the cross-bred Junglefowl have relatively the most slender shafts while the Silkies have the thickest.


Figure 69: Modern chicken breeds/types - tibiotarsus. BGPCA: $1^{\text {st }} P \mathbf{P C}=73.22 \%$ of the variance; $2^{\text {nd }} \mathbf{P C}=$ $16.20 \%$ of the variance. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

Figure 69 illustrates the first two principal components of the BGPCA which together are responsible for almost $90 \%$ of the variance within the sample. Almost all of the loadings (Appendix D, Section 4.I.8.4) are positively correlated with the first principal component: a biplot (not shown) indicates that the most significant ratios for the heavy breeds are those which use the distal measurements while for the lighter fowl the proximal end and the shaft breadth are important.

| P-values from Permanova of PC 1 and 2 scores |  |  |  |  |  |  |
| :--- | ---: | :--- | ---: | :--- | ---: | ---: |
|  | Dorking | X-B JF | O E Game | Silkie | Asian Game | Hamburgh |
| Dorking |  | $\mathbf{0 . 0 0 2 0}$ | $\mathbf{0 . 0 0 3 9}$ | 0.2972 | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 1 8}$ |
| X-B JF | $\mathbf{0 . 0 0 2 0}$ |  | 0.1611 | $\mathbf{0 . 0 0 3 9}$ | $\mathbf{0 . 0 0 1 5}$ | 0.0981 |
| O E Game | $\mathbf{0 . 0 0 3 9}$ | 0.1611 |  | $\mathbf{0 . 0 0 4 0}$ | 0.1833 | 0.4597 |
| Silkie | 0.2972 | $\mathbf{0 . 0 0 3 9}$ | $\mathbf{0 . 0 0 4 0}$ |  | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 2 5}$ |
| Asian Game | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 1 5}$ | 0.1833 | $\mathbf{0 . 0 0 1 2}$ |  | $\mathbf{0 . 0 3 2 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 1 8}$ | 0.0981 | 0.4597 | $\mathbf{0 . 0 0 2 5}$ | $\mathbf{0 . 0 3 2 3}$ |  |

Table 28: Modern breeds/types - tibiotarsus: p-values from Permanova of PC1 and PC2 scores.

The Permanova of the scores from the first two components shows in bold type the groups that are statistically distinct (Table 28). The test confirms that, for the tibiotarsus, the Asian Game are morphologically dissimilar from the Dorkings and Silkies, the breeds they usually plot with. This difference is probably associated with the narrow distal end of the Asian Game identified in Figures 67 and 68.

## Discriminant Function Analysis

Although the results of the discriminant function analysis are over-optimistic owing to the unequal and small sample sets, the scatterplot (Figure 70) suggests that the modern breed tibiotarsi have more breed-related morphological distinction than the other elements. The measurement ratios are initially effective at separating the different types, with correct classification at $79.17 \%$, although this was reduced to 52.08\% after cross-validation (Table 29). Details of individual classifications are in Appendix D, Section 4.I.5.4.


Figure 70: Modern chicken breeds/types - tibiotarsus. Discriminant function analysis plot of all ratios. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue -cross-bred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | X-B J-fowl | O E Game | Silkie | Asian G | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $9 / 7$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 1$ | 9 |
| Hamburgh | $0 / 0$ | $7 / 2$ | $0 / 2$ | $1 / 3$ | $0 / 0$ | $0 / 1$ | 8 |
| X-B Junglefowl | $0 / 0$ | $1 / 2$ | $7 / 4$ | $0 / 1$ | $0 / 0$ | $0 / 1$ | 8 |
| Old Eng. Game | $2 / 2$ | $3 / 3$ | $0 / 1$ | $5 / 4$ | $0 / 0$ | $0 / 0$ | 10 |
| Silkie | $1 / 1$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $6 / 4$ | $0 / 1$ | 7 |
| Asian Game | $0 / 0$ | $0 / 0$ | $0 / 0$ | $2 / 2$ | $0 / 0$ | $4 / 4$ | 6 |
| Total | $12 / 10$ | $11 / 8$ | $7 / 7$ | $8 / 11$ | $6 / 4$ | $4 / 8$ | 48 |

Table 29: Confusion matrix for all tibiotarsus ratios before/after cross-validation.
In order to be able to compare the results of the measurement ratios DFA with the DFA from the GMM data, a reduced set of ratios was used and the analysis repeated. The selected ratios were combinations of Bd, Dip, SC and GL, to capture the greatest length together with the breadth of the distal and proximal ends and the shaft breadth. Although comparison of the plots (Figures 70 and 7I) suggest that more ratios produce better separation, the cross-validated classification rate for the reduced ratios was more successful, with correct classification initially at $77.08 \%$, reduced to $60.42 \%$ after cross-validation (Table 30). Details of individual classifications are in the Appendix D, Section 4.I.5.4


Figure 71: Modern chicken breeds/types - tibiotarsus. Discriminant function analysis plot of six ratio combinations. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

|  | Dorking | X-B JF | O E Game | Silkie | Asian Game | Hamburgh | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $8 / 6$ | $0 / 0$ | $0 / 1$ | $1 / 2$ | $0 / 0$ | $0 / 0$ | 9 |
| X-B JF | $0 / 0$ | $8 / 6$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | 8 |
| O E Game | $1 / 1$ | $0 / 0$ | $5 / 4$ | $0 / 0$ | $1 / 1$ | $3 / 4$ | 10 |
| Silkie | $1 / 2$ | $0 / 0$ | $0 / 0$ | $6 / 5$ | $0 / 0$ | $0 / 0$ | 7 |
| Asian Game | $0 / 0$ | $0 / 0$ | $1 / 2$ | $0 / 0$ | $5 / 4$ | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $1 / 1$ | $2 / 2$ | $0 / 0$ | $0 / 1$ | $5 / 4$ | 8 |
| Total | $10 / 9$ | $9 / 7$ | $8 / 10$ | $7 / 7$ | $6 / 6$ | $8 / 9$ | 48 |

Table 30: Confusion matrix for six tibiotarsus ratio combinations before/after cross-validation.

### 5.3.6.2 Archaeological

There were a number of issues with the archaeological data. Only four tibiotarsi from Uley were complete and measureable. Inconsistent practise when collecting the metrics for Lyminge resulted in no distal breadth measurements being taken. Erratic normality tests for the SC measurements suggest that some of these may have been taken in differing planes. These irregularities are due to recorders following Cohen and Serjeantson rather than von den Driesch. Because of these limitations, the assemblages from Uley and Lyminge are not directly comparable with the modern breeds to the same extent as the other elements. Some comparisons were possible by selecting ratios and combinations which did not include either the Bd or SC metrics: these were then also used to plot Uley and Chester ratios. Between-groups PCA and discriminant function analysis was not carried out for Uley or Lyminge. Within these constraints, the combinations which gave the best separation between the groups were Dd/GL and Dip/GL. These describe the depth of the distal articulation and the diameter of the proximal end relative to the greatest length. The Lyminge values are variable (Figure 72) but the majority of the data fall within the same area as the Hamburgh/egg-type scatter, as do the Chester values (Figure 73). The group means for these two assemblages plot in a very similar location. Little can be concluded about the Uley tibiotarsi (Figure 74): the group mean (Appendix D, Section 4.I.3.4) indicates that the four complete specimens have a shallower distal articulation than those from the other two archaeological groups, but how far these are representative of the wider population cannot be ascertained. When the archaeological tibiotarsi are plotted independently using the same ratio combinations (Figure 75) the group means are not dissimilar: the Lyminge points have a wide distribution but with a central cluster while Chester and Uley plot close to this concentration. The narrower distal depth of the Uley tibiotarsi can be more clearly seen.


Figure 72: Modern chicken breeds/types and Lyminge - tibiotarsus. Ratio between Dd and GL plotted against ratio between Dip and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 73: Modern chicken breeds/types and Chester - tibiotarsus. Ratio between Dd and GL plotted against ratio between Dip and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Chester. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 74: Modern chicken breeds/types and Uley - tibiotarsus. Ratio between Dd and GL plotted against ratio between Dip and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 75: Archaeological tibiotarsi. Ratio between Dd and GL plotted against ratio between Dip and GL. Colour key: red - Chester; green - Lyminge; purple - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.

Because of the missing metrics in the Lyminge dataset, between-groups PCA of the three sites and modern material was not attempted.


Figure 76: Discriminant function analysis scatterplot of tibiotarsi from Uley, Lyminge and Chester using available ratio combinations. Colour key: red - Chester; green - Lyminge; purple - Uley.

Discriminant function analysis using ratio combinations of the available metrics produces a scatterplot with distinctive separation, both for the data and the group means (Figure 76), especially on the first axis. $77.08 \%$ of specimens were correctly classified; $66.67 \%$ after cross-validation (Table 31). The classification table is in Appendix D, Section 4.I.6.4.

|  | Chester | Lyminge | Uley | Total |
| :--- | :---: | :---: | :---: | :---: |
| Chester | $9 / 7$ | $2 / 4$ | $1 / 1$ | 12 |
| Lyminge | $7 / 10$ | $25 / 22$ | $0 / 0$ | 32 |
| Uley | $1 / 1$ | $0 / 0$ | $3 / 3$ | 4 |
| Total | $17 / 18$ | $27 / 26$ | $4 / 4$ | 48 |

Table 31: Confusion matrix for archaeological tibiotarsi before/after cross-validation.
However, it is likely that all the Uley tibiotarsi are from cocks and a majority of Lyminge are from hens: the graph could be reflecting differences in sex rather than type. This issue was further addressed using known-sex modern chickens.

## Sex Discrimination

The distribution of the data in the $\mathrm{Bd} / \mathrm{La} v \mathrm{Dip} / \mathrm{La}$ scatterplot for the modern chickens (Figure 67) suggests a within-group division between males and females: the females (circles) tend to plot towards the bottom-right of their breed groups and the males (squares) to the top-left. Mann-Whitney U-tests were performed on all the ratio values to test the group medians which indicated a degree of sexual dimorphism for some ratios (the results for the five ratios with statistical significance are given in Appendix D, Section 4.I.7.2). Discriminant function analysis was performed on the dataset using all five of the significant ratios as independent variables and sex as the dependent grouping variable. The percentage of tibiotarsi correctly classified was $83.33 \%$, reduced to $72.92 \%$ after cross-validation. Thirteen specimens were incorrectly classified including two spurred hens (r663 and r742). The confusion matrix (Table 32) shows the classifications before and after cross-validation. Figure 77 illustrates the relative positions of the correct (grey) and incorrectly classified (red) individuals using the ratios with the lowest $p$-values.

|  | Female | Male | Total |
| :--- | :---: | :---: | :---: |
| Female | $17 / 14$ | $4 / 7$ | 21 |
| Male | $4 / 6$ | $23 / 21$ | 27 |
| Total | $21 / 20$ | $27 / 28$ | 48 |

Table 32: Confusion matrix for DFA of modern chicken tibiotarsi before/after cross-validation.


Figure 77: Modern chickens grouped by sex- tibiotarsus. Ratio between Bd and Dip plotted against ratio between SC and Bd. Squares - male; circles - female. Red specimens are those incorrectly classified when this dataset is subjected to DFA.

While the results of this small study are encouraging, this modern dataset is not the most appropriate to use for comparison with archaeological domestic fowl remains. The analysis should be repeated using metrics from a variety of elements of known-sex Junglefowl, egg-types, Old English Game fowl and other traditional types. If the correct classifications remain high this method could be developed further to help estimate sex-ratios in archaeological assemblages.

### 5.3.7 Tarsometatarsus

### 5.3.7.1 Modern

| Tarsometatarsus |  |  |  |  |  |  |
| :--- | ---: | :--- | :--- | :--- | :--- | ---: |
|  | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| $\mathrm{Bd} / \mathrm{Bp}$ |  | 9 | 8 | 8 | 8 | 9 |
| $\mathrm{SC} / \mathrm{Bd}$ | 9 |  | 8 | 9 | 8 | 7 |
| $\mathrm{SC} / \mathrm{GL}$ | 8 | 8 |  | 11 | 10 | 5 |
| $\mathrm{Bp} / \mathrm{GL}$ | 8 | 9 | 11 |  | 9 | 9 |
| $\mathrm{Bd} / \mathrm{GL}$ | 8 | 8 | 10 | 9 |  | 6 |
| $\mathrm{SC} / \mathrm{Bp}$ | 9 | 7 | 5 | 9 | 6 |  |

Table 33: Modern chicken breeds/types - tarsometatarsus. Number of paired groups (out of a possible 15) distinguishable according to Permanova tests.

Results of the Permanova tests of the paired ratio combinations (Table 33) show that the two most effective ratio combinations were $\mathrm{Bp} / \mathrm{GL}$ and $\mathrm{Bd} / \mathrm{GL} v \mathrm{SC} / \mathrm{GL}$. The weakest ratio combination was $\mathrm{SC} / \mathrm{GL} v \mathrm{SC} / \mathrm{Bp}$, which was only effective in distinguishing Asian Game from the other groups.


Figure 78: Modern chicken breeds/types - tarsometatarsus. Ratio between SC and GL plotted against ratio between Bp and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

In Figure 78, the $x$-axis plots the smallest circumference of the shaft as a percentage of the greatest length. Results for the breed are as expected: the lighter birds have a more slender shaft. It is notable that Silkies again plot with Asian Game, despite the sample being composed entirely of bantam Silkies rather than large fowl. Results for the breadth of the proximal end relative to the greatest length are also on the whole as expected. Hamburghs and Old English Game have a smaller proximal articulation than the heavier breeds but the cross-bred Junglefowl are, as usual, very variable.


Figure 79: Modern chicken breeds/types - tarsometatasus. Ratio between Bd and Bp plotted against ratio between Bd and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie. Refer to tables in Appendix 4.1.3 for accurate group means.

Figure 79 illustrates, on the x -axis, the breadths of the distal articulation relative to the proximal. The mean of all the values for this combination is 100.29 so the tendency is for parity, but the plot highlights the differences between breeds with narrower distal breadths (Silkies) and those where the distal breadth is significantly larger
(Hamburgh/egg-types). While heavier breeds plot to the left and lighter types to the right, the cross-bred Junglefowl cover a broad range and do not cluster with the eggtypes as would be expected: this may be a consequence of the hybridisation within that dataset. The four points in the egg-type scatter which plot to the extreme right were all Spangled Hamburghs, three of them obtained from the same breeder.

The distributions for the breadth of the distal end relative to the greatest length ( $\mathrm{Bd} / \mathrm{GL}$ ) show considerable overlap but generally the lighter breeds have narrower distal ends. It is worth noting that, as for the distal tibiotarsus plot, the Asian Game plot in the middle, indicating a relatively narrow articulation.

## Between Groups PCA

The Between Groups PCA scatterplot of scores and biplot for the first two components (Figure 80 ) confirms the significance of the $\mathrm{Bd} / \mathrm{Bp}$ ratio for separating the Hamburghs and SC/Bd for the Asian Game. The Dorkings and Old English Game are similar.


Figure 80: Modern chicken breeds/types - tarsometatarsus. BGPCA. $1^{\text {st }} \mathrm{PC}=85 \%$ of the variance; $2^{\text {nd }} \mathbf{P C}=$ $10.53 \%$ of the variance. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

Table 34 gives the $p$-values following a Permanova of the first two components which together account for $96 \%$ of the variance. The differences between several of the groups are statistically significant. The Hamburgh/egg-types group is especially distinctive. However, within this group those individuals that plotted the furthest from the origin, both for the paired ratios and the BGPCA analysis, were consistently found to be closely-related Silver-Spangled Hamburghs from the same breeder while the other 'egg-types’ (e.g. Gold-Pencilled Hamburgh and Leghorn) were less distinct from the other groups.

| P-values from Permanova of PC 1 and 2 scores |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 1 5 3}$ | 0.2542 | 0.6864 | $\mathbf{0 . 0 1 3 4}$ | $\mathbf{0 . 0 2 4 6}$ |
|  |  |  |  |  |  |  |
| Hamburgh | $\mathbf{0 . 0 1 5 3}$ |  | $\mathbf{0 . 0 0 8 9}$ | $\mathbf{0 . 0 1 3 0}$ | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 1 9}$ |
| X-B JF | 0.2542 | $\mathbf{0 . 0 0 8 9}$ |  | 0.0563 | 0.0828 | $\mathbf{0 . 0 3 3 4}$ |
| O E Game | 0.6864 | $\mathbf{0 . 0 1 3 0}$ | 0.0563 |  | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 5 6}$ |
| Silkie | $\mathbf{0 . 0 1 3 4}$ | $\mathbf{0 . 0 0 1 5}$ | 0.0828 | $\mathbf{0 . 0 0 1 5}$ |  | 0.1964 |
| Asian Game | $\mathbf{0 . 0 2 4 6}$ | $\mathbf{0 . 0 0 1 9}$ | $\mathbf{0 . 0 3 3 4}$ | $\mathbf{0 . 0 0 5 6}$ | $\mathbf{0 . 1 9 6 4}$ |  |

Table 34: Modern breeds/types - tarsometatarsus: p-values from Permanova of PC1 and PC2 scores.

## Discriminant Function Analysis

The discriminant function analysis correctly classified $54.17 \%$ of the specimens, reduced to $41.67 \%$ after cross-validation. Although the convex hulls (Figure 81) suggest some distinction between the groups the assignation process was not particularly effective (Table 35). Details of individual classifications are in Appendix $D$, Section 4.I.5.5.


Figure 81: Modern chicken breeds/types - tarsometatarsus. Discriminant function analysis plot of all ratios. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie.

|  | Dorking | Hamburgh | Cross-bred <br> Junglefowl | Old English <br> Game | Silkie | Asian <br> Game | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $5 / 5$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | $1 / 1$ | $2 / 2$ | 9 |
| Hamburgh | $1 / 2$ | $5 / 3$ | $1 / 2$ | $1 / 1$ | $0 / 0$ | $0 / 0$ | 8 |
| X-B J-fowl | $0 / 0$ | $1 / 1$ | $3 / 3$ | $3 / 3$ | $1 / 1$ | $0 / 0$ | 8 |
| Old Eng. <br> Game | $1 / 1$ | $0 / 0$ | $3 / 4$ | $4 / 3$ | $0 / 0$ | $2 / 2$ | 10 |
| Silkie | $2 / 2$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $4 / 4$ | $1 / 1$ | 7 |
| Asian <br> Game | $0 / 1$ | $0 / 0$ | $0 / 0$ | $1 / 2$ | $0 / 1$ | $5 / 2$ | 6 |
| Total | $9 / 11$ | $6 / 4$ | $7 / 9$ | $10 / 10$ | $6 / 7$ | $10 / 7$ | 48 |

Table 35: Confusion matrix for all tarsometatarsus ratios before/after cross-validation.

### 5.3.7.2 Archaeological

Tarsometatarsi from the Uley, Lyminge and Chester assemblages were compared by site with tarsometatarsi from the modern breeds using the $\mathrm{SC} / \mathrm{GL} v \mathrm{Bp} / \mathrm{GL}$ ratio combination used earlier for comparing the modern breeds/types. The graphs show that Uley (Figure 82) and Chester (Figure 84) have similar distributions, plotting with the Hamburghs and Old English Game. Lyminge values are more widely spread (Figure 83), covering mostly the cross-bred Junglefowl with some overlap with the Hamburghs and Old English Game. When the three archaeological groups are compared separately from the modern breeds using this same ratio combination, the shape changes underlying these differences can be seen more clearly (Figure 85). On the $y$ axis, a significant proportion of the Lyminge values are above 18.0 (there are no Uley or Chester points in this range) indicating a sizeable proportion of the chickens from Lyminge had broader proximal ends relative to the greatest length than the other two groups. These are the individuals that are mostly outside the convex hulls of the Old English Game and the Hamburghs and plot with the cross-bred Junglefowl. Results for the SC/GL combination show that although Lyminge tarsometatarsi are more widely distributed those that have unusually narrow or broad shaft are few and the majority plot with Lyminge and Chester.


Figure 82: Modern chicken breeds/types and Uley - tarsometatarsus. Ratio between SC and GL plotted against ratio between Bp and GL. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 83: Modern chicken breeds/types and Lyminge - tarsometatarsus. Ratio between SC and GL plotted against ratio between Bp and GL. Colour key: yellow - Asian Game; brown - Dorking; green -
Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 84: Modern chicken breeds/types and Chester - tarsometatarsus. Ratio between SC and GL plotted against ratio between Bp and GL. Colour key: yellow - Asian Game; brown - Dorking; green -Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Chester. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 85: Archaeological tarsometatarsus. Ratio between SC and GL plotted against ratio between Bp and GL. Colour key: red - Chester; green - Lyminge; purple - Uley. Refer to tables in Appendix 4.1.3 for accurate group means.


Figure 86: BGPCA of measurement ratios - tarsometatarsi. Modern chicken breeds with Roman Uley, Saxon Lyminge and Early-modern Chester. Colour key: yellow - Asian Game; brown - Dorking; green -Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley (top), Lyminge (middle), Chester (bottom).

## Between-Groups Principal Component Analysis (BGPCA)

Figure 86 plots a BGPCA of the individual assemblages incorporating all the ratios. The Lyminge tarsometatarsi are by far the most numerous and have the largest variance many from this group plot with the cross-bred Junglefowl. The Uley distribution is rather narrow and overlaps with the more robust modern breeds: Asian Game, Silkie, Dorking as well as some of the cross-bred Junglefowl. The Chester specimens appear to be most like the Old English Game and Hamburghs.

The spurred tarsometatarsi and the profiles from the kernel density study give a reasonable idea of the sex-ratios within each archaeological assemblage. The Uley tarsometatarsi are all spurred and are assumed to be from male birds: the density curves from Lyminge and Chester indicate that the Lyminge assemblage is dominated by hens while the Chester chickens are probably a fairly even mix. As the domestic fowl tarsometatarsus is an element that is sexually dimorphic (based on the results of Mann-Whitney U-tests performed on the median values of the male and female groups using the $\mathrm{Bp} / \mathrm{GL}$ and $\mathrm{Bd} / \mathrm{GL}$ ratios - full results in the Appendix 4.I.7.2), it is possible that biased sex-ratios within the Uley and Lyminge groups are skewing the BGPCA.

## Discriminant Function Analysis

Discriminant function analysis (plot not illustrated) of the three archaeological assemblages using all the ratio combinations was moderately effective, with initial classification being $66.15 \%$ correct reduced to $64.62 \%$ after cross-validation (Table 36), but see the comments above on sexual dimorphism.

The classification table is in Appendix D. Section 4.I.6.5

|  | Uley | Lyminge | Chester | Total |
| :--- | :---: | :---: | :---: | :---: |
| Uley | $6 / 5$ | $2 / 2$ | $0 / 1$ | 8 |
| Lyminge | $2 / 2$ | $33 / 33$ | $13 / 13$ | 48 |
| Chester | $1 / 1$ | $4 / 4$ | $4 / 4$ | 9 |
| Total | $9 / 8$ | $39 / 39$ | $17 / 18$ | 65 |

Table 36: Confusion matrix for DFA of tarsometatarsi from all three archaeological sites before/after crossvalidation.

## Sex Discrimination

The tarsometatarsus is the most obviously sexually-dimorphic element of the chicken skeleton. In addition to the Mann-Whitney statistical tests (Appendix D, Section 4.I.7.3), examination of the point distribution in the $S C / G L \vee B p / G L$ scatterplot (Figure 87) reveals that the females (circles) tend to plot towards the top-left of their breed groups and the males (squares) to the bottom-right.


Figure 87: Modern chickens grouped by sex- tarsometatarsus. Squares - male; circles - female. Ratio between SC and GL plotted against ratio between Bp and GL. Red specimens are those incorrectly classified when this dataset is subjected to DFA.

Discriminant function analysis of this modern dataset using the $\mathrm{SC} / \mathrm{GL}$ and $\mathrm{Bp} / \mathrm{GL}$ ratios as independent variables and sex as the dependent grouping variable produces a correct classification rate of $85.42 \%, 83.33 \%$ after cross-validation (see the confusion matrix: Table 37). Two cocks and five hens were incorrectly classified: one of the cocks ( zOOI ) is a cross-bred Junglefowl and the hens are of heavier breeds. Two of the hens ( h 0 II and r 663 ) are spurred. These individuals are highlighted in red on the $\mathrm{x}-\mathrm{y}$ plot above (Figure 87). The results of the DFA are much as expected and this analysis would be unnecessary for tarsometatarsi exhibiting fused spurs or spur scars which
can normally be confidently classified as male (although some may be female, see Section 2.4). However, as immature tarsometatarsi without these features are often difficult to sex it would be worth assembling a dataset of immature tarsometatarsi (with unfused spurs) from known-sex light breeds and applying the same method. If this proved effective at assigning to the correct sex it may be a useful tool to apply to spurless archaeological tarsometatarsi.

|  | Female | Male | Total |
| :--- | :---: | :---: | :---: |
| Female | $17 / 16$ | $5 / 6$ | 22 |
| Male | $2 / 2$ | $24 / 24$ | 26 |
| Total | $19 / 18$ | $29 / 30$ | 48 |

Table 37: Confusion matrix for DFA of modern chicken tarsometatarsus before/after cross-validation.

### 5.3.8 Comments on results, by element

The results of the measurement ratios results will be considered by element.

### 5.3.8.1 Coracoids

Analysis of the shape-variation of modern breed coracoids showed consistent breedrelated patterns and relationships which also have implications for the archaeological material. During measurement of the modern coracoids it was observed that relatively shorter basal facets often have a greater depth, which seemed to be directly associated with a thicker corpus. This feature could be seen on very stocky types such as Indian Game, whereas in smaller, lighter birds the opposite was the case: the facet seemed more elongated and the corpus flattened. Unfortunately, no standard metrics currently exist to capture the depth of the basal articulation or the depth of the corpus. The complex shape of these features would make accurate measurements difficult to obtain - the margin of the basal facet is not always well-defined and spring callipers with $1 / 100 \mathrm{~mm}$ increments would be necessary to accommodate the hollowed curvature of the corpus on some coracoids - but as the variation seems to correlate with skeletal robusticity and breed/type these additional data would have the potential to help identify selective breeding and type development. However, the $x-y$ plots show that the $B f / B b$ ratio was effective at describing this variation and confirmed that the shape-differences were type-related. In the modern dataset, the heavier breeds generally had a relatively shorter Bf and the lighter breeds a longer Bf. Higher scores for the $\mathrm{Bb} / \mathrm{GL}$ ratio were also associated with stockier types, meaning that chickens
like the Dorkings were more likely to have a broader basal breadth relative to the length of the coracoid. From these results it can be postulated that low scores for the $\mathrm{Bb} / \mathrm{GL}$ ratio and high scores for the $\mathrm{Bf} / \mathrm{Bb}$ are characteristic of a lighter type, more akin to the early domesticated birds than later, more developed types. When these ratios were applied to archaeological material, distinct inter-site variation could be identified between Uley and Fishbourne, strongly suggesting type-differences between these two Roman assemblages (Figure 42) which was borne out by the Mann-Whitney U-tests. The scatterplots for the between-groups PCA of modern types and Fishbourne (Figure 43) confirm the distinctiveness of the Fishbourne coracoids and their position on the far left of the first component axis suggests that, while morphologically they are most similar to the cross-bred Junglefowl they. The eight modern Junglefowl in the dataset are almost certainly hybrids to an unknown degree, and it may be that the Fishbourne chickens would plot closer to pure-bred Junglefowl if these could be obtained. Increasing evidence for the introduction of exotic species at Fishbourne (Section 3.3.7) suggests that these chickens may have been kept as curiosities as much as for any practical purposes.

The coracoids from the three Saxon-period sites show less inter-site variation. The scatterplot for the $\mathrm{Lm} / \mathrm{GL}$ and $\mathrm{Bf} / \mathrm{Bb}$ combination (Figure 44) and examination of plots from all the other combinations (not illustrated) verified that the Coppergate coracoids were less variable than those from Lyminge and Flixborough. Large sample sizes from all three sites ruled out insufficient data as a factor and the results therefore suggest that the Anglo-Scandinavian chickens were less phenotypically (and possibly genetically) diverse group. At present, the underlying factors can only be speculated upon but as the settlement was a lively trading centre, economic and social isolation are unlikely to figure. Forthcoming results from genetic sequencing and isotope analysis of a number of these coracoids may help explain these patterns. The individual between-groups PCA plots for the three Saxon sites reveal a much wider distribution of points compared to the modern breeds. This undoubtedly reflects coracoid shapevariability but the fact that most of the modern chickens have been bred to meet very precise standards may exaggerate the relative diversity of the archaeological coracoids.

### 5.3.8.2 Humerus

Breed-related patterns can also be seen in the modern humeri. This distinguished the lighter-built chickens (cross-bred Junglefowl and Hamburghs) which have narrower proximal and distal ends relative to the greatest length and shaft breadth than the heavier breeds. The archaeological humeri also show this variation but to a much lesser extent - a small change through time can be discerned, with the humeri gradually becoming more robust; however, the progression is less pronounced than it is in the coracoid. The archaeological specimens show a slight chronological change, with the Early-modern humeri a little more like those of modern Dorkings than the more gracile Roman and Saxon humeri. However, the difference is not pronounced and, overall, the results of analyses for both the archaeological and modern humeri suggest that their morphological changes are more subtle when compared with other elements. The underlying reasons for this difference are no doubt complex: the increasing body-weight of domestic fowl is one of the primary pressures on skeletal morphology, increasing the robusticity of the leg bones as they adapt to support the heavier body. However, as chickens generally do not fly far without strong motivation, the wing bones have not been subject to the same loading and this may explain the relatively smaller degree of shape change in the humerus.

### 5.3.8.3 Femur

Results of the Permanova tests presented in Table 22 indicate that breed-related shape variation in the femur is mainly focused on the breadth and depth of the distal end. The ratio combinations that effectively separate the breed groups reveal that the lightly-built chickens have smaller distal and proximal ends relative to the total length of the femur while the heavier chickens are bigger. However, many of the paired ratios did not distinguish any of the breed groups at all, suggesting that some proportions (such as those between the breadth and depth of the distal end and the depth of the distal and breadth of the proximal end) remain consistent between breeds or, more likely because of overlap due to wide shape-variation within the individual groups.

Shape changes over time could not be detected in the archaeological femora: partly because of the broad variation in the Lyminge assemblage. The Chester points plotted in a discrete cluster in both the $x-y$ graphs and the between-group PCA, adding to the evidence for a relatively uniform group of chickens from this site.

Results for this element included the investigation of a small femur from the Lyminge assemblage which had been excluded from the dataset as an outlier and was assumed to be from a bantam. Comparison with other specimens using the measurement ratio method confidently identified this femur as being from a 'creeper' chicken. It is doubtful whether the femur would have been identified without this check: although the characteristic tibiotarsi and tarsometatarsi of creepers can be easily recognised, the effect of the gene is less obvious in proximal limb bones. As this identification brings the total number of creeper chickens from Uley, Chester and Lyminge to at least five, it seems reasonable to assume that the occurrence of this phenotype in past populations is significantly higher than was previously thought and there may be considerably more unidentified creeper chickens in the archaeological record than is currently acknowledged.

### 5.3.8.4 Tibiotarsus and tarsometatarsus

Results for the lower leg bones of both modern breeds and archaeological groups were encouraging. The tibiotarsus was most useful element for distinguishing between modern breeds/types, notwithstanding the issues with missing data and uneven sample sizes: the results for the archaeological tarsometatarsi were also promising.

The metric for the distal end of the tarsometatarsus captures the maximum breadth across the three trochlea; while the trochlea do not articulate with the extra toe in five-toed breeds, it was initially felt that polydactyly might have an indirect effect on the entire joint. However, results from analyses which included measurements from the distal tarsometatarsus did not seem to distinguish five-toed breeds (Figure 79) and a more realistic approach might be to devise a measurement to capture the breadth of the tarsometatarsus at the accessory metatarsal articulation. If a relatively broader measurement at this point was associated with polydactyly, it might help to identify the condition in cases where the accessory metatarsal has not fused to the shaft.

Asian Game were found to have surprisingly narrow distal tibiotarsi and tarsometatarsi, although the proximal diameters relative to the greatest length are relatively broad and compare with Dorkings. A number of factors may be involved, the most obvious being that large Asian Game are phylogenetically distinct from European chickens. However, biomechanics may also be relevant: the Shamo and Malays are tall birds but they are not as heavy as the Dorkings relative to their height. They are also
characterised by a very upright stance whereas the Dorkings have a more crouching posture. Further research including metrics from other 'tall' breeds such as Modern Game and German Langshans may throw some light on this.

### 5.3.8.5 Discussion

When using DFA to classify modern individuals to breed/type groups, the most successful elements were the coracoids and tibiotarsi although correct classification after cross-validation was low ( $52.08 \%$ and $50.00 \%$ respectively) and practical value is questionable. The least distinctive elements were the humeri and tarsometatarsi.

The measurement ratios that are consistently useful are those that combine breadths (or depths) of proximal and distal ends with greatest (or medial/lateral) length measurements. Ratios that included the smallest breadth of the corpus (SC) often failed to distinguish between types and this was particularly the case with femora and tibiotarsi. It may be that the shaft breadth of these elements is not particularly breed/type-related. However, the minimum breadth is not consistently located on the shaft, being sometimes towards the distal end and sometimes nearer the proximal and this also may have influenced the results.

P-values from Mann-Whitney tests of the tibiotarsus and tarsometatarsus ratios indicate a statistically significant difference between male and female. The same procedure applied to the other elements would be advisable to test whether they too show sexual dimorphism.

An unexpected result from this study was the similarity between the Silkies and Asian Gamefowl - in most analyses their bones (coracoids, humeri, femora and tarsometatarsi) showed no statistically significant morphological difference. Although both types originate from East Asia, their appearance is strikingly dissimilar (see Figures 3 and 5), however, there is some evidence to support a link: a phylogenetics study by Komiyama et al (2004) suggested that Japanese ornamental chickens (including Silkies) are genetically very close to Shamo.

Of the archaeological bones, those from Lyminge were the most variable and Chester the least. It was initially anticipated that the Chester coracoids would show more variation than those from the Roman and Saxon sites, reflecting the breed development that was assumed to have been in place by the Early-modern period.

However, the morphological similarity may reflect a move towards specialisation at Chester, suggesting a single population of chickens, of a 'type' if not strictly a breed, supplied by one poultry-breeder and raised especially for the table. By contrast, it was assumed that poultry-keeping at Lyminge might be a more casual affair involving a freerange, scavenging regime and unsupervised breeding, resulting in a more homogenous type. The wide shape-variability in the assemblage was unexpected, but perhaps explained by Lyminge's status as an important estate centre. It is entirely possible that chickens were coming into the centre from the surrounding villages, perhaps sold or maybe tendered as part of rental agreements, and different areas had developed different morphotypes. These results from Lyminge should be compared with data from other central places from the same period.

Of the three main archaeological assemblages, Uley - are the nearest to a 'Bankiva' type, frequently plotting near the Junglefowl, although the coracoids from Fishbourne suggest that these too may have closely resembled a Junglefowl. A change through time can be identified in all five elements for the three main assemblages and is most pronounced in the femur. There is not as much difference between Roman Uley and Saxon Lyminge as might be expected. Factors that may be contributing to this lack of distinction are the wide variation in the Lyminge sample and the probability that most if not all of the Uley chickens are male.

### 5.4 Limb bone proportional lengths

### 5.4.I Introduction

The aim of this study was to investigate whether there are differences in the ratios of greatest length measurements of chicken limb bones and, if so, if these are consistent within breed/type. Data from the small number of archaeological domestic fowl skeletons suitable were incorporated for comparison with the modern chickens. Modern specimens were selected to represent different types and conformation and include both sexes: as well as the Dorkings and Game Fowl mentioned above, the dataset included egg-type Hamburghs and Leghorns which are light Mediterranean breeds; Silkies, which are an ancient, exotic breed from China and cross-bred Junglefowl which are phenotypically close to the ancestral species.

### 5.4.2 Materials and methods

The method for calculating the limb bone indices is described in Section 4.2.6. The hind limb study calculates the greatest length (GL) measurements from the femur, tibiotarsus and tarsometatarsus as proportions of the total length. The carpometacarpi were missing from a number of museum specimens meaning data for a parallel three element analysis for the forelimb would be much reduced. Instead, the Brachial Index (BI) was used which is found by dividing the humerus GL by the ulna GL (Nudds et al 2007; Kaiser 2007: 288-89). Results for the modern groups were tested using Permanova (non-parametric MANOVA).

|  | Dorking | Old <br> English <br> Game | Hamburgh/ <br> egg-type | Silkie | Cross-bred <br> Junglefowl |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Male | 3 | 6 | 5 | 3 | 4 |
| Female | 6 | 4 | $3 / 2$ | 4 | 4 |
| Total | $\mathbf{9}$ | $\mathbf{1 0}$ | $\mathbf{8 / 7}$ | $\mathbf{7}$ | $\mathbf{8}$ |

Table 38: Leg/wing bones relative proportion study. Numbers of individuals from each breed/type included.
Table 38 shows the numbers of modern individuals from each breed/type included in the leg and wing bone studies. Archaeological samples were limited: requirements for confirmed associated bone groups with measurable femur, tibiotarsus and tarsometatarsus present meant that only four skeletons were suitable. These comprised: a chicken skeleton (probably a hen) deposited in a pot recovered from a mid-to-late Iron Age ditch, West Deeping, Lincolnshire, identified as female (Maltby 2005); a skeleton found in a pot from Roman deposits at Driffield Terrace, York (Foster 2012) and two ABGs from the Lyminge assemblage. The sex of the Lyminge chickens is not certain but they were skeletally mature with no spurs and are likely to have been hens.

### 5.4.3 Results

Results are presented as box plots. Each box shows $50 \%$ of the population of each breed, type or species with the central line indicating the median and the tails and whiskers showing the upper and lower $25 \%$. Outliers are marked by circles which mark data points beyond I. 5 times the box height from the box.

### 5.4.3.1 Leg bones

The following three box plots show the results from five modern breeds/types and the four archaeological ABGs.


Figure 88: Box plot showing the femur GL as a percentage of the total GL measurements of the femur, tibiotarsus and tarsometatarsus of five modern chicken breeds and four archaeological ABGs.


Figure 89: Box plot showing the tibiotarsus GL as a percentage of the total GL measurements of the femur, tibiotarsus and tarsometatarsus of five modern chicken breeds and four archaeological ABGs.


Figure 90: Box plot showing the tarsometatarsus GL as a percentage of the total GL measurements of the femur, tibiotarsus and tarsometatarsus of five modern chicken breeds and four archaeological ABGs.

The box plots above (Figures 88 to 90 ) show that the heavier-set Dorkings have a relatively long femur and shorter tarsometatarsus, as do the Silkies although they are the bantam version of the breed. Old English Game and the lighter Hamburghs/eggtypes have a shorter femur and longer tarsometatarsus. The cross-bred Junglefowl measurements, which might be expected to compare with traditional Mediterranean egg-type chickens, have a disappointingly broad range which likely reflects the lack of genetic purity within the sample.

| P-values of pairwise Permanova - modern chickens |  |  |  |  |  |
| :--- | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | RJF | OE Game | Silkie | Hamburgh |
| Dorking |  | 0.0681 | $\mathbf{0 . 0 0 7}$ | 0.6158 | $\mathbf{0 . 0 0 1 1}$ |
| RJF | 0.0681 |  | $\mathbf{0 . 0 2 8 1}$ | 0.1861 | $\mathbf{0 . 0 2 3 4}$ |
| OE Game | $\mathbf{0 . 0 0 7}$ | $\mathbf{0 . 0 2 8 1}$ |  | $\mathbf{0 . 0 0 5}$ | 0.1431 |
| Silkie | 0.6158 | 0.1861 | $\mathbf{0 . 0 0 5}$ |  | $\mathbf{0 . 0 0 1}$ |
| Hamburgh | $\mathbf{0 . 0 0 1 1}$ | $\mathbf{0 . 0 2 3 4}$ | 0.1431 | $\mathbf{0 . 0 0 1}$ |  |

Table 39: P-values of pairwise Permanova test for five modern chicken breeds/types. Leg element GLs.
A Permanova was carried out on the three leg element GLs as percentages of the total length with the modern breeds/types as grouping variables to test the differences
between the groups (Table 39). The null hypothesis is no difference. Statistically significant p -values are in bold type.

The data from the archaeological individuals are too few to produce box plots: the results are depicted as single lines or, in the case of the two Lyminge chickens, a small box. Results for the femur and tarsometatarsus show that the Roman chicken from Driffield Terrace plots closest to the median of the Hamburgh/egg-types. The position of the two Saxon Lyminge hens, which are almost identically proportioned, is shifted towards the more robust types. The Iron Age hen from West Deeping plots between the Roman and Saxon but nearer Lyminge.

### 5.4.3.2 Wing bones

Table 38 shows the numbers from each breed included for the modern wing bones study. The sample numbers are slightly reduced as the ulna was missing for a modern Hamburgh and one of the Lyminge ABGs. Other than these omissions, the individual specimens are the same as for the leg bone study.


Figure 91: Brachial index (humerus GL/ulna GL) of five modern chicken breeds/types and three ABGs.

Figure 91 shows the results from the brachial index calculations. Most of the chickens scored above one meaning that for those individuals the ulna is longer than the humerus. Dorkings have the most variable brachial index and are the only breed to register scores below I. Cross-bred Junglefowl also show a broad variance. Ranges are narrower in Hamburghs and Silkies (excluding the Silkie outlier). The Hamburghs plot surprisingly low on the graph - it was expected that they would contrast with the Dorkings. The highest median score is for the Old English Game

Of the archaeological chickens, Lyminge and West Deeping have a virtually identical brachial index both having a slightly longer ulna than humerus while the Driffield Terrace bones have a lower score and are of almost equal length.

A Permanova test of the indices for the modern chickens with the breeds/types as grouping variables showed that only the differences between the Hamburghs and cross-bred Junglefowl (bold type) were statistically significant (Table 40).

| P-values of pairwise Permanova - modern chickens |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: |
|  | Dorking | RJF | OE Game | Silkie | Hamburgh |
| Dorking |  | 0.0794 | 0.1366 | 0.3744 | 0.9115 |
| RJF | 0.0794 |  | 0.5967 | 0.324 | $\mathbf{0 . 0 2 2 7}$ |
| OE Game | 0.1366 | 0.5967 |  | 0.5603 | 0.0588 |
| Silkie | 0.3744 | 0.324 | 0.5603 |  | 0.183 |
| Hamburgh | 0.9115 | $\mathbf{0 . 0 2 2 7}$ | 0.0588 | 0.183 |  |

Table 40: P-values of pairwise Permanova for five modern chicken breeds/types. Brachial index (humerus/ulna).

### 5.4.4 Discussion

Result of the leg bone indices study show that the Dorkings' short-legged appearance is not solely due to their heavier build and fluffy plumage. While the values for this breed are quite variable, the Dorkings actually do have relatively shorter tarsometatarsi and longer femora, probably associated with greater weight-bearing ability. Silkies also show this characteristic, although the Silkie sample is problematic as the majority of individuals available were very small (probably under 2 kg ) and it is not known to what degree these results would parallel those that might be obtained from full-size birds. Hamburghs/egg-types and Old English Game show the opposite pattern, with shorter femora and longer tarsometatarsi. In the case of the Game Fowl this must be at least partly due to centuries of selection for fighting ability: Atkinson's authoritative guide to the English Game Fowl emphasises the importance of a short
thigh and long shank (Atkinson I89I:I9) but genetics would also be a contributory factor as both the game fowl and the Hamburghs have been developed from Mediterranean types.

As in other analyses in this chapter, the within-group cross-bred Junglefowl morphology was found to be quite disparate, probably as a result of unknown degrees of hybridization. It is also possible that sexual dimorphism influenced the results as Junglefowl and cockfighting breeds are more sexually dimorphic than heavier, modern breeds (Remeš and Szekely 2010). To investigate this, the leg bone data from all the modern chickens was further separated into male and female groups to see if sex was a contributory factor in element proportions but unfortunately there was insufficient data for meaningful analysis and results were inconclusive.

Considering the limitations of the modern and archaeological data, results should be interpreted cautiously. However, it seems clear that the Roman Driffield Terrace cock had relatively longer tarsometatarsi, more akin to the light egg-types and cross-bred Junglefowl, while the Saxon Lyminge hens were proportionally similar to a Dorking. This correspondence does not mean that the hens resembled Dorkings in other respects - they certainly would not have been as heavy - but it does suggest that the skeleton was adapted to carrying more weight as chickens were seen less as exotic curiosities and were being kept for more utilitarian purposes. It is surprising, therefore, that the Iron Age hen from West Deeping is not more like the Roman chicken but sexual dimorphism is an unknown factor and may have affected the results. It is interesting to note that the leg bone proportions from the Lyminge ABGs were virtually identical, hinting at consistency and perhaps the existence of a 'type' within the population. Present phasing places the contexts for both ABG in the $8^{\text {th }}-9^{\text {th }}$ centuries.

Results of the wing bone study were unanticipated and difficult to interpret: of the modern groups, the Dorkings had overall the lowest brachial index (long ulna/short humerus) although the Hamburghs had the lowest median value. As a very general rule, a low BI is associated with greater flying ability whereas flightless birds have a higher BI (Nudds et al 2004). As modern Dorkings are a relatively stocky chicken which do not readily fly this was unexpected. There is nothing to link the three Dorkings with the <I Bl values (relatively longer humeri): two are hens from the same
breeder but others from this source do not have this characteristic. The male Silkie outlier is a museum specimen.

The results for the archaeological samples were also unexpected when compared to the modern breeds. The Lyminge and West Deeping chickens have a virtually identical brachial index both having a slightly longer ulna than humerus while the Driffield Terrace bones have a lower score and are of almost equal length. The brachial index for the Roman chicken is low, being near-parity and closer to the Dorkings than any of the other modern types. The indices for the Iron Age and Saxon chickens are slightly higher but on the whole it is surprising that the archaeological specimens do not show more similarities with the cross-bred Junglefowl or egg-types.

This is the first time this approach has been applied to domestic fowl remains, either modern or archaeological. The method has the potential to provide an insight into changing morphologies due to domestication and selection but there are limitations. Inconsistencies in the brachial index suggest that study of the leg bones may be more worthwhile. The leg bone indices are unable to detect the degree of 'crouch' in the living bird: the angles at the femur/tibiotarsus joint and the tibiotarsus/tarsometatarsus, which obviously have a bearing on the conformation and therefore the 'squat' or 'leggy’ appearance of the chicken. Photographs and radiographs of modern specimens prior to culling would help to address this problem. More data is required from ancient and modern skeletons to expand the study, aid interpretation and strengthen the conclusions of this investigation.

### 5.5 Furcula

### 5.5.1 Introduction

Locomotion and flight requirements seem to correlate with different furcula shapes in some taxonomic groups. Domestic chickens, like their Junglefowl ancestors, are cursorial birds which spend most of their time on the ground and most modern breeds rarely take flight. Larger adults of the heavier breeds like the Cornish/Indian Game and the Buff Orpington do not fly at all, neither do Silkies although this is because of their characteristically fluffy plumage rather than weight. Others, including certain long-tailed Asian breeds and light Mediterranean types, are atypical in this
respect and fly relatively well. An investigation into the shape of the furculae of modern chickens was undertaken to determine whether the angle of the symphysis is correlated with body weight or flying ability in different breeds/types of chicken.

### 5.5.2 Materials and method

Specimens selected for this study are detailed in Appendix B, Section 2.7. A set of metrics designed to capture the shape of the furcula are described in Section 4.2.4. These measure the angle at the symphysis from points $10 \%, 50 \%$ and $100 \%$ of the measured length of the clavicles, from symphysis to tips. A fourth angle measurement is taken at the symphysis 10 mm along the clavicles. For statistical analysis, breeds are grouped into categories depending upon weight and flying ability.

### 5.5.3 Categorising by weight, flight ability and type

The carcass weight of all of the University of Leicester reference specimens was recorded prior to preparation. For some of the other skeletons these data were unavailable and in these cases the unknown weight has been estimated using parameters established for each breed by the Poultry Club of Great Britain (Roberts 2008). These weights were then categorised into one of five groups, from under I kg which comprised mostly bantams to over 4 kg which included the large Asian Gamefowl and the male Dorkings (Table 4I).

| Weight (g) | Category |
| :--- | :---: |
| $0-1000$ | 0 |
| $1001-2000$ | 1 |
| $2001-3000$ | 2 |
| $3001-4000$ | 3 |
| $>4000$ | 4 |

Table 41: Weight categories of modern chickens for furcula study.
A short survey was devised to gather data to enable categorisation of breeds by flying ability. Definitions were devised as per Table 42 and the survey was distributed to experienced poultry keepers and breeders of exhibition and utility fowl, many of whom had donated culled chickens for the skeletal reference collection. The results from this survey and further consultation indicated that the most significant factor affecting flying ability in domestic chickens is weight. However, the deceptively simple premise that lighter breeds are better able to fly than heavier ones is complicated by
other variables including age, sex and inclination. For example, crested Polands, although light in weight, are reluctant to fly as the large feathered crest can severely restrict their sight. Females and young birds of almost all breeds (except those with no flying ability at all, such as Silkies) are more inclined and more able to fly than males and older birds. Strong motivation can include escape from a predator, evading unwanted attention or trying to reach a rival. Flight ability is therefore difficult to define and the following qualitative classification scheme, used in Table 43, can only be a very general guide for mature birds of both sexes.

| Flying ability | Score |
| :--- | :--- |
| Cannot fly at all | 0 |
| Flies a little when motivated but not high or far | I |
| Flies without strong motivation over low fences (~1.5 m) | 2 |
| Can fly high (e.g. into trees) and over relatively long distances | 3 |

Table 42: Definitions and scores to categorise flying ability of modern breed chickens

| Breed | Score | Breed | Score |
| :--- | :--- | :--- | :--- |
| Brahma | I | Old English Game | 2 |
| Dorking | 2 | Poland bantam | I |
| Hamburgh | 3 | Red Junglefowl | 3 |
| Hamburgh bantam | 3 | Rosecomb bantam | 3 |
| Houdan | 2 | Ross broiler | 0 |
| Indian Game | I | Shamo | I |
| Japanese bantam | 2 | Silkie | 0 |
| Lakenvelder | 3 | Spanish | I |
| Leghorn | 3 | Sussex | I |
| Malay | I | Vorwerk | 3 |
| Marans | I |  |  |

Table 43: Chicken breeds scored by flying ability
The specimens were also categorised by type, according to poultry club standards.
The single cross-bred Junglefowl was classified with the bantams and the large number of ornamental crested fowl such as Polands and Sultans were given a category distinct
from 'egg-type'. The weight categories, flying ability scores and type categories can be found in Appendix B, Section 2.7 in the table of modern specimens for this study together with the angle measurements.

### 5.5.4 Results

For initial exploration of the data, Principal Components Analysis was carried out on all of the four measurements which capture the angle at the symphysis to ascertain the most influential. Convex hulls were applied to the scatterplots to examine the data with regard to weight, flight ability and type but these were largely uninformative with the different categories overlapping in a confused fashion. The exception was the position of the Asian Game when the 'type' categories were applied (Figure 92). The five individuals in this category form a distinct detached group confirming the speculation that the furculae of these birds are fundamentally different, not only from other domestic chickens but also Old English Game.


Figure 92: Principal component analysis of four new furcula metrics, grouped by type, with biplot.

| Angle | PC 1 (71.76\%) | PC 2 (16.88\%) | PC 3 (8.38\%) | PC 4 (2.98\%) |
| ---: | ---: | ---: | ---: | ---: |
| $10 \%$ | $\mathbf{0 . 6 7 9 2 4}$ | -0.51211 | 0.42134 | 0.31439 |
| $50 \%$ | 0.31693 | 0.45893 | 0.52598 | -0.64209 |
| $100 \%$ | 0.24509 | 0.72492 | 0.005653 | 0.64373 |
| 10 mm | $\mathbf{0 . 6 1 4 9 1}$ | 0.040218 | -0.73877 | -0.27292 |

Table 44: Loadings for principal component analysis of four new furcula metrics. Percentages of variance per component are also shown.

The biplot in Figure 92 and the loadings table (Table 44) clearly show that, for the first principal component all the metrics are correlated and the two which are the most significant are those which describe the angles measured the shortest distance from the symphysis (bold type). The data from the 10 mm measurements (Appendix $B$, Section 2.7) were selected for further analysis.

Box plots were drawn up to compare the variation in the data using the weight and flight ability categories above. Each box shows $50 \%$ of the population of each breed, type or species with the central line indicating the median and the tails and whiskers showing the upper and lower $25 \%$. Outliers are marked by circles which mark data points beyond I. 5 times the box height from the box.


Figure 93: Symphysis angle ( 10 mm metric) of modern chickens grouped by flight ability.

Using the 'IOmm' measurements and grouping by flight ability produces a plot with little variation across the groups (Figure 93). The median angles of the four categories are very similar (Grp. 0: 73.72; Grp. I: 75.95; Grp. 2: 75.75; Grp. 3: 76.32).

Permanova of the groups (Table 45) showed that the null hypothesis of no difference cannot be rejected.

| Pairwise p-values: flying ability |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: |
|  | 0 | 3 | 1 | 2 |
| 0 |  | 0.1200 | 0.1284 | 0.5372 |
| 3 | 0.1200 |  | 0.8535 | 0.1106 |
| 1 | 0.1284 | 0.8535 |  | 0.0889 |
| 2 | 0.5372 | 0.1106 | 0.0889 |  |

Table 45: P-values of pairwise Permanova of flying ability groups.


Figure 94: Symphysis angle ( 10 mm metric) of modern chickens categorised by weight.
However, when the weight categories are used, a correlation between weight and angle at the symphysis is evident (Figure 94). The median angles of these groups increase as the chickens become heavier, although there is a slight dip at group 3
(Grp. 0: 72.59; Grp. I: 73.90; Grp. 2: 80.89; Grp. 3: 75.95; Grp. 4: 86.82). The higher weight categories are associated with wider angles, so that the clavicles of the chickens in group 4 appear more 'splayed' than those in the lower groups.

Permanova of the groups (Table 46) showed that the null hypothesis of no difference can, in most cases, be rejected. Full summary statistics are in Appendix B, Section 2.7.

| Pairwise p-values: body weight |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0 | 1 | 2 | 3 | 4 |
| 0 |  | $\mathbf{0 . 0 4 2 7}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 0 0 7}$ |
| 1 | $\mathbf{0 . 0 4 2 7}$ |  | $\mathbf{0 . 0 0 5 1}$ | 0.1146 | $\mathbf{0 . 0 0 0 6}$ |
| 2 | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 5 1}$ |  | 0.2649 | $\mathbf{0 . 0 2 1 8}$ |
| 3 | $\mathbf{0 . 0 0 1 7}$ | 0.1146 | 0.2649 |  | $\mathbf{0 . 0 0 7 1}$ |
| 4 | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 2 1 8}$ | $\mathbf{0 . 0 0 7 1}$ |  |

Table 46: P-values of pairwise Permanova of body weight groups

### 5.5.5 Discussion

Principal component analysis of the different types shows that the Asian Game furculae are undoubtedly morphologically distinct from all European types and even other Asian soft feather breeds like the Brahma. Identification of this type of furcula in postmedieval deposits, especially around the south-west ports where the Asian Game breeds such as Malays were said to have been first introduced (Tegetmeier 1856: 65-6; Scrivener 2009: 92), would be interesting.

There does not appear to be a connection between flight-ability and furcula morphology. There may be several reasons for this: the categories devised for this study may be too broad to account for the variability in the sample and it is likely that other factors such as age, sex and inclination are significant. A revised sample set using a smaller number of more distinct categories (for example, light Mediterranean v. heavier Asian soft-feather) and an increased number of furculae might return more informative results. There does, however, seem to be a correlation between angle at the symphysis and body weight (which is also related to age and sex). The splayed clavicles may be an adaptation to the increased size of pectoral muscles that is strongly associated with weight gain in most breeds.

It is fortunate that the measurement most likely to be applied to fragmented archaeological material has been identified as one of the most effective for distinguishing between the weight groups. More data from chickens of known breed,
sex and cull-weight are needed to confirm or disprove the connection and develop the reliability of the method. Measurements from complete archaeological furculae for comparison would be ideal but as the most promising results are from the metric designed for fragmented remains complete elements are not imperative. The method has the potential to inform on a different aspect of the changing morphology of domestic chickens as a part of breed development.

### 5.6 Sex discrimination using the pelvis

### 5.6.1 Introduction

A small study was carried out using modern domestic fowl pelves of known sex to ascertain whether consistent sex-related shape differences existed in this element. No previous biometrical analysis has been carried out with this intention, probably because most archaeological chicken pelves are from immature birds and often recovered unfused or otherwise fragmented. Consequently, they have not been regarded as valuable when estimating sex-ratios within domestic fowl assemblages (more fully discussed in Section 3.5.2). It was felt, however, that if the areas of most variation could be identified this would provide a foundation for developing a simpler method of discrimination using a reduced suite of metrics more appropriate to archaeological material.

### 5.6.2 Materials and method

Metrics from 38 known-sex modern pelves were used for this study. Most of the specimens included were from the University of Leicester's comparative reference collection, these were supplemented by modern but unimproved chickens from Tigray, Ethiopia (ARCCH - Authority for Research and Conservation of Cultural Heritage). Details of the individual specimens are given in Appendix B, Section 2.6. The measurements used were the eight described by von den Driesch (1976:122-I24) (AA, BA, CB, DiA, GL, LS, LV and SB) together with the two newly developed measurements: the breadth between the extreme points of the two spinae dorsolateralis ilii (termed 'Bsdi') and the breadth between the processus terminalis ischii ('Bpti') illustrated in Section 4.2.4.

Raw metrics were normally distributed with the exception of the Bpti data, so for statistical analysis, all metrics were log-transformed (Log IO) to normalise distributions and exported to PAST. Specimens were assigned to one of two known groups, male (n.22) and female (n. 16). Discriminant function analysis was used to predict group membership and results were cross-validated by a leave-one-out jack-knifing procedure. Eigenvalues are given - these provide an indication of how well the characteristic root of each function differentiates the groups: the larger the value the more effective the process. Statistical significance between groups was assessed using Multivariate Analysis of Variance (MANOVA).

### 5.6.3 Results

Three variations of the test were undertaken using different combinations of the metrics. A Discriminant Function Analysis was carried out for each, with the confusion matrix and relevant loadings given. P-values from MANOVA tests are included - the full results for each MANOVA are given in Appendix B, Section 2.6.I. For all three of the analyses, the F -value was smaller than calculated F -statistic meaning the null hypothesis of no difference could be rejected.

## Metrics Group A

As archaeological avian pelves rarely survive intact and instances where the full suite of measurements can be taken are exceptional, the first analysis was carried out using different combinations of the most commonly available metrics. Many archaeological pelves are detached from the vertebrae, either through incomplete fusion or breakage, so in most cases a transverse measurement is not possible. The measurements considered to be most frequently available were: LV; DiA; LS; and GL. The breadth across the partes glutea (SB) was also included as this can often be taken in partly-fused specimens. Using this reduced set of measurements, discriminant function analysis correctly classified $78.95 \%$ of the pelves, $68.42 \%$ after cross-validation (Table 47).

|  | Female | Male | Total |
| :---: | :---: | :---: | :---: |
| Female | $12 / 9$ | $4 / 7$ | 16 |
| Male | $4 / 5$ | $18 / 17$ | 22 |
| Total | $16 / 14$ | $22 / 24$ | 38 |

Table 47: Confusion matrix for reduced set of pelvis measurements (Metrics Group A) before/after crossvalidation.

Eigenvalue $=0.68309$

Loadings show that the most significant measurements for distinguishing the sexes are LS and GL (Table 48).

| Measurement | Loading | Measurement | Loading |
| :---: | :---: | :---: | :---: |
| LS | -0.021369 | LV | -0.016654 |
| GL | -0.020429 | SB | 0.0038552 |
| DiA | -0.017606 |  |  |

Table 48: Loadings for the pelvis measurements following DFA of Metrics Group A
MANOVA test p-value: $0.0038^{* *}$

## Metrics Group B

Following inclusion of the remaining standard measurements (CB; AA; and BA), discriminant function analysis correctly classified $94.74 \%$ of the pelves, $73.68 \%$ after cross-validation (Table 49).

|  | Female | Male | Total |
| :---: | :---: | :---: | :---: |
| Female | $15 / \mathrm{II}$ | $1 / 5$ | 16 |
| Male | $1 / 5$ | $2 \mathrm{I} / \mathrm{I7}$ | 22 |
| Total | 16 | 22 | 38 |

Table 49: Confusion matrix for all standard v. d. Driesch pelvis measurements (Metrics Group B) before/after cross-validation.

Eigenvalue $=1.725 \mathrm{I}$
Loadings show the CB measurements make a significant contribution with the $A A$ and BA metrics carrying considerably less weight (Table 50).

| Measurement | Loading | Measurement | Loading |
| :---: | :---: | :---: | :---: |
| LS | 0.013447 | LV | 0.01048 |
| GL | 0.012855 | BA | -0.00004 |
| CB | 0.012412 | SB | -0.002426 |
| DiA | 0.011079 | AA | -0.0028399 |

Table 50: Loadings for the pelvis measurements following DFA of Metrics Group B
MANOVA test p-value: 0.000 I $^{* * *}$

## Metrics Group C

Discriminant function analysis after inclusion of the two new metrics produced a more successful result. $100 \%$ of the pelves were correctly classified, with $86.84 \%$ correctly classified after cross-validation (Table 5I).

|  | Female | Male | Total |
| :---: | :---: | :---: | :---: |
| Female | $16 / 13$ | $0 / 3$ | 16 |
| Male | $0 / 2$ | $22 / 20$ | 22 |
| Total | $16 / 15$ | $22 / 23$ | 38 |

Table 51: Confusion matrix for pelvis measurements including new metrics (Metrics Group C) before/after cross-validation.

Eigenvalue $=2.5795$
Loadings (Table 52) indicate that the newly devised transverse measurements spanning the caudal end of the pelvis are not only the most significant for determining sex but are considerably more reliable, especially when used in conjunction with the standard measurements.

| Measurement | Loading | Measurement | Loading |
| :---: | :---: | :---: | :---: |
| LS | -0.011 | BA | -0.0004 |
| GL | -0.0105 I | SB | 0.001984 |
| CB | -0.01015 | AA | 0.002322 |
| DiA | -0.00906 | Bpti | 0.020772 |
| LV | -0.00857 | Bsdi | 0.022686 |

Table 52: Loadings for the pelvis measurements following DFA of Metrics Group C
MANOVA test $p$-value: $0.00003^{* * *}$

The classifications for the discriminant analysis of the full suite of measurements show that after cross-validation the individuals incorrectly classified were a four-year-old male Poland bantam (r655), an II-month-old female Vorwerk (r665) a 27-month old Dorking hen (r723) and two Ethiopian unimproved ecotypes dI78 (female) and dI66 (male), both over two years old.

### 5.6.4 Discussion

The results of the analysis show that including the new metrics significantly improves the classification of modern chicken pelves according to sex. Reasons for incorrect

DFA classification when the full suite of measurements is used can only be speculated upon at this stage and it is unknown whether biological sexual ambiguity was a factor. Of the British chickens the Vorwerk, although young, was in regular egg production, as was the mature Dorking hen, and neither were spurred. The donor did not give a reason for culling the Poland bantam cock beyond stock management but the plumage, spurs and other physical male characteristics seemed normal during preparation. It is unlikely that an infertile male bird would have been kept for four years in a managed exhibition flock where regular culls are the norm, although it is possible that the bird's fertility was in decline. Neither of the Ethiopian chickens showed any physical signs of sexual ambiguity.

Breadths between both the spinae dorsolateralis ilii and the processus terminalis ischia appear to be diagnostically important in distinguishing male and female chicken pelves and should be considered if a discriminatory test more appropriate for archaeological material is devised. Despite the limitations associated with fragmented remains, it may be possible to gather useful data. For example, one way to capture the variation in unfused specimens might be to verify the line of fusion with the synsacrum and measure orthogonally from that line to the points of the spinae dorsolateralis ilii and the processus terminalis ischia. This would probably be best achieved using digital photographs of each pelvis and an image processing program such as tpsDig2 (Rohlf 2013) or ImageJ (Rasband 1997).

These results are very promising, but the sample included pelves of exhibition breeds, some of which may have more pronounced morphology due to selective breeding. More samples of unimproved types are needed to refine the technique, together with complete archaeological specimens to include in future analyses.

## 6 GMM Results

## 6.I Introduction

This chapter presents the results from the Geometric Morphometric analyses. In Section 6.2, an initial measurement error study was carried out to ensure that the measurement error introduced during photography and digitisation is less than the difference between specimens.

Sections 6.2 to 6.6 present the results from individual elements (coracoid, humerus, tibiotarsus and tarsometatarsus) using the landmark data from all modern and archaeological specimens including those with pronounced morphologies such as creepers. Procrustes superimposition, covariance matrix generation and principal component analysis of the complete databases for each element were carried out in MorphoJ. Colour-coded plots of the principal component scores enabled examination of group and individual relationships and outline graphs showed the associated shape changes. For the humerus and tarsometatarsus, a series of scatterplots illustrate the difference between selected breeds/types. The datasets were then refined to focus upon the breeds most relevant to the study. For each reduced dataset, a new GPA was performed and the Procrustes coordinates exported to Past for statistical analysis. For these analyses, the modern and archaeological datasets were matched as closely as possible to those constructed for the measurement ratios study (any differences are due mostly to incomplete disarticulation of museum specimens, slight damage to the bones or ambiguous anatomical features which meant they could be measured accurately but were not suitable for GMM). Between-groups PCA allowed examination of the group-relationships avoiding the problems caused by unequal group numbers and small sample sizes. Loadings for the $x-y$ coordinates for each landmark were combined to reveal the landmarks/areas with the most significant shapechanges.Initial results from discriminant function analysis (DFA) were disappointing because of the high numbers of variables compared with relatively few specimens overfitting resulted in initial classifications being typically as high as $90 \%$, reduced to just 20 or $30 \%$ after cross-validation. However, by carrying out the DFA using the scores from a reduced set of principal components rather than the entire set of Procrustes coordinates, the classification rate was improved. The PCs which explained
$90 \%$ of the variance were subjected to DFA and then gradually reduced in number to arrive at the optimum classification and cross-validation percentages. The number or proportion of PCs used is therefore not standardised but tailored to each analysis.

Finally, an attempt was made to classify archaeological chicken bones to type, using discriminant function analysis. The coracoid was chosen because the specimens available were relatively numerous and represented several different chronologies and site types. For many of the specimens, it will be possible to cross-reference the results with data from DNA and isotope analysis.

### 6.2 Measurement error pilot study

### 6.2.1 Introduction

The process of gathering landmark coordinate data will, to some extent, be associated with a degree of unavoidable measurement error, the effect of which is less significant the larger the morphological variation within a sample. Several factors can introduce variation and contribute to error, among them are:

- Preparation of specimens, which is more of a problem with soft tissues (Martinez et al 2013);
- Distortion of the image due to a low-quality or unsuitable camera lens - for example barrel-distortion which is particularly associated with wide-angle lenses (Janin 2015);
- Distortion of the image due to parallax - the effect of viewing a 3D object at differing oblique angles;
- Difficulty identifying landmarks due to biological ambiguity, unclear or badlyilluminated images;
- Incorrectly placed landmarks - this is more of an issue when more than one person is digitising the same dataset.

The effects of these factors can be offset to an extent by:

- Careful preparation of specimens;
- Eliminating distortion by setting the focal length of the lens to 35 mm or over and checking for distortion by taking an image of a rectangular grid (Figure 95 below);
- Consistent positioning of the specimens and the use of a dual spirit level to ensure orthogonality of the lens to the specimen;
- Maximising clarity of images with image processing software;
- Frequent reference to full and accurate descriptions of the landmarks during digitisation.


Figure 95: Minimised distortion: image taken with Nikon D60 digital SLR equipped with a Nikon AF-S DX Zoom-Nikkor 18-55mm f 3.5-5.6G lens

Despite these precautions, error cannot be completely removed and should be calculated before beginning analysis. Various recommendations for quantifying and addressing the problem have been developed (Arnqvist and Mårtensson 1998; von Cramon-Taubadel et al 2007; Fruciano 2016; Viscosi and Cardini 201I; Webster and Sheets 2010) all based on repetition of procedure and calculating the range of variation. For example, Webster and Sheets (20I0) propose repeated cleaning, mounting and photographing of the same specimen ten times to assess the margin of error. This study will use a combination of these recommendations together with unpublished guidelines by Klingenberg (2014).

### 6.2.2 Materials and Method

The modern and archaeological data gathered for the study represents a large assemblage of elements from over 160 modern chickens and non-chicken Galliformes, together with several hundred archaeological specimens. Including all of these in the measurement error study would be time-consuming so for practical purposes a subsample of representative specimens was chosen from the modern reference collection, to include males and females and a wide range of different species, breeds, ages and extremes of size. Table 53 lists the specimens: additional information on each can be found in Appendix A, Sections I.I and I.2.

| Specimen | Sex | ID | GMM no | Hum | Cor |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Black grouse | male | bgm | BI759 | y | y |
| Brahma | female | brf | a005 | $y$ | y |
| Crested rumpless Turkish | unknown | crx | t040 | $y$ |  |
| Dorking | female | dkf | r724 | $y$ | y |
| Hamburgh bantam | female | hbf | r729 | $y$ | $y$ |
| Hamburgh bantam | male | hbm | r731 | $y$ | y |
| Hamburgh | female | hmf | r742 | $y$ | y |
| Hamburgh | male | hmm | r736 | y | y |
| Indian Game | female | igf | r726 | $y$ | y |
| Japanese bantam | male | jbm | r652 | $y$ | $y$ |
| Lakenvelder | male | lam | r659 | y | y |
| Oxford Game | male | ogm | r732 | $y$ |  |
| Poland bantam | male | pbm | a001 | y | y |
| Pheasant | male | phm | a004 | $y$ | $y$ |
| Shamo | male | shm | r658 | y | y |
| Silkie | female | sif | r661 | y | y |
| Silkie | male | sim | r666 | $y$ | $y$ |

Table 53: Specimens included in the measurement error study
The software used was downloaded from the Department of Ecology and Evolution, State University of New York, Stony Brook, NY. and Klingenberg Lab, University of Manchester. Image capture was carried out with the same equipment and methods used for the main study, detailed in Section 4.I.3.8. For each element, a tpsUtil (Rohlf
2013) file was compiled comprising a selection of representative specimens (to assess individual effect), two replicated images of each specimen (to assess imaging error) and replicates of each of those images (to assess digitising error). The file thus contained four images for each specimen. The three-letter breed/species identifiers were augmented with codes for image and replica to make classifier variables specifying the effects for the Procrustes ANOVA. For example, the four images of the male black grouse humerus were labelled bgm I_I; bgm I_2; bgm2_I and bgm2_2, indicating first image/first replica; first image/second replica; second image/first replica and second image/second replica respectively.

Landmarks (defined in Sections 4.I.4.I and 4.I.4.2) were digitised on all images using tpsDig (Rohlf 2013). Procrustes distances and tangent distances were computed in tpsSmall (Rohlf 2015): this program was developed to determine whether the amount of shape variation is small enough to permit statistical analyses to be performed in the linear tangent space which approximates to non-linear Kendall's shape space (for an explanation of Kendall's shape space see Section 4.3.I). General Procrustes Analysis (GPA) and Principal Components Analysis (PCA) were performed using MorphoJ (Klingenberg 201I) and used to check the distance between the replicas in relation to the distance between the specimens. A Procrustes ANOVA (analysis of variance) was then applied to calculate random variation at multiple levels of error, in this case variation due to biological interest, error introduced by image capture and then further error during digitisation. Centroid size and shape were analysed separately.

### 6.2.3 Results - Humeri

## Tangent space approximation of Kendall's shape space

The shape variation between linear tangent space and Kendall shape space was computed using tpsSmall. The resulting plot (Figure 96) of tangent distances ( $y$-axis) $v$ Procrustes distances ( $x$-axis) shows a linear relationship of the points on the regression line indicating that, as expected, shape variation is very small and the projection of shape coordinates in tangent shape space is good enough for further statistical analysis.

The slope of the Euclidean distances in the tangent space onto Procrustes shape distances in the curved Procrustes shape space was 0.999569 .

Correlation: $\mathrm{P}=1.000000$


Figure 96: Tangent distances v Procrustes distances for humeri
The mean and maximum Procrustes shape distances to the sample mean shape were 0.025489 and 0.075 I 29 units of Procrustes shape distance, which is an excellent approximation and well within Klingenberg's recommended maximum of 0.2 units (Klingenberg 2014).

## Principal Component Analysis

Carrying out a Procrustes fit and calculating the first two principal components of the same file in MorphoJ shows the specimens and their replicas in clusters of four datapoints, each point representing a configuration of landmarks.


Figure 97: PC1 v PC2 of the humeri and their replicas.

The scatterplot (Figure 97) illustrates the variability in the data after principal component analysis. The first two principal components accounted for $72 \%$ of the variance in this dataset: this high percentage is explained by the inclusion of the considerably stouter Japanese Bantam humerus which is plotted at the far left of the graph. The red dots indicate the first image of each specimen and its replica; the blue dots are the second images and replicas. The variation between replicas is considerably less than the variation between specimens, indicating that the variance caused by imaging and landmarking error is much smaller than the biological variation. The specimen towards the bottom of the graph (circled) shows rather more separation between the first two replicas and the second - examination of the four images showed that the second photograph was slightly blurred, demonstrating the importance of sharp focusing.

## Procrustes ANOVA

Results for centroid size and shape for the humeri are presented in Table 54. Results for the two-factor ANOVA for centroid size show a very large F-value for specimens (calculated by dividing the mean squares of the specimens by the mean squares of imaging error). This is to be expected as the range of sizes in the humeri dataset is very wide. However, for the two lowest levels the F-value is only 3.95 , indicating that although imaging error is approximately four times larger than digitising error, both are insignificant when compared to the difference due to biological variance.

| Centroid size |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :--- |
| Effect | SS | MS | df | F | P (param) |
| Specimens | 67921.9 | 4528.13 | 15 | 22690.40 | $<.000 \mathrm{I}$ |
| Imaging | 3.19298 | 0.19956 | 16 | 3.95 | 0.0005 |
| Digitising | 1.61859 | 0.05058 | 32 |  |  |
| Shape Procrustes ANOVA |  |  |  |  |  |
| Effect | SS | MS | df | F | P (param) |
| Specimens | 0.05386 | $9 \mathrm{E}-05$ | 600 | 123.74 | $<.000 \mathrm{I}$ |
| Imaging | 0.00046 | $7.3 \mathrm{E}-07$ | 640 | 13.93 | $<.000 \mathrm{I}$ |
| Digitising | $6.7 \mathrm{E}-05$ | $5.2 \mathrm{E}-08$ | 1280 |  |  |

Table 54: Centroid size and shape following Procrustes ANOVA on the humeri

The results for shape variance are calculated in a similar way. Because shape has been discounted as part of the General Procrustes Analysis, the differences between the specimen variation and the imaging and digitising error are less extreme. The F-values show that biological variation is still considerably larger than error in the lower two levels.

### 6.2.4 Results - Coracoids

Tangent space approximation of Kendall's shape space
The same procedure was repeated to check for shape variation between linear tangent space and Kendall shape space for the coracoid file. The linear relationship of points on the regression line (Figure 98) of tangent distances ( $y$ axis) v Procrustes distances ( $x$ axis) shows that shape variation is small and will not affect statistical analysis.


Figure 98: Tangent distance v Procrustes distance for coracoids digitisation error
The slope is 0.998854 (regression coefficient for the regression through the origin of the tangent distance on to the Procrustes distance).

Correlation: $\mathrm{P}=1.000000$

The mean and maximum Procrustes shape distances to the sample mean shape were within 0.2 units, being 0.036258 and 0.118469 respectively.

## Principal Component Analysis - coracoids

Using the same data, the scatterplot (Figure 99) of the first two principal components for the coracoids dataset shows that, although the specimens and replicas are not so
tightly clustered as the humeri they are still clearly defined and the variation between replicas is less than the variation between specimens.


Figure 99: PC1 v PC2 of the coracoids and their replicas.
The first two principal components explain $49.97 \%$ of the variance in the dataset. The points are clustered in groups of four (two red, two blue), showing that variation between replicas is less than that between specimens. Although the specimens are grouped, they are slightly more scattered than the humeri. On explanation for this may be positioning inconsistencies - the coracoid does not have the inherent stability of the humerus.

## Procrustes ANOVA coracoids

Results for the centroid size (Table 55) again show a large F-value for specimens with a much smaller F -value of 3.55 for the difference between imaging and digitising.

The F-values for shape variance show that error due to biological variation is still significantly larger than error in the lower two levels.

| Centroid size |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :--- |
| Effect | SS | MS | df | F | P (param) |
| Specimens | 22230.5 | 1590.18 | 14 | 16582.70 | $<.000 \mathrm{I}$ |
| Imaging | I .4384 I | 0.09589 | 15 | 3.55 | 0.00 I 5 |
| Digitising | 0.80986 | 0.027 | 30 |  |  |
| Shape Procrustes ANOVA |  |  |  |  |  |
| Effect | SS | MS | df | F | P (param) |
| Specimens | 0.05688 | I.69E-04 | 336 | 65.99 | $<.000 \mathrm{I}$ |
| Imaging | 0.00092 | $2.57 \mathrm{E}-06$ | 360 | 4.13 | $<.000 \mathrm{I}$ |
| Digitising | 0.00045 | $6.2 \mathrm{IE}-07$ | 720 |  |  |

Table 55: Centroid size and shape following Procrustes ANOVA on the coracoids.

### 6.2.5 Conclusion

For both the humeri and coracoids, the approximation of Kendall's shape space to tangent space is sufficiently robust to permit statistical analysis.

Scatterplots of the first two principal components showed a limited degree of error in the imaging and digitisation process for both the humeri and coracoid datasets, but the variation this caused was insignificant in comparison to natural biological shape variation between specimens. Results from the Procrustes ANOVA confirmed that Fvalues of biological variation were much higher than those from operator induced error.

Apart from small inconsistencies during landmark placement, the measurement error study suggested two other factors as possible sources of error: unfocused images and variable presentation of the specimens to the camera lens, which highlight the importance of uniformity during the imaging process. On the whole though, operator errors within the proposed methodology were small compared to the natural variation within the sample and, if care is taken regarding camera focusing and object placement, revision of the proposed methodology is considered to be unnecessary.

### 6.3 Coracoids

### 6.3.1 Modern breeds - complete dataset

First, an exploration of the complete modern breed dataset was carried out (sample size $\mathrm{n}=83$ ). A GPA (Generalised Procrustes Analysis) was performed on the raw data coordinates, a covariance matrix generated and a PCA (Principal Components Analysis) requested. The percentages of variance for the first five principal components are presented in Table 56 (The complete table is in Appendix E, Section 5.I.I). The cumulative percentage of variance shows that almost two-thirds of the variance within the sample can be described by the first four principal components.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :--- | :--- | :--- | :--- |
| I | 0.00027255 | 29.363 | 29.363 |
| 2 | 0.00013649 | 14.704 | 44.067 |
| 3 | 0.00011825 | 12.74 | 56.806 |
| 4 | 0.0000826 | 8.899 | 65.705 |
| 5 | 0.00005885 | 6.341 | 72.046 |

Table 56: All modern chicken breeds - coracoids. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components


Figure 100: All modern chicken breeds - coracoids. Scatterplot of scores from principal components $1(29 \%$ of the variance) and 2 ( $15 \%$ of the variance). Colour key: Asian Game - orange; Creepers - purple; Crested - blue; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink; misc. - grey.

The scatterplot for the first two principal components (Figure 100) revealed some groupings which seemed to be related to breed and type. For the first component, which explains $29 \%$ of the variance, the coracoids with positive scores which plot to the right of the graph tend to be the lighter types such as crested Poland bantams (blue), cross-bred Junglefowl (light-blue) and Hamburgh/egg-types (green). Those to the left are predominantly heavier types like Asian Game (orange) and Dorkings (brown), together with the Silkies (pink). The greyed individuals not grouped by type also follow this pattern, on the right are various bantams and light breeds; on the left are modern broilers, Marans, a Buff Orpington and other large fowl. Old English Game (red) mostly plot around the mean but with some trending more towards the heavier fowl. The scatterplot shows the Japanese Bantams (purple) positioned on the extreme left of the PCI axis. The only other creeper coracoid included in this dataset is from the Scots Dumpy (e005) which plots near to the average on both the PCI and PC2 axes but is obscured by the green point of one of the Hamburghs. Notwithstanding the small sample size for creepers, this suggests that the creeper gene may express itself in a shape change to the coracoid in some breeds but these effects may not be consistent across all breeds that carry the gene. Differences between breeds/types are not as pronounced for the second component, responsible for $15 \%$ of the variance, although some distinction can be seen between the Polands and Junglefowl which tend to group towards the top.

The shape changes for principal components I and 2 are illustrated in Figure IOI, exaggerated by a scale of $-0.1 / 0$.I for ease of interpretation (subsequent scale factors will be $-0.05 / 0.05)$. The scale factor relates directly to the scores on the axes, either side of the mean, and is therefore an indication of the extent of the exaggeration. The light blue outline represents the mean shape and the dark blue shows, on the right, the positive deviation from that mean and, on the left, the negative deviation. It should be remembered that all landmark shifts are relative to other landmarks in the configuration. The first component relates to the breadth of the corpus including a significant compression of the lateral process (landmark 4). Principal component 2 is characterised by changes to the 'hook' (processus acrocoracoideus) (landmarks 9, I0, II and I2), a shift of the lateral process towards the basal articulation and a reduction of the medial angle (landmark I). A slight lateral curvature of the body is also suggested (landmarks 6 and 14).


Figure 101: All modern chicken breeds - coracoids. Outline graphs showing shape changes for $1^{\text {st }}$ and $2^{\text {nd }}$ principal components. Scale factor $=\mathbf{- 0 . 1}$ (left) and 0.1 (right).

Principal component analysis of the complete dataset reveals that the lighter breeds and bantams have much more slender coracoids whilst in the heavier breeds such as Asian Game, Dorkings and modern broilers the coracoid is more robust. The shape change for the second component is more complex and there seems to be little association between this change and the types of chicken. The cross-bred Junglefowl and most of the Polands trend towards the positive end of the axis, reflecting the change seen in the bottom-right diagram (Figure IOI), while the remaining groups plot mostly negatively of the mean, suggesting a light/heavy distribution. However, the greyed datapoints (representing miscellaneous individuals which are not identified on the graph) are evenly scattered and do not follow this pattern.

### 6.3.2 Modern breeds/types - reduced dataset

The dataset was reduced to match, as closely as possible, that used for the measurement ratios and subjected to between-groups principal component analysis.


Figure 102: Modern breeds/types - coracoids. Scatterplot of PCs $1(28 \%$ of the variance) and $2(16 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Percentages of variance for the principal components are given in Appendix E, Section 5.I.2. Figure 102 plots the scores for the first two components and shows clearly that the shape change associated with PCI (which is almost identical to that seen in Figure IOI) is significant in separating the lighter breeds with the positive scores from the heaver ones with negative scores. The PC2 shape changes are different from the previous analysis and are illustrated in Figure I03. This component does not separate the heavier types as effectively, although the Hamburghs and cross-bred Junglefowl do form discrete clusters on this axis.


Figure 103: Modern breeds/types - coracoids. Outline graphs showing shape changes for the $2^{\text {nd }}$ principal component. Scale factor $=0.05$ (left) and -0.05 (right).

## Discriminant Function Analysis

To overcome the problem of overfitting due to the number of variables (see Section 4.3.6), the first 10 principal components were used for the discriminant function analysis. The first two axes are illustrated in Figure 104.

The biplot shows that the most significant shape-change that distinguishes the crossbred Junglefowl is PCI, which accounted for $27.81 \%$ of the variance in the original PCA of this breeds/types dataset. This relates to the breadth of the corpus - narrow in the Junglefowl and robust in the Asian Game, and is the same shape change that was seen in the analysis of the complete dataset (Figure I02). PC2 (Figure I03), representing $16 \%$ of the variance, is significant for some of the Dorkings and rather less so for the Silkies and relates mainly to the changes seen at the sternal end, especially shifts in the location of the medial angle (landmark I) and lateral process (landmark 4). Running the DFA on 10 principal components resulted in $82.05 \%$ of the specimens being correctly classified, reduced to $48.72 \%$ after cross-validation. The confusion matrix for this DFA showing correct classifications before and after cross-
validation is presented in Table 57: the classifications can be found in Appendix E, Section 5.I.3.


Figure 104: Modern breeds/types: DFA of first 10 PCs. Axis 1 accounts for $66 \%$ of the variance, Axis 2 for $16 \%$ of the variance. Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

|  | Dorking | Hamburgh | X-B J-fowl | OEG | Silkie | Asian G | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $5 / 4$ | $1 / 1$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $6 / 2$ | $0 / 1$ | $1 / 4$ | $0 / 0$ | $0 / 0$ | 7 |
| X-B J-fowl | $0 / 0$ | $0 / 0$ | $6 / 5$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 6 |
| O E Game | $0 / 0$ | $2 / 5$ | $0 / 0$ | $5 / 2$ | $1 / 1$ | $1 / 1$ | 9 |
| Silkie | $1 / 2$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 4$ | $0 / 1$ | 7 |
| Asian Game | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $4 / 2$ | 4 |
| Total | $6 / 7$ | $9 / 8$ | $6 / 6$ | $6 / 8$ | $7 / 6$ | $5 / 4$ | 39 |

Table 57: Modern breeds/types - DFA of first 10 PCs. Confusion matrix before/after cross-validation.


Figure 105: Between-groups PCA of modern breeds/types - coracoids. Scatterplot of scores from principal components 1 ( $68 \%$ of the variance) and 2 ( $14 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Figure 105 plots the scores from the BGPCA. The analysis separates the groups well with the first component distinguishing between the stockier types to the left of the graph and the lighter breeds to the right. The shape changes associated with these principal components are not the same as the ones in the initial PCA but the most significant landmark shifts can be inferred from the loadings which are given in Appendix E, Section 5.I.4. For the first principal component, the most significant loadings relate to the basal area (landmarks 4 and I) and the breadth of the corpus (landmarks I4 and I3) and for component two they relate to the basal area (landmarks 2 and I) and the lateral edge of the hook at the humeral articulation (landmarks 7 and 9). Results of a Permanova test for this analysis (using scores from the first two principal components) can be found in Appendix E, Section 5.I.8.

### 6.3.3 Archaeological samples

### 6.3.3.1 Roman coracoids

It was not possible to compare the two Roman sites, Uley and Fishbourne, as the Fishbourne coracoids were not included in the GMM study. Uley results are presented in Section 6.3.3.3.

### 6.3.3.2 Saxon coracoids



Figure 106: Principal component analysis of three Saxon sites - coracoids. $1^{\text {st }} \mathrm{PC}=16.84 \%$ of the variance; $2^{\text {nd }}$ $\mathbf{P C}=15.26 \%$ of the variance. Colour key: red - Coppergate; black - Flixborough; green - Lyminge.

Principal component analysis was carried out on landmark configurations of coracoids from the three Saxon sites (percentages of variance shown in Appendix E, Section 5.I.5). Examination of the plots of the first five components (of which only PCI v PC2 is shown) revealed that there was little to differentiate the three groups. Figure 106 illustrates the first two components (which together account for approximately $32 \%$ of the variance) and shows that on the whole the groups overlap, although PC2 identifies a slight distinction in some of the Coppergate specimens. Components I to 5 (3-5 not illustrated) all show that Flixborough has the least shape-variation of the three assemblages, which is at odds with the results of the measurement ratio study.

Shape changes for this analysis are shown in Figure 107. The most obvious difference between the Saxon and modern coracoids (in Figure IO2) is that the relative slenderness of the coracoid is less significant in the ancient material. This shape-change is now the second component and only accounts for $15 \%$ of the variance in the sample. A number of the Coppergate coracoids appear to be exceptionally slender (Figure 106). Principal component I now describes variation at the sternal end, most notably a shift in the lateral process (landmark 4) and a change in the length of the corpus.


Figure 107: Saxon assemblages - coracoids. Outline graphs showing shape changes for $1^{\text {st }}$ and $2^{\text {nd }}$ principal components. Scale factor $=\mathbf{- 0 . 0 5}(\mathrm{left})$ and 0.05 (right).

## Discriminant function analysis

The analysis was carried out using scores from the first 10 components from the previous PCA. Figure 108 includes the loadings biplot which confirms that the second component (breadth of the corpus) is significant for many of the Coppergate coracoids. Sixty-five per cent of the specimens were classified correctly: 5I.67\% after cross-validation (Table 58). Classifications are in Appendix E, Section 5.I.6.


Figure 108: Discriminant Function Analysis plot of Saxon coracoids using first 10 principal components. Colour key: red - Coppergate; black - Flixborough; green - Lyminge.

|  | Lyminge | Coppergate | Flixborough | Total |
| :--- | :---: | :---: | :---: | :---: |
| Lyminge | $23 / 19$ | $5 / 8$ | $8 / 9$ | 36 |
| Coppergate | $6 / 8$ | $37 / 31$ | $10 / 14$ | 53 |
| Flixborough | $5 / 7$ | $8 / 12$ | $18 / 12$ | 36 |
| Total | $34 / 34$ | $50 / 51$ | $36 / 35$ | 120 |

Table 58: DFA of Saxon coracoids using first 10 PCs. Confusion matrix before/after cross-validation.


Figure 109: BGPCA Modern chicken breeds with Anglo-Scandinavian Coppergate, Anglo-Saxon Flixborough and Lyminge. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Coppergate (top), Flixborough (middle) and Lyminge (bottom).

## Between-groups PCA

When the individual Saxon assemblages are subjected to between-groups PCA with the modern breeds/types, most of the points from Flixborough and Lyminge are concentrated in the lower right of the plots (Figure 109), showing more similarities with the Junglefowl and the Old English Game and Hamburgh/egg-types. The Coppergate points are more widely distributed but still trending towards that area. Results of individual Permanova tests for these analyses (using scores from the first two principal components) can be found in Appendix E, Section 5.I.8.

### 6.3.3.3 Roman, Saxon and Early-modern

Figure 110 plots the scores from a principal components analysis of the three main sites. The Uley points are concentrated in a relatively small area around the origin while Lyminge and Chester are distributed more widely.


Figure 110: Principal component analysis of Uley, Lyminge and Chester - coracoids. $1^{\text {st }} \mathbf{P C}=18.77 \%$ of the variance; $2^{\text {nd }} P C=14.66 \%$ of the variance. Colour key: red - Chester; purple - Uley; green - Lyminge.

Principal component 2


Principal component 1


Figure 111: Uley, Lyminge and Chester - coracoids. Outline graphs showing shape changes for $1^{\text {st }}$ and $2^{\text {nd }}$ principal components. Scale factor $=\mathbf{- 0 . 0 5}$ (left) and 0.05 (right).

Figure III shows the shape-changes associated with Figure IIO. The first principal component describes a change which is mostly related to the breadth of the entire bone, including the humeral end, and a shift in the lateral process (landmark 4). The second PC change describes variation in the length of the basal facet and compression/expansion of the humeral articulation.

## Discriminant function analysis

Discriminant function analysis was carried out on scores from the first II principal components which accounted for $90 \%$ of the variance. Initially, $77.27 \%$ of the specimens were classified correctly, reduced to $54.55 \%$ after cross-validation (Table 59). Classifications are listed in Appendix E. Section 5.I.7.

|  | Chester | Uley | Lyminge | Total |
| :--- | :---: | :---: | :---: | :---: |
| Chester | $10 / 5$ | $1 / 2$ | $2 / 6$ | 13 |
| Uley | $0 / 1$ | $16 / 11$ | $0 / 4$ | 16 |
| Lyminge | $9 / 12$ | $3 / 5$ | $25 / 20$ | 37 |
| Total | $19 / 18$ | $20 / 18$ | $27 / 30$ | 66 |

Table 59: DFA of Uley, Chester and Lyminge coracoids using first 11 PCs. Confusion matrix before/after crossvalidation.


Figure 112: BGPCA of modern breeds/types with Uley, Lyminge and Chester - coracoids. Colour key: yellow Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley (top), Lyminge (middle) and Chester (bottom).

## Between-groups PCA

Between-groups PCA was applied to the modern breed groups and Chester, Lyminge and Uley on a site-by-site basis: the graphs (Figure II2) show the archaeological coracoids plotting in similar locations relative to the modern coracoids, but it is notable that while the Uley and Chester points are mostly separate from the modern breeds, a little more overlap can be seen on the Lyminge graph. There is a suggestion of two concentrations of points on the Lyminge graph but when a PCA was carried out solely on the Lyminge Procrustes coordinates (not illustrated) no separation was apparent for any combination of components up to PC5. Results of Permanova tests for these analyses (using scores from the first two principal components) can be found in Appendix E, Section 5.I.8.

### 6.4 Humeri

### 6.4.1 Modern breeds

A GPA (Generalised Procrustes Analysis) was performed on the raw data coordinates to facilitate an exploration of the complete modern breed dataset ( $n=96$ ). A covariance matrix was generated and a PCA (Principal Components Analysis) carried out. The eigenvalues for the first five principal components are presented in Table 60 (complete percentages of variance are in Appendix E, Section 5.2.I). The remaining 35 components only account for approximately $23 \%$ of the variance and were not investigated further.

| Principal <br> component | Eigenvalues | \% Variance | Cumulative \% |
| :--- | :--- | :--- | :--- |
| 1 | 0.00033213 | 51.957 | 51.957 |
| 2 | 0.00008355 | 13.071 | 65.028 |
| 3 | 0.00002939 | 4.598 | 69.626 |
| 4 | 0.0000263 | 4.114 | 73.74 |
| 5 | 0.00002097 | 3.281 | 77.021 |

Table 60: All modern breed chickens - humeri. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components

The percentages of variance show that over half of the variance in the sample is explained by the first principal component. This is due to the inclusion of breeds which carry the creeper gene, in which the long bones (including the humerus) are
shortened. The breadth of the shape changes described by the first principal component can be seen in the outline graphs below (Figure II3), exaggerated for interpretative purposes. The graphs clearly show the change from the relatively short and stout shafts typical of creeper chickens to the more gracile humeri of the Junglefowl and lighter breeds.


Figure 113: All modern reference chicken breeds - humeri. Outline graphs showing shape change associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below)

Scores from the first and second components are plotted in Figure II4. Principal component I clearly shows the pronounced shape change effected by the creeper gene. Individuals to the left of the mean show the relatively shortened elements: these comprise specimens r668 and r652 (Japanese Bantams), k164 (Krüper) and e005 (Scots Dumpy). It is interesting to note that the humerus from an Indian Game (r725) is also relatively shortened, as are those from the two Ross broilers (e002 and e003). Despite its name, the Indian Game (also called the Cornish Game) is not a game fowl but was originally bred for the table. The breed standard specifies very stout shanks (tarsometatarsi) and selection for this characteristic seems also to have affected the bones of the forelimb. This trait is similarly apparent in modern broilers, including the

Ross strains, which were developed from the Cornish Game. Humeri plotted towards the right of the mean are much more gracile: the shaft is straighter and the proximal and distal articulations are both relatively smaller.


Figure 114: All modern reference chicken breeds - humeri. Scatterplot of scores for principal components 1 and 2, with shortened humeri highlighted in red.

This first exploration of the data gives an interesting insight into the similar skeletal morphology of creepers and recently-developed meat-breeds but their inclusion has skewed the dataset and it was decided to omit the Japanese Bantams (r668 and r652), Krüper (kI64), Scots Dumpy (e005), Indian Game (r725) and Ross broilers (e002 and e003) and re-run the analysis. A covariance matrix was generated for this new dataset and a PCA carried out.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :--- | :---: | :---: |
| I | 0.00012462 | 30.21 | 30.213 |
| 2 | 0.00007717 | 18.70 | 48.920 |
| 3 | 0.00002917 | 7.073 | 55.993 |
| 4 | 0.0000267 | 6.473 | 62.466 |
| 5 | 0.00001782 | 4.321 | 66.787 |
| 6 | 0.00001736 | 4.208 | 70.996 |

[^0]It can be seen from Table 61 (complete table in Appendix E, Section 5.2.2) that the first and second principal components now account for $30 \%$ and $19 \%$ of the variance respectively - much reduced from the first attempt but still approximately half of the variance in the dataset. None of the remaining PCs were responsible for more than $8 \%$ of the variance. Therefore, for this investigation, only the first two PCs were examined.

Although the creepers have been removed from the dataset, the shape changes associated with the first principal component (Figure II5) still describe a similar transition from robust humeri with stout shafts to those with more slender profiles. Negative scores describe humeri thickened along the entire length of the element including the proximal and distal articulations. The shaft is slightly more curved dorsally. Positive scores represent a slender and straight humerus in which the crista coracoidea (landmark 6) does not extend to the edge of the proximal articulation and the dorsal tubercle (landmark I) is less pronounced. Shape changes associated with the $2^{\text {nd }}$ principal component mostly affect the shaft and proximal articulation with the distal articulation relatively unchanged. Positive scores describe a straighter shaft and a broader proximal articulation involving expansion of the ventral tubercle (landmarks 7 and 8 ) and a relatively larger caput. The pectoral muscle scar (landmark 22) extends more distally along the dorsal edge of the shaft. Negative scores describe a shaft curved slightly dorsally, a smaller caput and compression in the region of the ventral tubercle. The pectoral muscle scar is shorter and terminates more proximally.


Figure 115: Modern breed chickens excluding creepers and meat breeds - humeri. Outline graphs showing shape changes associated with the $1^{\text {st }}$ and $2^{\text {nd }}$ principal components. Scale factor: $\mathrm{PC} 1=\mathbf{- 0 . 0 5}$ (left) and 0.05 (right) PC2 $=0.05$ (left) and -0.05 (right)

Scores from the first two principal components plot in an indistinct cloud with no obvious clusters. However, there are consistent patterns of shape variation associated with breeds and types within the scatter. The following graphs (Figures II6 to I20) highlight a selection of breeds and types which show noteworthy shape differences.

Figure 116 shows two purportedly ancient types which both originated as dualpurpose but were further developed as market pressures forced specialisation. Dorkings (brown) are large, 'square-bodied' fowl mostly bred for meat, while Hamburghs, Pheasant Fowl and Leghorns are Mediterranean 'egg-types'. These are well-separated by PCs I and 2. As expected, PC I shows the Dorkings have more robust humeri than the lighter Hamburghs but PC2 indicates that they also have a straighter humeral shaft. Specimen e014, which is the most gracile of the Dorking humeri, is from a two-year-old male which reportedly died of a "tumerous liver". It is possible that this ailment was a chronic condition which had an effect on bone development.


Figure 116: Modern chickens excluding creepers and meat breeds - humeri. Scatterplot of scores from principal components 1 and 2. Dorkings (brown) and Hamburgh/egg-type (green).

Sussex fowl are also dual-purpose with a tendency towards egg-production. Figure 117 shows that Sussex (orange) generally also have a more gracile humerus and mostly
plot towards the right of the Dorkings (brown), although the distinction is not so pronounced as between the Dorkings and Hamburghs. Despite their name, Sussex fowl were developed after the introduction of large, soft-feather breeds from Asia and their plumage and general morphology owes much to breeds such as Cochin and Brahma.


Figure 117: Modern chickens excluding creepers and meat breeds - humeri. Scatterplot of scores from principal components 1 and 2. Dorkings (brown) and Sussex (orange).

Figure II8 shows two different types of game fowl. Old English Game (red) are compared with different types of Asian game fowl (black). Differences associated with principal components I and 2 can both be identified but separation is more apparent on the $y$ axis. The first principal component shows that Asian Game humeri are generally more robust than the Old English Game, while the second component shows that the Old English Game have a straighter shaft. The shape variation here is not surprising as they have been developed in isolation and are morphologically very different from each other despite their common use for fighting.


Figure 118: Modern chickens excluding creepers and meat breeds - humeri. Scatterplot of scores from principal components 1 and 2. Old English Game (red) and Asian Game fowl (black)


Figure 119: Modern chickens excluding creepers and meat breeds - humeri. Scatterplot of scores from principal components 1 and 2. Silkies (pink) and Polands (blue)

Figure II9 shows two 'fancy' breeds. Polands (blue) and Silkie (pink). Both have a crest, although the Silkie's is much smaller than the Poland's. Both once had utility roles but in Britain they are now bred mainly for exhibition. A number of things are notable about this graph: first, the Poland points are quite scattered (especially along the second component axis), showing considerable shape variation of the humerus within the sample specimens of this breed, while the Silkies are more closely-clustered; second, the Silkies have a slightly more robust and straighter humeral shaft; and finally the humerus r660 (arrowed) from a Silkie with a pronounced cerebral hernia does not plot with the Polands, suggesting that any Poland genes which may have been introduced to increase the size of the crest did not influence the shape of the humerus, making it more 'Poland-like'.


Figure 120: Modern chickens excluding creepers and meat breeds - humeri. Scatterplot of scores from principal components 1 and 2. cross-bred Junglefowl (red)

Finally, Figure 120 shows the location of the cross-bred Junglefowl humeri. The data from a wild species would be expected to cluster closely but here the wide scatter on the second component reflects the genetic variability in the specimens used for the study. This is not unexpected as it was accepted that few if any of the individuals sourced were true wild-type Junglefowl owing to the introgression and dilution of the
species in recent years. However, it can be seen that the humeri of the specimens available all tend to be more slender, similar to the egg-type fowl and although they exhibit both curved and straight shafts the majority are curved.

The principal component scores of breeds represented by only one or two specimens were also inspected - on the whole these plotted as expected, with lighter types to the right of the mean on the PCI axis and heavier breeds to the left. Scatterplots of scores of principal components other than I and 2 were subjected to an initial inspection but did not separate the breeds effectively and were not analysed further.

### 6.4.2 Modern breeds/types - reduced dataset

The dataset was further reduced and categorised to match as closely as possible the groups used for the measurement ratios. Principal component analysis was performed on this dataset. The resulting percentages of variance can be found in Appendix E, Section 5.2.2: shape changes relating to the principal components are almost identical to those from the previous PCA (see Figure II5) except that the transfer to Past has 'flipped' the points for PC2 and the positive scores are now negative and vice versa.


Figure 121: Between-groups PCA of modern breeds/types - humeri. Scatterplot of scores from principal components 1 and 2. Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

In Figure I2I, principal component I clearly shows the progression from a robust humerus (negative) to a more gracile humerus (positive), while the second component identifies a curved shaft and relatively small proximal end (negative) and a straighter shaft and broader proximal end (positive).


Figure 122: Modern breeds/types: DFA of first 7 PCs. Axis 1 accounts for $47 \%$ of the variance, Axis 2 for $28 \%$ of the variance. Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Discriminant function analysis was carried out using scores from the first seven components. Figure 122 illustrates the initial separation of the groups: the biplot indicates that PCI is most significant in separating the lighter Junglefowl and Mediterranean types and PC2 the stockier Silkies.

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $9 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $0 / 1$ | $0 / 1$ | 9 |
| Hamburgh | $0 / 0$ | $8 / 7$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 8 |
| X-B JF | $0 / 0$ | $1 / 3$ | $5 / 2$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 6 |
| O E Game | $1 / 1$ | $1 / 2$ | $0 / 0$ | $8 / 7$ | $0 / 0$ | $0 / 0$ | 10 |
| Silkie | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $7 / 6$ | $0 / 0$ | 7 |
| Asian G | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 2$ | $0 / 0$ | $6 / 3$ | 6 |
| Total | $10 / 9$ | $10 / 12$ | $5 / 2$ | $8 / 12$ | $7 / 7$ | $6 / 4$ | 46 |

Table 62: Modern breeds/types - DFA of first 7 PCs. Confusion matrix before/after cross-validation.

Classification to correct group was initially very high at 93\%, reduced to $67 \%$ after cross-validation. The confusion matrix (Table 62) gives details of the classifications before and after cross-validation.

Between-groups PCA


Figure 123: Between-groups PCA of modern breeds/types - humeri. Scatterplot of scores from principal components 1 ( $61 \%$ of the variance) and 2 ( $24 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Figure I23 plots the scores from the BGPCA. The graph shows clearly that there are morphological similarities between Dorkings, Old English Game and Silkies and between Junglefowl and Hamburghs, while the Asian Game plot separately from the rest. Loadings (Appendix E, Section 5.2.3) show that the most significant shape-changes for PCI are associated with landmarks 22, I, I9 and II, which all relate to expansion of the proximal and distal end and reflect relative robusticity. For PC2, landmarks I, 21,7 and 10 show shape-change at the proximal and in the curvature of the shaft. Landmark 22 was designed to capture the extent of the pectoral muscle scar but examination of Figure II5 shows that for PCI this is actually reflecting the expansion
of the proximal end and variation in the length of the scar is more properly seen in the PC2 shape-change. This illustrates the caution which must be exercised when selecting landmark locations and interpreting landmark shifts. A one way Permanova test (using scores from the first two principal components) for this analysis is presented in Appendix E, Section 5.2.7.

### 6.4.3 Archaeological samples

The archaeological dataset consisted of humeri from Uley, Lyminge and Chester, as closely matched as possible with the measurement ratios dataset. A GPA (Generalised Procrustes Analysis) was performed on the raw data coordinates, a covariance matrix generated and a PCA (Principal Components Analysis) carried out to investigate shape differences between these three assemblages and identify any outliers. The humeri from the Uley creepers (u063 and u076) were obvious outliers and subsequently excluded.

Percentages of variance for the first five principal components are presented in Table 63 (complete results are in Appendix E, Section 5.2.5).

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00003338 | 17.92 | 17.92 |
| 2 | 0.00002537 | 13.62 | 31.53 |
| 3 | 0.00002046 | 10.98 | 42.52 |
| 4 | 0.00001386 | 7.44 | 49.96 |
| 5 | 0.00001123 | 6.03 | 55.99 |

Table 63: Archaeological chickens - humeri. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components.

Table 63 shows that the first three principal components account for just over $42 \%$ of the variance in the dataset. Outline graphs presented in Figure 124 show the shape changes for these first three principal components. Negative scores on the first principal component axis reflect a relatively broader shaft and stouter proximal end. The pectoral muscle scar (landmark 22) is extended distally along the shaft and the dorsal supracondylar tubercle (landmark 19) is shifted slightly proximally. At the other extreme, the shaft is more slender and slightly curved: landmark 19 is shifted more distally, landmark 22 shifted proximally. The caput is relatively smaller.

Shape changes associated with the second principal component mostly affect the curvature of the shaft and the relative size of the proximal end. Negative scores indicate a generally more robust shape, with significant expansion at the proximal end, especially around the dorsal tubercle (landmarksI and 21). Positive scores are associated with a straighter, more slender shaft with both proximal and distal ends relatively smaller. The caput is slightly 'flattened' and the pneumatic foramen does not extend so far distally although this may be the result of the overall size reduction of the proximal end.


Figure 124: Archaeological chickens - humeri. Outline graph showing shape changes associated with the $1^{\text {st }}, 2^{\text {nd }}$ and $3^{\text {rd }}$ principal components. Scale factor $=\mathbf{- 0 . 0 5}$ (left) and 0.05 (right).

For the third principal component, negative scores show a significantly more slender and curved shaft. The profile of the distal articulation is club-like, mainly owing to a broader ventral condyle (described by landmarks 14, 15 and 16). At the proximal end there is compression at the ventral tubercle (landmarks 7 and 8) and the incisura defined by landmark 4 is twisted dorsally. The caput is relatively larger with a muchreduced dorsal tubercle (landmark I) and the pectoral muscle attachment scar extends further distally (landmark 22). At the other extreme of this component the shaft is thickened and straighter with expansion at the proximal end, especially at the dorsal and ventral tubercles (landmarks I and 7/8). The caput is smaller and 'flatter' and the incisura (landmark 4) penetrates much deeper and more directly. The pectoral muscle
attachment is smaller (landmark 22). The distal articulation is slightly broader, with expansion at the dorsal condyle (landmarks 17, I8 and 19).


Figure 125: Archaeological chickens - humeri. Scatterplot of scores for principal components 1 and 2 . Red $=$ Chester; green = Lyminge; purple = Uley .

Figures I 25 and I 26 plot the scores for the first three principal components. The first two components (Figure I25) show an almost equal distribution of points on both axes, with very little indication of assemblage-associated shape-variation. The Chester points are distributed evenly along both axes with no concentrations. The first component identifies a small difference between Uley and Lyminge: the Uley humeri (purple) tend slightly towards the positive scores, reflecting a more gracile shape with a smaller proximal end for the majority of specimens from this site, while the Lyminge humeri (green) show the opposite pattern.

A slightly more significant result is seen in the scatterplot for PCI v PC3 (Figure I26). The widest variation on the PC3 axis is seen in the Chester assemblage, but this is due to just one specimen; however the Uley humeri are slightly concentrated around the mean and towards the positive end of the scale, denoting the 'squarer' shape seen to the bottom-right of Figure 123.


Figure 126: Archaeological chickens - humeri. Scatterplot of scores for principal components 1 and 3. Red = Chester; green = Lyminge; purple = Uley.

The scores from principal components 4 to 8 inclusive were plotted and examined but no further patterns were discernible.

## Discriminant function analysis

Discriminant function analysis was carried out using scores from the first 10 principal components: $77.05 \%$ of the specimens were initially classified correctly, $60.66 \%$ after cross-validation. The biplot on the graph (Figure 127) indicate the relative significance of the PCs on each group, including the influence of the third component on some of the Uley specimens. The confusion matrix for the classifications before and after cross-validation are shown in Table 64: the classifications are presented in Appendix E, Section 5.2.6.


Axis 1

Figure 127: Archaeological humeri: DFA of first 10 PCs. Axis 1 accounts for $62 \%$ of the variance, Axis 2 for $38 \%$ of the variance. Colour key: Uley - purple; Lyminge - green; Chester - red.

|  | Uley | Lyminge | Chester | Total |
| :--- | :---: | :---: | :---: | :---: |
| Uley | $16 / 13$ | $2 / 3$ | $1 / 3$ | 19 |
| Lyminge | $6 / 8$ | $21 / 18$ | $3 / 4$ | 30 |
| Chester | $0 / 2$ | $2 / 4$ | $10 / 6$ | 12 |
| Total | $22 / 23$ | $25 / 25$ | $14 / 13$ | 61 |

Table 64: DFA of Uley, Lyminge and Chester humeri using first 10 PCs. Confusion matrix before/after crossvalidation.


Figure 128: BGPCA of modern breeds/types with Uley, Lyminge and Chester - humeri. Colour key: yellow Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Uley (top), Lyminge (middle) and Chester (bottom).

## Between-groups PCA

Between-groups PCA was applied to the modern breed groups and Chester, Lyminge and Uley on a site-by-site basis: the graphs (Figure I28) show all three of the archaeological humeri plotting in similar locations relative to the modern humeri, with points falling on or around the more gracile end of the Old English Game distribution. The Uley points overlap a little with the Hamburghs and Junglefowl and the Lyminge points have a slightly wider distribution with some plotting further to the top-right of the graph but overall there is little distinction to be made between the archaeological groups. One way Permanova tests (using scores from the first two principal components) of each of these analyses are presented in Appendix E, Section 5.2.7.

### 6.5 Tibiotarsi

### 6.5.I Modern breeds

A GPA (Generalised Procrustes Analysis) was performed on the raw data coordinates of 95 modern breed tibiotarsi, including those from creepers, for an initial exploration of relative shape changes. A covariance matrix was generated and PCA (Principal Components Analysis) carried out. The percentages of variance for the first six principal components are presented in Table 65 (the complete percentages of variance table is in Appendix E, Section 5.3.1). The remaining 12 PCs account for approximately $10 \%$ of the variance and are not likely to be significant.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :--- | :---: | :---: |
| I | 0.00037793 | 50.41 | 50.41 |
| 2 | 0.00020072 | 26.78 | 77.19 |
| 3 | 0.00004139 | 5.52 | 82.71 |
| 4 | 0.00002817 | 3.76 | 86.47 |
| 5 | 0.00002368 | 3.16 | 89.63 |
| 6 | 0.00001669 | 2.23 | 91.85 |

Table 65: All modern chicken breeds - tibiotarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first six principal components

The results show that over half of the variance in the sample is explained by the first principal component. This is due to the inclusion of the breeds which carry the creeper gene, in which the long bones (including the tibiotarsus) are shortened.


Figure 129: All modern chicken breeds - tibiotarsus. Outline graphs showing shape change associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below)

The shape changes associated with the first principal component are illustrated in the outline graphs in Figure 129. These are overwhelmingly related to the relative breadth of the entire element, with a suggestion of a slight change in the angle of the lateral crista cnemialis (landmark 3) and a narrowing of the angle of the distal condyles (landmarks 6 and 8 ).

The first two principal components together account for $77 \%$ of the variance and their scores are plotted in Figure I30. As the tibiotarsi from the creepers have been included, the scatter plot shows a similar pattern to the initial plot for the PC scores from the humeri (Figure II4). For the first component, the Japanese Bantam creepers (specimens r652 and r668) again show extreme morphological change and the larger Krüper (kI64) and Scots Dumpy (e005), which also carry the gene, rather less so. The very stocky Indian Game (r725) and broilers (e002 and e003) also follow this trend.


Figure 130: All modern chicken breeds - tibiotarsi. Scatterplot of scores for principal components 1 and 2, with shortened tibiotarsi highlighted

### 6.5.2 Modern breeds/types - reduced dataset

These outliers were excluded and the dataset further reduced to match as closely as possible the groups used for the measurement ratios. This comprised 45 specimens a few bones were excluded due to unavoidable circumstances such as pathology.

Principal component analysis, discriminant function analysis and between-groups PCA was carried out on this reduced dataset.

The percentages of variance for the first five principal components are presented in
Table 66 (the full set are given in the Appendix E, Section 5.3.2).

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00015555 | 39.02 | 39.02 |
| 2 | 0.00008713 | 21.85 | 60.87 |
| 3 | 0.00005077 | 12.74 | 73.61 |
| 4 | 0.00002649 | 6.64 | 80.25 |
| 5 | 0.00001732 | 4.35 | 84.60 |

Table 66: Modern chicken breeds/types - tibiotarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components.

The first three principal components now account for over 73\% of the variance in the dataset, with none of the remaining PCs responsible for more than $7 \%$ of the variance. Therefore, for this investigation, the first three PCs only were examined.


Figure 131: Between-groups PCA of modern breeds/types - tibiotarsi. Scatterplot of scores from principal components 1 ( $39 \%$ of the variance) and 2 ( $22 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Figure I3I plots the scores for the first two components and shows clearly that the shape change associated with PCI (Figure 133) is significant in separating the lighter breeds with the positive scores from the heaver ones with negative scores. The PC2 shape changes (illustrated in Figure I34) is less effective and there is considerable overlap within the groups although the general trend is for the lighter breeds to score negative of the mean.

Principal component 3 (shown in Figure 132) is partly effective at separating the Dorkings and Asian breeds from the Mediterranean domestics. The cross-bred Junglefowl points cluster around the mean, indicating that the shape-changes identified by the third component are not necessarily associated with unimproved types.


Figure 132: Between-groups PCA of modern breeds/types - tibiotarsi. Scatterplot of scores from principal components 1 ( $39 \%$ of the variance) and 3 ( $13 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.


Figure 133: Modern chickens breeds/types- tibiotarsus. Outline graphs showing shape change associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below).

Shape changes associated with the first principal component (Figure I33) are most apparent at the proximal end: changes at the distal end are more subtle. Positive scores (above) reflect a more slender shaft. The medial process (landmark I) is smaller and there is compression of the cranial crista cnemialis (landmark 2). The point of the lateral crista cnemialis (landmark 3) is shifted slightly distally and the fibular crest (landmark 4) is relatively short. The distal articulation is smaller and the tendinal bridge is narrower. Negative scores (below) show movement in the opposite direction. Lines between landmarks, especially those that show the thickness of the shaft and the curve between landmarks 3 and 4 should be viewed with caution as no landmarks are located in this area and the outlines are a suggestion only.

Principal component 2 shape changes (Figure 134) are more related to robusticity of the whole element. Positive scores (above) show a thicker shaft with broader distal and proximal ends and a broader tendinal bridge. The medial process (landmark I) and the lateral crista cnemialis (landmark 3) are expanded. Negative scores relate to a tibiotarsus that is more gracile overall, with relatively narrower distal and proximal ends and a much compressed medial process shifted proximally.


Figure 134: Modern chickens, breeds/types - tibiotarsus. Outline graphs showing shape change associated with the $2^{\text {nd }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below)


Figure 135: Modern chickens, breeds/types - tibiotarsus. Outline graphs showing shape change associated with the 3 rd principal component. Scale factor $=0.05$ (above) and -0.05 (below)

For the third component (Figure 135), negative scores identify a narrowing of the distal shaft and articulation together with what appears to be a bend in the distal shaft, although the lack of landmarks on the medial edge of the shaft makes interpretation difficult. The proximal end shows a proximal shift in the lateral crest (landmark 3) with a corresponding shift towards the distal in the medial process (landmark I). Positive scores show the opposite shape-change.

## Discriminant function analysis

Discriminant function analysis was carried out using scores from the first seven components. Figure 136 illustrates the separation of the groups: the biplot indicates that PCI shape-changes distinguish the lighter Junglefowl and Mediterranean types, PC2 separate the more robust Dorkings and PC3 the Silkies. The confusion matrix in Table 67 gives the classifications before and after cross-validation: $82.22 \%$ were initially classified correctly, 7 I.II\% after cross-validation. Classifications can be found in Appendix E, Section 5.3.3.


Figure 136: Modern breeds/types - tibiotarsi: DFA of first 7 PCs. Axis 1 accounts for $58 \%$ of the variance, Axis 2 for $30 \%$ of the variance. Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $7 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $2 / 3$ | 9 |
| Hamburgh | $0 / 0$ | $5 / 5$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | $0 / 0$ | 6 |
| X-B JF | $0 / 0$ | $1 / 1$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 7 |
| O E Game | $0 / 1$ | $1 / 1$ | $0 / 0$ | $8 / 7$ | $0 / 0$ | $1 / I$ | 10 |
| Silkie | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $7 / 5$ | $0 / 1$ | 7 |
| Asian G | $0 / 1$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | $1 / 1$ | $4 / 3$ | 6 |
| Total | $7 / 9$ | $7 / 7$ | $6 / 6$ | $9 / 8$ | $9 / 7$ | $7 / 8$ | 45 |

Table 67: Modern breeds/types - tibiotarsi: DFA of first 7 PCs. Confusion matrix before/after cross-validation.

## Between Groups PCA



Figure 137: Between-groups PCA of modern breeds/types - tibiotarsi. Scatterplot of scores from principal components 1 ( $61 \%$ of the variance) and 2 ( $23 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Figure 137 plots the scores from the BGPCA. The graph shows that, for the first principal component, positive scores are typified by lighter breeds (with the Junglefowl clearly separated), while the negative scores relate to the stockier types. The second component seems to be associated with a shape-change other than robusticity as the Junglefowl plot in the centre of the range. Loadings (Appendix E, Section 5.3.4) show that the most significant landmarks for PCI are $4,2, \mathrm{II}$ and 3 and for PC2 they are 4 , 8 , II and 3 , indicating that variability in the fibular crest, the crests of the proximal articulation and the tendinal bridge are all significant. One way Permanova tests (using scores from the first two principal components) of each of these analyses are presented in Appendix E, Section 5.3.7.

### 6.5.3 Archaeological samples

The tibiotarsus is relatively fragile: the crests at the proximal end are vulnerable to damage and the shaft is slender and easily broken. Complete archaeological tibiotarsi were therefore limited: the dataset comprised I5 from Lyminge, 12 from Chester and two from Uley. The two Uley elements were left in for the initial PCA in order to ascertain their shape in relation to those from the other two sites but excluded for subsequent analyses.

Generalised Procrustes Analysis was carried out on the 29 archaeological tibiotarsi for an initial data exploration. A covariance matrix was generated and Principal Components Analysis performed on this matrix. Eigenvalues and percentages of variance are presented in Table 68: the complete results are in Appendix E, Section 5.3.5.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00010128 | 45.44 | 45.44 |
| 2 | 0.00004536 | 20.35 | 65.79 |
| 3 | 0.00001901 | 8.53 | 74.32 |
| 4 | 0.00001412 | 6.34 | 80.66 |
| 5 | 0.0000107 I | 4.81 | 85.46 |
| 6 | 0.00000923 | 4.14 | 89.60 |

Table 68: All archaeological chickens - tibiotarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first six principal components


Figure 138: All archaeological chickens - tibiotarsi. Outline graphs showing shape change associated with the 1 st principal component. Scale factor $=\mathbf{- 0 . 1}$ (above) and 0.1 (below)


Figure 139: All archaeological chickens - tibiotarsi. Outline graphs showing shape change associated with the $2^{\text {nd }}$ principal component. Scale factor $=-0.05$ (above) and 0.05 (below)

Shape changes associated with the first and second principal components, which explain approximately $66 \%$ of the variance, are depicted in Figures I38 and I39. The first principal component (for which the scale has been increased to -0.1 to 0.1 to exaggerate the more subtle differences in the archaeological assemblage) describes a
pronounced variation in the length of the crista fibularis (landmark 4) and a change at the distal end, from broader condyles to narrower. The proximal articulation appears compressed in specimens with negative scores. For the second component, there is a transition from robust to slender affecting the whole of the element with the most variation occurring at the proximal articulation. Negative values represent expanded crests giving a larger area for muscle attachment while for specimens having positive scores these features are much reduced. At the distal end, the condyles at the positive end of the range are shorter relative to the shaft and there is expansion at the lateral condyle (landmark 6) giving the impression of a flared edge. Negative values show a stouter articulation with slightly converging condyles (landmarks 6, 7 and 8).


Figure 140: All archaeological chickens - tibiotarsi. Scatterplot of scores for principal components 1 and 2. Colour key: purple - Uley; green - Lyminge; red - Chester.

Scores from this initial PCA are plotted in Figure 140. This analysis shows that no distinction can be made between the tibiotarsi from Chester and Lyminge on the PCI axis but on the PC2 axis (with the exception of one outlier) the Chester specimens are more closely clustered around the mean. The two tibiotarsi from Uley plot just positive of the mean on both axes. Close to the origin are three overlapping Chester
points (arrowed). These all represent left-sided tibiotarsi and are therefore derived from different chickens but seem almost identical in form. It can be speculated that this similarity reflects a close genetic relationship and these chickens are all from the same population.

Discriminant function analysis


Figure 141: DFA histogram of two groups of archaeological tibiotarsi. Colour key: red - Chester; blue Lyminge.

Discriminant function analysis was carried out using scores from the first five principal components. Initial correct classification was $62.96 \%$ of the dataset: $48.15 \%$ after cross-validation. This relatively low success rate illustrates the similarity within the dataset, which can be seen in the histogram (Figure 141) and the confusion matrix (Table 69). Classification table is in Appendix E, Section 5.3.6.

|  | Lyminge | Chester | Total |
| :--- | :---: | :---: | :---: |
| Lyminge | $11 / 8$ | $4 / 7$ | 15 |
| Chester | $6 / 7$ | $6 / 5$ | 12 |
| Total | $17 / 15$ | $10 / 12$ | 27 |

Table 69: DFA of Chester and Lyminge tibiotarsi using scores from the first five PCs. Confusion matrix before/after cross-validation.


Figure 142: BGPCA of modern breeds/types with Lyminge and Chester - tibiotarsi. Colour key: yellow - Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge (middle) and Chester (bottom).

## Between-groups PCA

Between-groups PCA was applied to Chester and Lyminge and the modern breed groups: the graphs (Figure 142) show that the archaeological tibiotarsi plot in similar locations compared to the modern groups but Lyminge has a slightly wider distribution, trending more towards the more robust breeds. A one way Permanova test (using scores from the first two principal components) for this analysis is presented in Appendix E, Section 5.3.7.

### 6.6 Tarsometatarsi

### 6.6.1 Modern breeds

Raw data coordinates from the complete modern breed dataset (9I specimens) were subjected to a Generalised Procrustes Analysis (GPA) and a covariance matrix generated. A Principal Components Analysis (PCA) was carried out and percentages of variance for the first five principal components are presented in Table 70 below. None of the remaining components account for more than $2 \%$ of the variance and can be considered insignificant. The full percentages of variance are listed in Appendix E, Section 5.4.I.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00057823 | 70.50 | 70.50 |
| 2 | 0.00004229 | 5.16 | 75.66 |
| 3 | 0.00003238 | 3.95 | 79.61 |
| 4 | 0.00002908 | 3.55 | 83.15 |
| 5 | 0.0000248 | 3.02 | 86.18 |

Table 70: All modern chicken breeds - tarsometatarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components

It is immediately obvious from the table that the shape change related to the first principal component is unusually large: over $70 \%$ ascribed to PCI which, together with PC2 accounts for 75\% of the variance in the dataset. Scores from the analysis are plotted in Figure 143.


Figure 143: All modern reference chicken breeds - tarsometatarsi. Scatterplot of scores for principal components 1 and 2. Red points indicate creepers and meat breeds.

It is clear that the tarsometatarsi from the creepers ( $\mathrm{r} 652, r 668, \mathrm{e} 005$ ), together with those from the Indian Game and broilers (r725, e002, e003) (highlighted in red), are responsible for the high percentage of variance described by the first principal component. The shape change associated with PCI is illustrated in Figure 144.


Figure 144: All modern chicken breeds - tarsometatarsus. Outline graphs showing shape change associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below)

Practically all of the change is due to a broadening of the shaft and a proportional increase in the breadth of the proximal and distal ends. The creepers and meat breeds were removed from the dataset and the PCA repeated. The percentages of variance for the first six components are shown in Table 71: the first principal component now accounts for only $39 \%$ of the variance.

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00014695 | 39.25 | 39.25 |
| 2 | 0.00004257 | 11.37 | 50.61 |
| 3 | 0.00003173 | 8.47 | 59.09 |
| 4 | 0.00002884 | 7.70 | 66.79 |
| 5 | 0.00002217 | 5.92 | 72.71 |
| 6 | 0.0000155 | 4.14 | 76.85 |

Table 71: Modern chickens, reduced dataset - tarsometatarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first six principal components.


Figure 145: All modern chicken breeds - tarsometatarsus. Outline graphs showing shape change associated with the $2^{\text {nd }}$ and $3^{\text {rd }}$ principal components. Scale factor $=-0.05$ (left) and 0.05 (right).

The associated shape change for PCI is virtually the same as in Figure 144: those relating to components two and three are shown in Figure 145. Positive scores for PC2 mostly describe a broadening of the proximal articulation with a corresponding slight increase in shaft width. The changes relating to PC3 are more complex: negative scores reflect a narrower shaft, a more medial position for the intercondylar eminence (landmark 3), a proximal shift for the distal vascular foramen (landmark I7) and a smaller trochlea of the second metatarsal (landmark 16) with positive scores showing the opposite. The outline diagrams suggest a significant alteration in the morphology of the lateral and medial cotylae of the proximal articulation but there are no landmarks
defining these features and the apparent changes are likely an artefact of the visualisation method.

Although there are no obvious discrete clusters of points within the general scatters produced by combinations of these three components, some breeds and types do group in meaningful patterns. The following graphs (Figures 146 to 150) highlight the same breeds and types which were selected in Section 6.4.I, to enable comparison between the humerus and tarsometatarsus.

Figure 146 illustrates the difference between heavy Dorkings and the lighter Hamburgh/egg-types. As expected, principal component I separates the two types into robust and gracile groups. The exception, specimen e014 (arrowed), is from a two-year-old male which died of a "tumerous liver"; this individual also plots as an outlier from the Dorking group in the humerus comparison graph (Figure II6), being more slender and less "Dorking-like". Components 2 and 3 (PC3 not illustrated) do not separate the two groups.


Figure 146: Modern chickens excluding creepers and meat breeds - tarsometatarsi. Scatterplot of scores from principal components 1 and 2. Dorkings (brown) and Hamburgh/egg-type (green).


Figure 147: Modern chickens excluding creepers and meat breeds - tarsometatarsi. Scatterplot of scores from principal components 1 and 2. Dorkings (brown) and Sussex (orange)

Figure 147 shows Dorkings compared with Sussex: another old, slightly lighter dualpurpose breed. A PCA of the humerus configurations separated these two breeds (Figure II7), but the tarsometatarsus does not show the same variability and no significant differences can be discerned between these two breeds using PCs I, 2 or 3.

Figure 148 shows the relative positions of the Old English Game and Asian Game. The first component does not clearly distinguish the two types, although the Asian Game have a tendency towards a more robust tarsometatarsus. For the second component however, the Old English Game plot with predominantly negative scores and the Asians with positive, indicating that the Asians have a relatively broader proximal articulation. For the third component (not illustrated) the Asian points are widely scattered but the Old English are tightly clustered around the mean. The graph for the humerus (Figure II8) shows that for this element too, PC2 separates the two types more effectively than PCI.


Figure 148: Modern chickens excluding creepers and meat breeds - tarsometatarsi. Scatterplot of scores from principal components 1 and 2. Old English Game (red) and Asian Game fowl (black).


Figure 149: Modern chickens excluding creepers and meat breeds - tarsometatarsi. Scatterplot of scores from principal components 1 and 2. Silkies (pink) and Polands (blue).

Figure 149 compares two crested exhibition breeds. The Polands are much more widely distributed along the PCI axis than the Silkies and are generally more gracile although there is a little overlap. The second component identifies a more convincing
shape-distinction, with the Silkies showing a relatively broader proximal articulation. As with the humeri (Figure II9), the Silkie with the pronounced cerebral hernia (r660) does not show any similarities with the Polands.

Figure 150 illustrates the position of the cross-bred Junglefowl. As with the humerus PCA (Figure 120), the points are distributed relatively widely on the first component axis, reflecting the genetic variability within the sample. However, for the second component, the Junglefowl scores are much more concentrated and indicate homogeneity in the shape of the proximal articulation. For PC3 (not illustrated), the scores are predominantly negative reflecting a narrower shaft, a medially-located intercondylar eminence, a proximal shift for the distal vascular foramen and a smaller trochlea of the second metatarsal.


Figure 150: Modern chickens excluding creepers and meat breeds - tarsometatarsi. Scatterplot of scores from principal components 1 and 2 . cross-bred Junglefowl (red)

### 6.6.2 Modern breeds/types - reduced dataset

The dataset was further reduced and categorised to match as closely as possible the groups used for the measurement ratios. Principal component analysis was performed on this dataset.

| PCs | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00018863 | 46.24 | 46.24 |
| 2 | 0.00004928 | 12.08 | 58.32 |
| 3 | 0.00003179 | 7.79 | 66.12 |
| 4 | 0.00002575 | 6.31 | 72.43 |
| 5 | 0.00001962 | 4.81 | 77.24 |

Table 72: Modern breeds/types - tarsometatarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components.

The full percentages of variance table can be found in Appendix E, Section 5.4.2. The percentage of variance associated with the first principal component is now $46 \%$ but the related shape changes are almost identical to those from the previous PCA (see Figure 144) except that the positive and negative scores are transposed and the negative scores now represent a more robust bone. The changes associated with the second and third components are illustrated in Figure 151: PC3 is similar to the third component shape-change from the previous PCA (Figure 145), except that the scores are again transposed. PC2 is different altogether and describes a transition from a broad proximal articulation, laterally-curved shaft and small medial trochlea to a narrower proximal articulation, a medially-curved shaft and a larger medial trochlea.


Figure 151: Modern breeds/types - tarsometatarsi. Outline graphs showing shape changes associated with the $2^{\text {nd }}$ and $3^{\text {rd }}$ principal components. Scale factor $=-0.05$ (left) and 0.05 (right).

Figures 152 and 153 plot the scores from the first three components which relate to the shape changes shown in Figure 144 (although Past has 'flipped' the scores for the first component and negative scores now appear as positive on the plot and vice versa) and Figure 15I.

Principal component I (Figure I52) reflects the robusticity of the tarsometatarsus as a whole and the groups are positioned along the axis in a predictable sequence. However, the groups' relationship to each other was more unconventional on the second and third PC axes. For PC2 (Figure 152), the cross-bred Junglefowl plots with the Silkies which would not normally be the case and for PC3 (Figure I53) the eggtype Hamburghs and the cross-bred Junglefowl are at opposite ends of the axis, with the Hamburghs grouping near the Asian Game and Dorkings. The shape-changes associated with the tarsometatarsus are therefore more complex than and perhaps not as predictable as the other elements.


Figure 152: PCA of modern breeds/types - tarsometatarsi. Scatterplot of scores from principal components 1 ( $46 \%$ of the variance) and 2 ( $12 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl -light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.


Figure 153: PCA of modern breeds/types - tarsometatarsi. Scatterplot of scores from principal components 1 ( $46 \%$ of the variance) and 3 ( $8 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl -light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

## Discriminant Function Analysis

DFA was carried out using scores from the first six components. Figure 154 illustrates the relationship of the groups: the Old English Game and the Hamburgh/egg-types show the most similarity but the rest separate relatively well. The biplot indicates that PCI defines the shape-change in the Silkies and PC3 in the cross-bred Junglefowl. PC2 is not strongly associated with any one group, but is closest to some of the Hamburghs and Old English Game.


Figure 154: Modern breeds/types - tarsometatarsi: DFA of first 6 PCs. Axis 1 accounts for $56 \%$ of the variance, Axis 2 for $27 \%$ of the variance. Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Total |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | $7 / 4$ | $0 / 1$ | $0 / 0$ | $0 / 1$ | $0 / 1$ | $1 / 1$ | 8 |
| Hamburgh | $0 / 1$ | $6 / 3$ | $0 / 1$ | $1 / 2$ | $0 / 0$ | $0 / 0$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $7 / 6$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | 7 |
| O E Game | $1 / 1$ | $1 / 2$ | $0 / 0$ | $7 / 6$ | $0 / 0$ | $0 / 0$ | 9 |
| Silkie | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $7 / 7$ | $0 / 0$ | 7 |
| Asian G | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $5 / 5$ | 6 |
| Total | $9 / 7$ | $7 / 6$ | $7 / 7$ | $8 / 10$ | $7 / 8$ | $6 / 6$ | 44 |

Table 73: Modern breeds/types - tarsometatarsi: DFA of first 6 PCs. Confusion matrix before/after crossvalidation.

The confusion matrix (Table 73) gives the classifications before and after crossvalidation: $88.64 \%$ were initially classified correctly, $70.45 \%$ after cross-validation.

Classifications can be found in Appendix E, Section 5.4.3.


Figure 155: Between-groups PCA of modern breeds/types - tarsometatarsi. Scatterplot of scores from principal components 1 ( $68 \%$ of the variance) and 2 ( $16 \%$ of the variance). Colour key: Asian Game - orange; Cross-bred Junglefowl - light-blue; Dorking - brown; Hamburgh/egg-type - green; Old English Game - red; Silkie - pink.

Figure 155 plots the scores from the BGPCA. The graph shows similarities between Dorkings and Asian Game; Old English Game and Hamburgh/egg-types. The crossbred Junglefowl and Silkies are morphologically distinct and plot separately from the rest. Loadings (Appendix E, Section 5.4.4) show that the most significant shape-changes for PCI are associated with landmarks 5,2 and land I 6 , which all relate to the breadth of the proximal end and 16 which relates to the expansion of the trochlea of the second metatarsal. For PC2, landmarks 17 and 6 capture shifts in the position of the distal foramen and the lateral foramen (proximal) respectively; landmarkI8 relates to the breadth of the shaft and landmark 2 identifies shape-change in the medial cotyla. A one way Permanova test (using scores from the first two principal components) for this analysis is presented in Appendix E, Section 5.4.7.

### 6.6.3 Archaeological samples

The archaeological dataset consisted of 6I tarsometatarsi from Uley, Lyminge and Chester, as closely matched as possible with the measurement ratios dataset. As with the measurement ratio dataset, numbers of specimens from the three sites were heavily biased in favour of Lyminge which produced a very large number of tarsometatarsi of which 47 (well-preserved, left-sided) were selected. Only five were suitable from Uley and nine from Chester. A GPA (Generalised Procrustes Analysis) was performed on the raw data coordinates, a covariance matrix generated and a PCA (Principal Components Analysis) carried out to investigate shape differences between these three assemblages and identify any outliers.

Percentages of variance for the first five principal components are presented in Table 73 (complete results are in Appendix E, Section 5.4.5).

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00003928 | 22.78 | 22.78 |
| 2 | 0.00002501 | 14.51 | 37.29 |
| 3 | 0.00001852 | 10.74 | 48.04 |
| 4 | 0.00001564 | 9.07 | 57.11 |
| 5 | 0.00001118 | 6.48 | 63.59 |

Table 74: Archaeological chickens - tarsometatarsi. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first five principal components.

Figures 156 to 158 show the shape changes associated with the first three principal components, which together account for nearly half of the variance. The first principal component (Figure 156) seems to describe a transition from robust to slender but closer examination reveals that positive scores are associated with more similar proximal, distal and mid-shaft breadths, producing a bone with a more parallel outline. Specimens with negative scores have a smaller mid-shaft breadth compared to proximal and distal measurements, giving a more 'nipped-in' profile. The second component reflects a change from a broader, 'flatter' proximal articulation, thicker shaft and medially-inclined central trochlea to a narrower articulation with a more prominent medial cotyla edge and a more slender shaft (landmark 2).


Figure 156: All archaeological chickens - tarsometatarsi. Outline graphs showing shape change associated with the $1^{\text {st }}$ principal component. Scale factor $=\mathbf{- 0 . 0 5}$ (above) and 0.05 (below)


Figure 157: All archaeological chickens - tarsometatarsi. Outline graphs showing shape change associated with the $2^{\text {nd }}$ principal component. Scale factor $=-0.05$ (above) and 0.05 (below)

PC3 (Figure 158) describes changes at the distal articulation, with negative scores associated with larger central and lateral trochlea and smaller lateral trochlea and
positive scores showing the opposite. PC3 also reflects changes at the proximal articulation, with a hint of a bowed shaft.


Figure 158: All archaeological chickens - tarsometatarsi. Outline graphs showing shape change associated with the $3^{\text {rd }}$ principal component. Scale factor $=-0.05$ (above) and 0.05 (below)


Figure 159: All archaeological chickens - tarsometatarsi. Scatterplot of scores for principal components 1 and 2. Colour key: purple - Uley; green - Lyminge; red - Chester.


Figure 160: All archaeological chickens - tarsometatarsi. Scatterplot of scores for principal components 1 and 3. Colour key: purple - Uley; green - Lyminge; red - Chester.

Scores from the initial PCA are plotted in Figures 159 and 160. For this analysis, the specimens with spurs or spur scars have been depicted with square points. In Figure 159, the Lyminge points are broadly distributed. The Uley tarsometatarsi (all from spurred and therefore presumably male birds) cluster at the positive end of the PCl axis: the spurred Chester tarsometatarsi and most of the spurred Lyminge also have positive scores. The second component does not distinguish between Lyminge and Uley, although the Chester specimens are more alike and plot quite closely around the mean. PC3 (Figure 160) does not distinguish between Lyminge and Chester but the Uley specimens plot around the mean. These results suggest basic shape-similarities in male tarsometatarsi across space and time and perhaps between different 'breeds' or types.

## Discriminant Function Analysis

Discriminant function analysis was carried out using scores from the first four principal components: $68.85 \%$ of the specimens were initially classified correctly, $62.3 \%$ after cross-validation. The biplot (Figure 161) indicates the relative significance of the PCs
on each group and clearly show the influence of the first component on the Uley specimens.


Figure 161: Archaeological tarsometatarsi: DFA of first 4 PCs. Axis 1 accounts for $95 \%$ of the variance, Axis 2 for $5 \%$ of the variance. Colour key: Uley - purple; Lyminge - green; Chester - red.

The confusion matrix is presented in Table 74 and classifications can be found in Appendix E, Section 5.4.6.

|  | Lyminge | Uley | Chester | Total |
| :--- | :---: | :---: | :---: | :---: |
| Lyminge | $33 / 32$ | $2 / 2$ | $12 / 13$ | 47 |
| Uley | $0 / 0$ | $4 / 3$ | $1 / 2$ | 5 |
| Chester | $2 / 3$ | $2 / 3$ | $5 / 3$ | 9 |
| Total | $35 / 35$ | $8 / 8$ | $18 / 18$ | 61 |

Table 75: DFA of Lyminge, Uley and Chester tarsometatarsi using first five PCs. Confusion matrix before/after cross-validation.


Figure 162: BGPCA of modern breeds/types with Lyminge and Chester - tarsometatarsi. Colour key: yellow Asian Game; brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; blue - cross-bred Junglefowl; pink - Silkie; black - Lyminge (middle) and Chester (bottom).

## Between-groups PCA

Between-groups PCA was applied to each archaeological group individually with the modern breed groups: the graphs (Figure 162) show that the archaeological tarsometatarsi plot in similar locations compared to the modern groups, showing more similarities with the cross-bred Junglefowl. The Lyminge points are more numerous and have a wider distribution: some overlap with the more robust Dorking and Old English Game. A one way Permanova test (using scores from the first two principal components) for this analysis is presented in Appendix E, Section 5.4.7.

### 6.7 Classifying unknowns: archaeological coracoids

### 6.7.I Introduction

The previous analyses show that shape-differences can be identified between the modern breeds/groups and the archaeological datasets also show some variation. Classifying the archaeological material according to type is problematic: the datasets are unequal risking overfitting of the data and over-optimistic results when running discriminant function analysis (DFA). In an attempt to overcome these problems, a combination of BGPCA and DFA was used to categorise the archaeological bones. The coracoid was chosen for a number of reasons: the results from the initial modern and archaeological analyses indicate that differences between types can be identified using this element; there are five different archaeological datasets for the coracoid (whereas there are only three for the humerus, tibiotarsus and tarsometatarsus); significantly, many of these specimens have been submitted for DNA and isotope analysis and the resulting data can be used in future multi-disciplinary investigations.

### 6.7.2 Method

The analysis was initially carried out using coracoids from all six of the modern breed/type groups and those from Uley, Flixborough, Coppergate, Lyminge and Chester. Five new datasets were constructed in Morphof (one for each archaeological assemblage) and a new Generalised Procrustes Analysis carried out and covariance matrix generated. The data were exported to Past and between-groups PCA run on the Procrustes coordinates. The PC scores from these analyses were subjected to DFA with the archaeological specimens renamed as '?’ This method produces a cross-
validated result for the modern categorised specimens but not the 'unknowns'. Unsurprisingly, very few archaeological coracoids were classified as Silkies or Asian Game so for a subsequent analysis these were removed from the modern breed/types dataset leaving a heavy type (Dorking) an egg-type (Hamburgh), a fighting breed (Old English Game) and the cross-bred Junglefowl. The graphs in the results section (Figures 163 - 167) illustrate only the latter, four-group, analyses but comparative information on the six-group analyses are presented in Table 75 and classification tables for each are given in the appendices (Appendix F, Sections 6.I-6.5), along with accompanying confusion matrices.

### 6.7.3 Results



Figure 163: Four modern breeds/groups and Uley - coracoids. DFA of PC scores following BGPCA. Colour key: brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; black - Uley.

The Uley chickens (Figure 163) have most specimens classified as Hamburghs, with 38\% falling into this group. Both Dorkings and Old English Game were classified equally at $31 \%$. None were classified as cross-bred Junglefowl.


Figure 164: Four modern breeds/groups and Flixborough - coracoids. DFA of PC scores following BGPCA. Colour key: brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; black - Flixborough.

The Flixborough chickens are mostly concentrated in the same area as the Old English Game (Figure 164). The classification table (Appendix F: Section 6.2.2) shows that $68 \%$ are categorised as Old English Game and 29\% as Hamburghs.

The Coppergate chickens also show similarities with Old English Game (Figure 165). Sixty-six per cent are classified as Old English Game, 26\% as Hamburghs, 4\% as Dorkings and 4\% as cross-bred Junglefowl.

Well over half (6I\%) of the Lyminge coracoids were classified as Old English Game (Figure 166); Hamburgh and Dorking at $19 \%$ and $17 \%$ respectively and cross-bred Junglefowl at 3\%.


Figure 165: Four modern breeds/groups and Coppergate -coracoids. DFA of PC scores following BGPCA. Colour key: brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; black - Coppergate.


Figure 166: Four modern breeds/groups and Lyminge - coracoids. DFA of PC scores following BGPCA. Colour key: brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; black - Lyminge.


Figure 167: Four modern breeds/groups and Chester - coracoids. DFA of PC scores following BGPCA. Colour key: brown - Dorking; green - Hamburgh/egg-type; red - Old English Game; black - Chester.

The Chester coracoid classifications were distributed equally between Old English Game, Dorking and Hamburgh (all 3I\%) with cross-bred Junglefowl at 7\% (Figure 167), Reference to the shape change diagrams and original image (not illustrated) suggests that the Chester outlier on PC2 (at approximately -4.08) may be the result of a misplaced landmark at the humeral end.

### 6.8 Methods comparison and discussion

### 6.8.I Modern groups - discriminant function analysis

Comparisons can be drawn between the results from measurement ratios and geometric morphometrics using the four elements from modern chickens grouped by six breeds/types. Table 76 shows the condensed results from confusion matrices generated by discriminant function analysis using these six named groups. Element numbers (columns headed ' N ') are occasionally inconsistent between measurement ratio samples and GMM samples due to incomplete disarticulation, pathology etc. which means that the datasets are not exactly comparable but in all other respects the analysis has been as consistent as possible. For example, the ratios for the tibiotarsus were reduced to six, derived from just four measurements, to closely match the
method for the coracoid, humerus and tarsometatarsus. Graphs visualising the percentage of correct classifications for each breed and element, after cross-validation, are presented in Figure 168. Results for the measurement ratios are derived from
Tables: 15; 20; 30; and 35 (Sections 5.3.3.I; 5.3.4.I; 5.3.6.I; and 5.3.7.I respectively).
Results for the GMM are from Tables: 57; 62; 67; and 72 (Sections 6.3.2; 6.4.2; 6.5.2; and 6.6.2 respectively).

| MEASUREMENT RATIOS |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  |  | Humerus |  |  | TBT |  |  | TMT |  |  |
| Breed | $N$ | Class | Breed | N | Class | Breed | N | Class | Breed | N | Class |
| Dorking | 9 | 7/4 | Dorking | 9 | 3/1 | Dorking | 9 | 8/6 | Dorking | 9 | 5/5 |
| H'burgh | 8 | 4/4 | H'burgh | 9 | 6/5 | H'burgh | 8 | 5/4 | H'burgh | 8 | 5/3 |
| X-B JF | 7 | 6/5 | X-B JF | 8 | $6 / 6$ | X-B JF | 8 | 8/6 | X-B JF | 8 | 3/3 |
| OEG | 9 | 6/4 | OEG | 10 | 6/4 | OEG | 10 | 5/4 | OEG | 10 | 4/3 |
| Silkie | 7 | 6/3 | Silkie | 7 | 3/1 | Silkie | 7 | 6/5 | Silkie | 7 | 4/4 |
| Asian G | 6 | 3/3 | Asian G | 6 | 3/3 | Asian G | 6 | 5/4 | Asian G | 6 | 5/2 |
| Percent |  | 69/50 |  |  | 55/40 |  |  | $77 / 60$ |  |  | 54/41 |
| GEOMETRIC MORPHOMETRICS |  |  |  |  |  |  |  |  |  |  |  |
| Coracoid |  |  | Humerus |  |  | TBT |  |  | TMT |  |  |
| Breed | N | Class | Breed | $N$ | Class | Breed | N | Class | Breed | $N$ | Class |
| Dorking | 6 | 5/4 | Dorking | 9 | 9/6 | Dorking | 9 | $7 / 6$ | Dorking | 8 | 7/4 |
| H'burgh | 7 | 6/2 | H'burgh | 8 | 8/7 | H'burgh | 6 | 5/5 | H'burgh | 7 | 6/3 |
| X-B JF | 6 | 6/5 | X-B JF | 6 | 5/2 | X-B JF | 7 | 6/6 | X-B JF | 7 | 716 |
| OEG | 9 | 5/2 | OEG | 10 | 8/7 | OEG | 10 | 8/7 | OEG | 9 | 716 |
| Silkie | 7 | 6/4 | Silkie | 7 | $7 / 6$ | Silkie | 7 | 7/5 | Silkie | 7 | $7 / 7$ |
| Asian G | 4 | 4/2 | Asian G | 6 | 6/3 | Asian G | 6 | 4/3 | Asian G | 6 | 5/5 |
| Percent |  | 82/48 |  |  | 93/67 |  |  | 82/71 |  |  | 88/70 |

Table 76: Condensed results of DFA of the modern breeds/types groups using measurement ratios and geometric morphometrics. Key: $\mathbf{N}=$ number of specimens; Class = correct classification before/after crossvalidation; Percent $=$ percentage of correct classifications for each element before/after cross-validation.

It can be seen from Figure 168 that, for the humerus, tibiotarsus and tarsometatarsus, geometric morphometrics is generally more successful than measurement ratios at identifying features which separate the three modern groups. This especially applies in the case of the tarsometatarsus, which returns a very high cross-validated success-rate
for Asian Game, Silkies (I00\%), Old English Game and Cross-bred Junglefowl. The tibiotarsi also seem to display distinct breed-related morphologies.

The coracoid results are more complex - here, GMM has identified a similarity between Old English Game and Hamburghs which significantly reduces the correct classifications for these two types. The humerus results are interesting: measurement ratios cannot easily distinguish between the more robust Dorking and Silkie humeri while the cross-bred Junglefowl separate successfully using measurement ratios but are confused with Hamburghs when GMM is applied.


Figure 168: Correct classifications after cross-validation from Table 75 presented as percentages. Lines should not be interpreted as a connection between the datapoints but as an heuristic device to aid interpretation.

### 6.8.2 Modern groups - Between-groups PCA

Table 76 compares results from between-groups principal component analyses using the same six named modern groups. It is based on the $p$-values from Permanova tests
of the scores from the first two components following the BGPCA of the measurement ratios, derived from Tables: 14; 19; 28; and 34 (Sections 5.3.3.I; 5.3.4.I; 5.3.6.I; and 5.3.7.I respectively), and for the GMM, derived from tables in Appendix E Sections 5.I.8; 5.2.7; 5.3.6; and 5.4.6.

| Element | p -value | Number of breed pairs separated |  |
| :--- | :---: | :---: | :---: |
|  |  | Measurement ratios | GMM |
| Coracoid | $<0.05$ | II | II |
|  | $<0.00 \mathrm{I}$ | 5 | 4 |
| Humerus | $<0.05$ | II | 13 |
|  | $<0.00 \mathrm{I}$ | 3 | 8 |
|  | $<0.05$ | 10 | 14 |
|  | $<0.00 \mathrm{I}$ | 0 | 7 |
| Tarsometatarsus | $<0.05$ | 10 | 13 |
|  | $<0.00 \mathrm{I}$ | 0 | 8 |

Table 77: Summary of results from Permanova tests of scores from ${ }^{\text {1st }}$ and $2^{\text {nd }}$ PCs following BGPCA.
The results show the number of breed pairs (from a possible 15 comparisons) that can be statistically separated using the two techniques (returning a p-value of $<0.05$ ). For all four elements, geometric morphometrics separates as many or more pairs than the measurement ratio method. The table also summarises the number of pairs that were very confidently separated (with a p-value of $<0.00 \mathrm{I}$ ): with the exception of the coracoid, geometric morphometrics appears much more successful overall in determining the shape variation, especially when applied to the leg bones. The measurement ratios are marginally better at separating the breeds using the humerus and coracoid than the leg bones. However, there are significant differences between the two methods depending upon which element they are applied to.

Table 77 summarises the breed pairs unable to be distinguished according to element and method. The six individual breed/types are listed in the left column: the columns headed coracoid, humerus, TBT and TMT list the breeds which cannot be distinguished (i.e. with $p$-values $>0.05$ ) according to the two methods. For example, when using the measurement ratios, Dorking coracoids are confused with Silkies, when using GMM they are indistinguishable from both Silkies and Asian Game.

| Measurement ratios |  |  |  | Humerus |
| :--- | :--- | :--- | :--- | :--- |
| Breed | TBT | TMT |  |  |
| Dorking | Sk | Sk, Asian G | Sk | X-B JF, OEG |
| Hamburgh | OEG | Sk | X-B JF, OEG | - |
| X-B JF | - | - | OEG, H'burg | Dk, OEG, Sk |
| OEG | H'burg, Sk | - | X-B JF, Asian <br> G, H'burg | Dk, X-B JF |
| Silkie | Dk, Asian G, <br> OEG | Dk, H'burg, <br> Asian G | Dk | X-B JF, Asian G |
| Asian G | Sk | Dk, Sk | OEG | Sk |
| Geometric | Morphometrics |  |  |  |
| Breed | Coracoid | Humerus | TBT | TMT |
| Dorking | Sk, Asian G | - | - | - |
| Hamburgh | OEG | X-B JF | - | OEG |
| X-B JF | - | H'burg | - | - |
| OEG | H'burg | Sk | - | H'burg, Asian G |
| Silkie | Dk, Asian G | OEG | Asian G | - |
| Asian G | Dk, Sk | - | Sk | OEG |

Table 78: Results from Permanova tests of scores from 1st and 2 ${ }^{\text {nd }}$ PCs following BGPCA. Key: Dk - Dorking; H'burg - Hamburgh/egg-type; X-B JF - Cross-bred Junglefowl; OEG - Old English Game; Sk - Silkie; Asian G - Asian Game.

Of the four elements, the coracoid produces the most consistent results - neither GMM nor measurement ratios can distinguish between Hamburghs and Old English Game, or between Silkies, Dorkings and Asian Game. This consistency is not evident in results from the other elements, particularly the humerus. Here, the p-values are frequently contradictory: while (as expected) Dorking v Asian Game and Silkie v Asian Game both return high p-values (similar morphology) in the measurement ratio test, they produce very low p-values in the GMM test. Conversely, the Old English Game v Silkie and Hamburgh v Cross-bred Junglefowl produced high values for the GMM test but their measurement ratio p-values are very low. This would suggest that, for the humerus at least, the two methods are identifying different diagnostic features and the results are not necessarily incompatible.

### 6.8.3 Archaeological specimens - Between-groups PCA and DFA

Permanova tests were carried out on the scores from the first two principal components following between-groups PCA of the Procrustes coordinates. Results (pvalues from the BGPCA) for the coracoid are presented in Appendix E, Section 5.I.8. These results suggested similarities between the archaeological specimens and traditional breeds, especially the Hamburgh/egg-types. Applying discriminant function analysis to the full set of PC scores allowed further investigation into the differences between these assemblages.

| DFA using six modern groups |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Uley |  | Flixborough |  | Coppergate |  | Lyminge |  | Chester |  |
| Breed | N | \% | N | \% | N | \% | N | \% | N | \% |
| Dorking | 5 | 31 | 0 | 0 | 2 | 3.5 | 4 | 11 | 1 | 7.5 |
| Hamburgh | 8 | 50 | 14 | 45 | 20 | 38 | 14 | 38 | 7 | 54 |
| X-B JF | 0 | 0 | 0 | 0 | 2 | 3.5 | 1 | 2.5 | 2 | 15.5 |
| OEG | 3 | 19 | 16 | 52 | 29 | 55 | 18 | 48.5 | 2 | 15.5 |
| Silkie | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| Asian G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 7.5 |
| Total | 16 |  | 31 |  | 53 |  | 37 |  | 13 |  |
| DFA using four modern groups |  |  |  |  |  |  |  |  |  |  |
|  | Uley |  | Flixborough |  | Coppergate |  | Lyminge |  | Chester |  |
| Breed | N | \% | N | \% | N | \% | N | \% | N | \% |
| Dorking | 5 | 31 | 1 | 3 | 2 | 4 | 6 | 16 | 4 | 31 |
| Hamburgh | 6 | 38 | 9 | 29 | 14 | 26 | 8 | 22 | 4 | 31 |
| X-B JF | 0 | 0 | 0 | 0 | 2 | 4 | 1 | 3 | 1 | 7 |
| OEG | 5 | 31 | 21 | 68 | 35 | 66 | 22 | 59 | 4 | 31 |
| Total | 16 |  | 31 |  | 53 |  | 37 |  | 13 |  |

Table 79: Results of DFA breed classifications using PC scores from BGPCA of the Procrustes coordinates.
Key: No - Number of coracoids classified to each breed per site; \%-percentage of the total number of coracoids for that site.

Table 79 and Figure 169 present the condensed results of the discriminant function analyses carried out in Section 6.7. While comparative analysis is somewhat restricted by the small number of specimens from Uley and Chester, it is clear that there are type-differences between the assemblages. The results do not mean that the archaeological coracoids were derived from chickens of these breeds, simply that they show closer resemblance to the modern examples. Generally, most of the coracoids
were classified as either Hamburgh/egg-type or Old English Game, with somewhat fewer heavy Dorking-types and only four lighter Junglefowl. For the Saxon period sites, the percentages for each type are similar between Flixborough and Coppergate, with Old English Game dominating; the Lyminge assemblage has more Dorking-types at the expense of Hamburghs. Uley (Roman) and Chester (Early-modern) show more diversity for both analyses but the smaller sample sizes for these sites may be a factor. With this in mind, the evidence does suggest that more of the chickens from Uley and Chester were of a robust type. The dominance of spurred tarsometatarsi from Uley and the ritual nature of the site indicate that the majority of the bones recovered were from male birds and the robusticity here might therefore be associated with sexualdimorphism. The Chester assemblage is derived from a feasting deposit and it is reasonable to assume that some, at least, of the chickens from the feasting pit may have been selected for a heavier carcass.


Figure 169: Stacked barchart illustrating data from Table 79. Coracoids from five archaeological assemblages assigned (left) to one of six breeds/types, and (right) to one of four breeds/types.

## 7 Species differentiation study - Galliform distinction

## 7.I Introduction

As well as investigating breed-related skeletal morphology in domestic fowl, a parallel study was also undertaken to ascertain if shape analysis using geometric morphometrics could separate four species of closely-related Galliformes, i.e. domestic fowl, guinea fowl, common pheasant and black grouse. The difficulty in distinguishing these species and the significance of identification errors and subsequent misinterpretation has been covered in Section 3.2.6.

Following evaluation of the material available and discussion with other zooarchaeologists (see Section 3.2.6), a combination of 'easy' (coracoid and tarsometatarsus) and 'difficult' (humerus and tibiotarsus) elements were selected for the study. A brief summary of specimens included is given at the beginning of each section; further details are available in Appendix A, Section I.2. Datasets comprising archaeological chicken bones from Roman and Saxon contexts were used for comparison.

General Procrustes Analysis was carried out on the dataset for each element and pooled within-group (species) regression analysis undertaken to determine whether size and shape were independent. Depending on the results, principal component analysis was carried out on the original dataset or, if allometry was considered to be a factor, on the residuals from the regression. This was followed by further analysis and testing using between-groups principal component analysis (BGPCA), Permanova (nonparametric Manova) and discriminant function analysis (DFA).

### 7.2 Coracoid results

Sixty-two specimens were initially included in the coracoids analysis: 26 pheasant; 12 black grouse; and eight guinea fowl together with 16 chickens from Uley. Generalised Procrustes Analysis (GPA) was performed on the raw data coordinates to facilitate an exploration of the complete dataset. A covariance matrix was generated and a Principal Components Analysis (PCA) was conducted on this matrix. Examination of the scatterplot of PC scores from this preliminary PCA (not illustrated) showed that the black grouse coracoids were clearly separated whilst the other three species
showed considerable mixing. As the coracoid of black grouse can be easily distinguished from chicken, pheasant and guinea fowl due to the distinctive shape of the processus lateralis and the angulus medialis, the 12 grouse coracoids were excluded and the Procrustes analysis repeated on the reduced dataset in an attempt to improve separation between pheasants, chickens and guinea fowl.

Pooled within-group (species) regression analysis was carried out on the dataset to test for the presence of allometry and assess whether variation in shape is related to size difference. The results are presented in Appendix G, Section 7.I. The p-value of 0.452 indicated that the null hypothesis of independence cannot be rejected - shape and size are probably independent and allometry is unlikely to be a factor.

Principal Components Analysis (PCA) was carried out on the reduced dataset and a table of the eigenvalues of the first 10 principal components can be found in Appendix G, Section 7.I. These first 10 components explain approximately $90 \%$ of the variance within the dataset with the remaining 14 only accounting for $10 \%$ of the variance.


Figure 170: Modern guinea fowl and pheasants with Uley chickens - coracoids. Scatterplot of scores for principal components 1 ( $33 \%$ var.) and 2 ( $15 \%$ var.). Colour key: Red - pheasant; blue - guinea fowl; purple Uley.

The scores for the first two principal components responsible for $33 \%$ and $15 \%$ of the variance respectively are plotted in Figure 170. Shape changes associated with the first principal component distinguish chickens, which plot negatively of the mean, from pheasants which have mostly positive scores. Guinea fowl are more scattered, however, it is interesting to note that the 'unimproved' individual (e028) plots at the extreme negative end of the scale. The second component separates the pheasants and chickens from the guinea fowl but not from each other. Principal components other than the first two were not effective in separating the three species and were not included in further analyses.

Outline diagrams to illustrate shape changes associated with the first principal component are presented in Figure 171. Negative scores (above) on the PCI axis are characterised by a slightly narrower corpus and significant compression at the processus lateralis (landmark 4) and a shift in landmarks 10 and II which gives the appearance of a smaller processus acrocoracoideus. All of the chicken coracoids cluster in this area. Positive scores (below) reflect the opposite: a broader corpus with expansion at the lateral process and expansion of the acrocoracoidal process. These features are more likely to characterise pheasants. The changes can be compared with diagnostic features observable in Tomek and Bocheński's reference manual (2009:26), in particular, the pronounced lateral process and changes at the acrocoracoidal process resulting in a more 'open' triosseal canal in pheasants compared to chickens.

Shape changes related to the second principal component (Figure 172) separate guinea fowl but not pheasants and chickens. Positive scores (above) seem to show a distorted corpus, although caution must be used when interpreting outline graphs as the lines between landmarks are a suggestion only. There is considerable broadening at the processus procoracoideus (landmark I3) and expansion at the extreme point of the cranial end (landmark 9). The point of the processus acrocoracoideus (landmark 12) is diminished resulting in a less well-defined 'hook', while the lateral angle (landmark 2) is positioned more centrally. Negative scores (below) show the inverse, with the most obvious shape change being a slimmer articulation with the scapula (landmarks 5 and 13) and a more pronounced processus acrocoracoideus (landmark 12). The changes associated with positive scores can be observed on guinea fowl coracoids, especially
the shift in the position of the lateral angle which results in a shorter facies articularis sternalis.


Figure 171: Modern guinea fowl and pheasants with Uley chickens - coracoids. Shape change graphs associated with the $1^{\text {st }}$ principal component. Scale factor $=\mathbf{- 0 . 0 5}$ (above) and 0.05 (below).


Figure 172: Modern guinea fowl and pheasants with Uley chickens - coracoids. Shape change graphs associated with the $2^{\text {nd }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below).

A Permanova (no of permutations $=9999$ ) of the Procrustes coordinates was used to test the results as MANOVA requires the number of cases to exceed the number of variables, which was not true of the guinea fowl specimens. Full results are presented in Appendix G, Section 7.I.

|  | Pheasant | Guinea fowl | Chicken |
| :---: | :---: | :---: | :---: |
| Pheasant | - | $0.000 \mathrm{I} / 6.283$ | $0.000 \mathrm{I} / \mathrm{I} 4.92$ |
| Guinea Fowl | $0.000 \mathrm{I} / 6.283$ | - | $0.0003 / 7.286$ |
| Chicken | $0.000 \mathrm{I} / 14.92$ | $0.0003 / 7.286$ | - |

Table 80: Modern pheasants and guinea fowl with Uley chickens - coracoids. Permanova p-values/F-values from pairwise comparisons.

In the case of guinea fowl/pheasants and guinea fowl/chicken, the F-stat (9.715) is larger than the F -value and the null hypothesis (of no difference) cannot be rejected, but the pheasant/chicken F -value is larger, meaning the null-hypothesis can be rejected and these two groups can be completely separated (Table 80).

## Between-groups PCA



Figure 173: Modern pheasants, guinea fowl and Uley chickens - coracoids. Scatterplot of Between-Groups PCA components 1 ( $54 \%$ var.) and 2 ( $46 \%$ var.). Colour key: Red - pheasants; blue - guinea fowl; purple Uley.

A between-groups principal component analysis was carried out using the same coordinates. The scores are plotted in Figure 173.

## Discriminant Function Analysis

The PC scores from the BGPCA were subjected to discriminant function analysis using the same method as for the chicken coracoids in Section 6.7 (Figure 174). Ninety-six per cent of the specimens were classified correctly - after cross-validation this was still 96\% (see Table 81).


Figure 174: Pheasants, guinea fowl and Uley chickens - coracoids. DFA of PC scores following BGPCA. Colour key: Red - pheasants; blue - guinea fowl; purple - Uley.

|  | Pheasant | Guinea fowl | Uley | Total |
| :--- | :---: | :---: | :---: | :---: |
| Pheasant | $25 / 25$ | $0 / 0$ | $1 / 1$ | 26 |
| Guinea fowl | $0 / 0$ | $7 / 7$ | $1 / 1$ | 8 |
| Uley | $0 / 0$ | $0 / 0$ | $16 / 16$ | 16 |
| Total | $25 / 25$ | $7 / 7$ | $18 / 18$ | 50 |

Table 81: Pheasants, guinea fowl and Uley chickens - coracoids. Confusion matrix before/after crossvalidation.

### 7.3 Humeri results

Sixty-five specimens were initially included in the database: 21 archaeological humeri from 4th-century Uley together with 25 pheasant; 10 black grouse; and nine guinea fowl from modern reference skeletons. A Generalised Procrustes Analysis (GPA) was performed on the raw data coordinates, a covariance matrix was generated and a Principal Components Analysis (PCA) was conducted on this matrix. The resulting scatterplot (not illustrated) of the scores from the first two principal components identified the creeper humeri from Uley as outliers (u063 and u076): these were subsequently excluded. A humerus (e028) from the only 'unimproved' guinea fowl in the dataset consistently plotted with the pheasants but was left in to investigate the differences between this individual and the more developed types of guinea fowl bred for meat.

Regression analysis was carried out on this reduced dataset to test for the presence of allometry, to determine whether variation in shape is related to size difference. The results of this analysis are presented in Appendix G, Section 7.2. The p-value of 0.1194 indicates that the null hypothesis of independence cannot be rejected - shape is probably independent of size therefore allometry is not a factor and the original data (excluding creepers) was used.

A new Generalised Procrustes Analysis was performed, a new covariance matrix generated and a Principal Components Analysis (PCA) was conducted on this matrix. A table showing the results for the first II principal components can be found in Appendix G, Section 7.2. The cumulative percentages column shows that the first two components together account for approximately $60 \%$ of the variance.

A scatterplot of the scores from the first two principal components is presented in Figure 175. The first principal component ( $35 \%$ of the variance) effectively separates the chickens and pheasants while the grouse are positioned at the negative end of the scores range and the guinea fowl are much more scattered. PC2 ( $23 \%$ of the variance) distinguishes the grouse and guinea fowl but not the chickens and pheasants. Note the guinea fowl outlier (e028) positioned within the pheasant cluster. All groups were more mixed when using the third and subsequent components (not illustrated) and although some separation was apparent, these were less useful than the first two PCs.


Figure 175: Modern other Galliformes with Uley chickens - humeri. Scatterplot of scores for principal components 1 ( $35 \%$ var.) and 2 ( $23 \%$ var.). Colour key: Red - pheasant; blue - guinea fowl; black - black grouse; purple - Uley.

Figure 176 shows shape changes associated with PCI which accounts for approximately $35 \%$ of the variance. The top outline shows changes described by the positive scores (which plot right of the mean on the scatterplot); the points in this area represent all of the chicken humeri and some of the guinea fowl. There is a general broadening along the entire element: the proximal and distal ends are expanded and the shaft is thicker. The curve of the shaft is maintained. The caput (proximal articular surface between landmarks 2 and 21 ) accounts for a relatively smaller area of the entire breadth of the proximal end as the tuberculum dorsale (landmark I) is more prominent. The condyles at the distal articulation (landmarks I218) are less pronounced, leading to a flatter outline.

The lower diagram shows change associated with the negative scores at the opposite end (left of the mean); the points here represent the grouse, almost all of the pheasants and some of the guinea fowl. The humerus is much narrower and appears
somewhat straighter. At the proximal end, the tuberculum dorsale is much less welldefined meaning the caput is relatively larger, also the tip of the crista coracoidea (landmark 6) does not extend to the margin. The distal condyles (landmarks 12-18) are much more distinct and the tuberculum supracondylare (landmark II) is less pronounced.


Figure 176: Modern other Galliformes with Uley chickens. Outline graphs showing shape changes associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below)

Figure I77 shows shape changes associated with PC2 which accounts for $24 \%$ of the variance. The top outline shows changes described by the positive scores which plot above the mean on the scatterplot (Figure 175). The most obvious changes are the straightened shaft and the expansion of the tuberculum ventral (landmarks 7 and 8) at the proximal end. The tuberculum dorsale (landmark I) is reduced. The distal end is narrower and there is greater definition of the central condyle (landmarks 14-16) making a more uneven outline.

The lower diagram shows change associated with the negative scores at the opposite end (left of the mean). The shaft has a more pronounced curve dorsally. The distal end
is relatively larger with less prominent condyles while the proximal end is more rounded and club-like.


Figure 177: Modern other Galliformes with Uley chickens. Outline graphs showing shape change associated with the $2^{\text {nd }}$ principal component. Scale $=0.05$ (above) and -0.05 (below)

The results were tested using a Permanova (with 9999 permutations) of the Procrustes coordinates. Results are in Appendix G, Section 7.2.

|  | Chicken | Pheasant | Guinea fowl | Black grouse |
| :---: | :---: | :---: | :---: | :---: |
| Chicken |  | $0.000 \mathrm{I} / 37.75$ | $0.000 \mathrm{I} / \mathrm{I} 5.43$ | $0.000 \mathrm{I} / 33.29$ |
| Pheasant | $0.000 \mathrm{I} / 37.75$ |  | $0.000 \mathrm{I} / \mathrm{I} 0.85$ | $0.000 \mathrm{I} / \mathrm{I} 7.62$ |
| Guinea fowl | $0.000 \mathrm{I} / \mathrm{I} 5.43$ | $0.000 \mathrm{I} / \mathrm{I} 0.85$ |  | $0.000 \mathrm{I} / 20.24$ |
| Black grouse | $0.000 \mathrm{I} / 33.29$ | $0.000 \mathrm{I} / \mathrm{I} 7.62$ | $0.000 \mathrm{I} / 20.24$ |  |

Table 82: Modern Galliformes and Uley chickens - humeri. Permanova p-values/F-values from pairwise comparisons.

Comparison of the F-stat with F-values (Table 82) shows that in the case of chicken/guinea fowl, pheasant/guinea fowl, pheasant/black grouse and guinea fowl/black grouse, the F-stat (22.1) is larger than the F-value and the null hypothesis (that they are the same) cannot be rejected, but the chicken/black grouse and chicken/pheasant F-values are larger, meaning that in these cases the null-hypothesis can be rejected and the groups can be confidently separated.

## Between-groups PCA

A between-groups principal component analysis was carried out using the same coordinates. The scores are plotted in Figure I78.


Figure 178: Modern Galliforms with Uley chickens - humeri. Scatterplot of Between-Groups PCA components 1 ( $57 \%$ var.) and 2 ( $34 \%$ var.). Colour key: Red - pheasant; blue - guinea fowl; black - black grouse; purple Uley.

## Discriminant Function Analysis

A discriminant function analysis was carried out on the scores from the BGPCA. Although the plot (Figure 179) shows some confusion between the guinea fowl and pheasants, classification was almost I00\% correct - $98.41 \%$ before and after crossvalidation (Table 83).


Figure 179: Pheasants, guinea fowl and Uley chickens - humeri. DFA of PC scores following BGPCA. Colour key: Red - pheasants; blue - guinea fowl; black - black grouse; purple - Uley.

|  | Uley | Pheasant | Guinea fowl | Black grouse | Total |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Uley | $19 / 19$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 19 |
| Pheasant | $0 / 0$ | $25 / 25$ | $0 / 0$ | $0 / 0$ | 25 |
| Guinea fowl | $0 / 0$ | $1 / 1$ | $8 / 8$ | $0 / 0$ | 9 |
| Black grouse | $0 / 0$ | $0 / 0$ | $0 / 0$ | $10 / 10$ | 10 |
| Total | $19 / 19$ | $26 / 26$ | $8 / 8$ | $10 / 10$ | 63 |

Table 83: Pheasants, guinea fowl, black grouse and Uley chickens - humeri. Confusion matrix before/after cross-validation.

### 7.4 Tibiotarsi results

Fifty-two specimens were available for inclusion in the analysis of the tibiotarsi: 21 pheasant; 10 black grouse; and 6 guinea fowl, together with 15 specimens from the Lyminge assemblage (used in this case in place of the Uley tibiotarsi which only numbered two complete and undamaged specimens). The landmark configurations were subjected to Generalised Procrustes Analysis (GPA) and a covariance matrix was
generated. Principal Components Analysis (PCA) was conducted on this matrix for initial investigation of the data.

Regression analysis was carried out on the dataset to test for the presence of allometry, to determine whether variation in shape is related to size difference. The results of this analysis are presented in Appendix G, Section 7.3. The p-value of 0.7716 indicates that the null hypothesis of independence cannot be rejected - shape and size are probably independent of each other and allometry is not a factor.

The original data was used for further analysis. A Generalised Procrustes Analysis was performed, a new covariance matrix generated and a Principal Components Analysis (PCA) was conducted on this matrix. Results for the first II principal components are presented in Appendix G, Section 7.3. The cumulative percentages column shows that the first two components together are responsible for approximately $80 \%$ of the variance, with the first component alone accounting for $60 \%$. The contribution of the remaining components is minor.


Figure 180: Modern other Galliformes with Lyminge chickens - tibiotarsi. Scatterplot of scores for principal components 1 ( $60 \%$ var.) and 2 ( $18 \%$ var.). Colour key: Colour key: Red - pheasants; blue - guinea fowl; black black grouse; green - Lyminge.

The scatterplot for principal components I v 2 (Figure I80) shows clustering of the groups but without separation. Although the variance appears wide on the first component, the points are mostly concentrated around the mean with little distinction between chickens, pheasants and grouse. Guinea fowl have mostly negative scores, towards the right of the axis, although the shape of the 'wild type' guinea fowl tibiotarsus (e028) is the closest of all to the mean and does not show the modification of the farmed specimens. A couple of the pheasants are positioned away from the main cluster at the extreme right. For the second component, the chickens and grouse lie positive and negative of the mean respectively but it is not effective in separating the guinea fowl and pheasants.

The plot for principal components 2 v 3 (Figure I8I) showed that the third component, although responsible for only $6 \%$ of the variance, effectively separated the grouse and pheasants and the chickens and pheasants. The guinea fowl were more scattered but, like the pheasants, tended towards the positive scores.


Figure 181: Modern other Galliformes with Lyminge chickens - tibiotarsi. Scatterplot of scores for principal components 2 ( $18 \%$ var.) and 3 ( $6 \%$ var.). Colour key: Red - pheasants; blue - guinea fowl; black - black grouse; green - Lyminge.

Some separation was apparent using the fourth and subsequent components (not illustrated) but these were not as useful as the first three components and were not investigated further.

Shape changes associated with the first, second and third principal components are depicted in Figures I82 to I84.


Figure 182: Modern other Galliformes with Uley chickens - tibiotarsi. Outline graph showing shape changes associated with the $1^{\text {st }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below).

Figure 182 shows shape changes associated with PCI which accounts for approximately $60 \%$ of the variance. The main shape change is a proportional and overall transition from a gracile bone (positive scores) to a more robust one (negative scores). Also of note is the shift of landmark 4 which marks the terminal extent of the crista fibularis. Examination of the graphs which show variation from the mean for each individual specimen following initial GPA (not illustrated) reveals that those individuals which most strongly display this characteristic are pheasants (in which the crista fibularis terminates more proximally) and guinea fowl (the landmark is placed distal of the mean). This concurs with the scatterplot (Figure 180).


Figure 183: Modern other Galliformes with Uley chickens. Outline graphs showing shape changes associated with the $2^{\text {nd }}$ principal component. Scale factor $=0.05$ (above) and -0.05 (below).

Second PC shape changes were associated with $18 \%$ of the variance (Figure I83). Positive scores exhibit a broad shaft and a relatively larger distal articulation. The proximal end is expanded, with a flared medial edge (landmark I). Negative scores are associated with a narrow shaft and a small distal articulation with small condyles: the medial and lateral edges of the proximal end (LMs I and 3) are compressed, especially at landmark I.


Figure 184: Modern other Galliformes with Uley chickens - tibiotarsi. Outline graphs showing shape changes associated with the $3^{\text {rd }}$ principal component. Scale factor $=-0.05$ (above) and 0.05 (below).

Although the third principal component (Figure 184) only accounted for 6\% of the variance the shape changes were significant in separating the groups. At the proximal end, negative scores indicated a reduced point of the crista cnemialis cranialis (landmark 2) while in the specimens with positive scores this was relatively elongated Tomek \& Bocheński (2009:66) identify the relatively short crista cnemialis cranialis as a distinguishing feature of grouse, which are grouped at the negative end of the PC3 vector (Figure 181 ). At the distal end of the tibiotarsus, for positive scores the sulcus extensiorus is placed medial of the centre, which is noted as an identifying feature for pheasants (ibid:73). The pons supratendinius (delimited by landmarks 10 and II) appears relatively broad and the medial condyle (landmarks 8 and 9 ) is smaller relative to the lateral. The apparent curvature of the distal shaft is likely to be an artefact of the visualisation graph caused by the shift in the position of landmark II rather than an actual deformation of the shaft.

The results were tested using a Permanova (with 9999 permutations) of the Procrustes coordinates. Results are presented in Appendix G, Section 7.3.

|  | Pheasant | Guinea fowl | Black grouse | Lyminge |
| :---: | :---: | :---: | :---: | :---: |
| Pheasant |  | $0.000 \mathrm{I} / 22.26$ | $0.00 \mathrm{I} 7 / 6.788$ | $0.000 \mathrm{I} / \mathrm{I} 0.77$ |
| Guinea fowl | $0.000 \mathrm{I} / 22.26$ |  | $0.0003 / 26.34$ | $0.000 \mathrm{I} / 16.45$ |
| Black grouse | $0.00 \mathrm{I} 7 / 6.788$ | $0.0003 / 26.34$ |  | $0.000 \mathrm{I} / 18.7 \mathrm{I}$ |
| Lyminge | $0.000 \mathrm{I} / \mathrm{I} 0.77$ | $0.000 \mathrm{I} / 16.45$ | $0.000 \mathrm{I} / \mathrm{I} 8.7 \mathrm{I}$ |  |

Table 84: Modern Galliformes and Lyminge chickens - tibiotarsi. Permanova p-values/F-values from pairwise comparisons.

Comparison of the F-statistic (I5.5I) with F-values (Table 84) shows that in the case of chicken/pheasant and black grouse/pheasant, the F-statistic is larger than the F-value and the null hypothesis (that they are the same) cannot be rejected, but for all other pairs the F -values are larger, meaning that in these cases the null-hypothesis can be rejected and the groups can be confidently separated.

## Between-groups PCA

A between-groups principal component analysis was carried out using the same coordinates. The scores are plotted in Figure 185.


Figure 185: Modern Galliformes with Uley chickens - tibiotarsi. Scatterplot of Between-Groups PCA components 1 ( $77 \%$ var.) and 2 ( $16 \%$ var.). Colour key: Red - pheasants; blue - guinea fowl; black - black grouse; green - Lyminge.


Figure 186: Pheasants, guinea fowl, black grouse and Lyminge chickens - tibiotarsi. DFA of PC scores following BGPCA. Colour key: Red - pheasants; blue - guinea fowl; black - black grouse; green - Lyminge.

## Discriminant Function Analysis

A discriminant function analysis carried out on the scores from the BGPCA produced a very high correct classification of $96.15 \%$ both before and after cross-validation (Table 85). The plot (Figure 186) and the classification table (Appendix G, Section 7.3) show that the only specimens to be incorrectly classified were two guinea fowl tibiotarsi.

|  | Pheasant | Guinea fowl | Black grouse | Lyminge | Total |
| :--- | :---: | :---: | :---: | :---: | :---: |
| Pheasant | $2 \mathrm{I} / 2 \mathrm{I}$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 21 |
| Guinea fowl | $1 / 1$ | $4 / 4$ | $0 / 0$ | $1 / \mathrm{I}$ | 6 |
| Black grouse | $0 / 0$ | $0 / 0$ | $10 / 10$ | $0 / 0$ | 10 |
| Lyminge | $0 / 0$ | $0 / 0$ | $0 / 0$ | $15 / 15$ | 15 |
| Total | $22 / 22$ | $4 / 4$ | $10 / 10$ | $16 / 16$ | 52 |

Table 85: Pheasants, guinea fowl, black grouse and Lyminge chickens - tibiotarsi. Confusion matrix before/after cross-validation.

### 7.5 Tarsometatarsi results

Ninety-seven specimens were included in the tarsometatarsus study: 10 black grouse; 27 pheasant; 51 chickens (from the Lyminge assemblage); and nine guinea fowl. After an initial Generalised Procrustes Analysis Principal Component Analysis of the covariance matrix, a scatterplot of the first two components (not illustrated) showed the black grouse were very well separated. As this element is considerably smaller and relatively more gracile than the other three species it was considered to be easily distinguished using macroscopic or traditional metrical methods and was excluded from further analyses. A new GPA was performed on the remaining 87 tarsometatarsi and Principal Components Analysis (PCA) conducted on the covariance matrix.

Regression analysis was carried out on the dataset to test for the presence of allometry, to determine whether variation in shape is related to size difference. The p -value of 0.0480 indicated that the null hypothesis of independence can be rejected shape and size are probably related and allometry may be influencing the results. Although the $p$-value was close to the alpha level of 0.05 , a covariance matrix was generated on the residuals from the regression and used for further analysis to exclude this factor. Principal Components Analysis (PCA) was carried out and results
for the first II components are presented in Appendix G, Section 7.4. The cumulative percentages column shows that the first two components together are responsible for well over half ( $57 \%$ ) of the variance, with the first component alone accounting for $46 \%$. The contribution of the remaining components is relatively minor.


Figure 187: Modern pheasants and guinea fowl with Lyminge chickens - tarsometatarsi. Scatterplot of scores for principal component analysis of regression residuals: PC1 (46\% var.) and PC2 (11\% var.). Colour key: Colour key: Red - pheasants; blue - guinea fowl; green - Lyminge.

A scatterplot of the scores for principal components I and 2 (Figure 187) shows that the first component effectively separates the guinea fowl, which all have scores negative of the mean, but the chickens and pheasants are less distinct with considerable overlap. The second component places the chickens mostly negative of the mean but distinction between the guinea fowl and pheasants is unclear. The scatters become more confused using the third and subsequent components (not illustrated) and these are not investigated further.

Figure 188 shows shape changes associated with PCI which accounts for approximately $46 \%$ of the variance. The overall shape change is a proportional transition from a robust bone (negative scores) which characterises the guinea fowl to
a more gracile one (positive scores) displayed by the chickens and, to a greater degree, the pheasants.


Figure 188: Modern chickens and pheasants with Lyminge chickens - tarsometatarsi. Outline graphs showing shape changes associated with the $1^{\text {st }}$ principal component. Scale factor $=\mathbf{- 0 . 0 5}$ (above) and 0.05 (below).


Figure 189: Modern chickens and pheasants with Lyminge chickens - tarsometatarsi. Outline graphs showing shape changes associated with the $2^{\text {nd }}$ principal component. Scale factors $=\mathbf{- 0 . 0 3}$ (above) and 0.03 (below).

The scaling for the second PC shape changes (percentage) was reduced to 0.03 to offset the level of distortion and make interpretation easier (Figure 189). Negative scores represented a reduction of the lateral side of the element, from proximal to distal, with compression at the lateral tubercle (proximal end) and a relatively smaller lateral condyle (distal end). In addition, compression at the tip of the intercondylar
eminence (landmark 3) reduced this feature to make the proximal end much 'flatter'. Positive scores characterised opposite changes with the medial side of the bone reduced and the lateral more bulky together with a pronounced elongation of the intercondylar eminence (landmark 3).

|  | Pheasant | Guinea fowl | Lyminge |
| :---: | :---: | :---: | :---: |
| Pheasant |  | $0.000 \mathrm{I} / 36.32$ | $0.0001 / \mathrm{I} 8.95$ |
| Guinea fowl | $0.000 \mathrm{I} / 36.32$ |  | $0.0001 / 37.85$ |
| Lyminge | $0.000 \mathrm{I} / \mathrm{I} 8.95$ | $0.000 \mathrm{I} / 37.85$ |  |

Table 86: Modern pheasants and guinea fowl with Uley chickens - tarsometatarsi. Permanova p-values/f-values from pairwise comparisons.

Results from a Permanova test of the residuals (permutation no. 9999) are shown in Table 86. Comparison of the F-statistic (29.73) with F-values (Table 86) shows that in the case of chicken/pheasant, the F-stat is larger than the F -value and the null hypothesis (that they are the same) cannot be rejected, but for guinea fowl/pheasant and guinea fowl/chicken the F-values are larger, meaning that in these cases the nullhypothesis can be rejected and the groups can be confidently separated.


Figure 190: Modern pheasants and guinea fowl with Lyminge chickens - tarsometatarsi. Scatterplot of betweengroups PCA components 1 ( $93 \%$ var.) and 2 ( $7 \%$ var.). Colour key: Red - pheasant; blue- guinea fowl; green Lyminge.

A between-groups principal component analysis was carried out using the same coordinates. The scores are plotted in Figure 190.

## Discriminant function analysis



Figure 191: Pheasants, guinea fowl, black grouse and Lyminge chickens - tarsometatarsi. DFA of PC scores following BGPCA. Colour key: Red - pheasants; blue - guinea fowl; black - black grouse; green - Lyminge.

The PC scores from the BGPCA were subjected to discriminant function analysis (plot shown in Figure 191). $94.25 \%$ of the specimens were classified correctly - after crossvalidation this was slightly reduced to $93.1 \%$ (Table 87). Full classification table is in Appendix G, Section 7.4.

|  | Pheasant | Guinea fowl | Lyminge | Total |
| :--- | :---: | :---: | :---: | :---: |
| Pheasant | $25 / 24$ | $0 / 0$ | $2 / 3$ | 27 |
| Guinea fowl | $1 / \mathrm{I}$ | $8 / 8$ | $0 / 0$ | 9 |
| Lyminge | $2 / 2$ | $0 / 0$ | $49 / 49$ | 5 I |
| Total | $28 / 27$ | $8 / 8$ | $5 \mathrm{I} / 52$ | 87 |

Table 87: Pheasants, guinea fowl, black grouse and Lyminge chickens - tarsometatarsi. Confusion matrix before/after cross-validation.

### 7.6 Discussion

Procrustes superimposition and ordination techniques have identified species-related variations in the shape of the coracoid, humerus, tibiotarsus and tarsometatarsus which appear to be consistent in modern black grouse, pheasants, archaeological chickens and, to a lesser extent, guinea fowl. Results are not directly comparable due to the black grouse being omitted from the analyses of the coracoid and tarsometatarsus.

Principal component analysis of the coracoids was effective at capturing some of the shape changes noted by Tomek and Bocheński (2009), particularly variation at the sternal end. Expansion at the humeral end, especially around the scapular articulation, is associated with the guinea fowl (identified by PC2) but is not mentioned in the manual or apparent in the photographs (ibid. 2009: 19-26). One reason may be that the specimens used in the GMM study were modern farmed guinea fowl and Romanperiod chickens: by contrast, the guinea fowl used for the manual may have been an 'unimproved' type and the chicken a modern breed. If this is the case, this morphological variation may be a feature of domestication.

All four species were included in the humerus dataset. This element is more difficult to identify to species macroscopically, particularly separating chicken and pheasants. Diagnostic features for these two species include a number of muscle attachment scars at the distal end (ibid. 2009: 35) which were not digitised. However, the relative robusticity of the humerus, the curve of the shaft and the outlines of the proximal and distal articulations defined by the first principal component (Figure 176) separate chickens from pheasants very clearly. PC2, which describes the transition from a straighter shaft and more angular proximal and distal articulations to a generally more curved, smoother outline (Figure 177), effectively distinguishes the black grouse from the guinea fowl. These changes are often so subtle that they cannot be seen in reference material or photographs.

Principal component analysis of the Procrustes coordinates of the tibiotarsi has identified distinguishing features between the four species, some of which appear in identification manuals and others that do not. Variation in the length of the crista fibularis is apparent on photographs of guinea fowl and pheasant tibiotarsi in the manual (ibid. 2009: 7I) but is not noted as a distinguishing feature in the text. This has
the potential to be a useful characteristic for discriminating between these two species when only fragmentary remains are available. Similarly, the relatively smaller medial condyle of pheasants can also be identified on reference material. Other shape changes identified by the first three components are consistent with distinguishing features proposed in the manual.

Black grouse tarsometatarsi are relatively small and were not included in this study. Pheasants have a bony blade connecting the hypotarsus with the shaft and mature male pheasants and chickens bear spurs which are distinctive to species. However, damaged tarsometatarsi and those of female and immature birds may lack these features and the male guinea fowl (Numida meleagris) does not have spurs so there is still potential for confusion. Principal components analysis identifies several features highlighted in the manual - for example, the second component picks up the bulge at the medial side of the cotyla medialis which distinguishes chickens from guinea fowl and the shorter trochlea of the second metatarsal, also a feature of guinea fowl.

Table 88 summarises the incorrect classifications from the discriminant function analysis. The guinea fowl e028 and the pheasant t079 classify incorrectly more than once but always to the same species (pheasant and chicken respectively) which implies a consistency of form across the skeleton for at least some of the specimens.

| DFA classification errors |  |  |  |
| :---: | :---: | :---: | :---: |
| Specimen | Element | Correct species | After c-v DFA |
| e02I | coracoid | guinea fowl | chicken |
| e016 | tarsometatarsus | pheasant | chicken |
| e028 | humerus | guinea fowl | pheasant |
|  | tibiotarsus |  |  |
|  | tarsometatarsus |  |  |
| t079 | coracoid | pheasant | chicken |
|  | tarsometatarsus |  |  |
| t080 | tarsometatarsus | pheasant | chicken |
| w614 | tibiotarsus | guinea fowl | chicken |

[^1]One of the most striking observations from this study is the wide shape-variability of the guinea fowl elements which overlap, not just with the black grouse and (arguably semi-domesticated) pheasants, but also with the archaeological chickens. In several cases, the archaeological chicken points cluster more closely in the scatterplots. This skeletal variability in the modern guinea fowl available for the study is very likely the result of the source material being composed almost entirely of commercially-farmed birds, suggesting that domestication and selection for a larger carcass has introduced similar morphological changes to those seen in the bones of modern domestic chickens. Guinea fowl currently raised for meat production in the UK are often imported from France as fertile eggs and are of a strain which is heavier and fastermaturing than traditional, heritage types. It is possible that some of the reference specimens accessed for the study were of these strains. The classification of the ‘unimproved’ guinea fowl (e028) humerus, tibiotarsus and tarsometatarsus as pheasant suggests that the archaeological remains of this species may not be as easily distinguished as the guinea fowl bones in this study. This individual was consistently shown to have more gracile bones, including the coracoid (classified correctly) which had a slimmer corpus and a smaller basal facet and plotted with the chickens in the principal component analysis graph.

Section 3.2.6 discussed the difficulty of separating the elements by conventional means, noting that while the coracoid and tarsometatarsus are relatively easy for an experienced zooarchaeologist to distinguish, humeri and tibiotarsi are more problematic. Statistical testing of the Procrustes coordinates showed that for the humeri, GMM successfully distinguished the Uley chickens from black grouse and pheasants. The tibiotarsi were more distinct: black grouse could be separated from the Lyminge chickens and guinea fowl could be separated from all three of the other species (summary in Appendix G, Section 7.5).

On the whole, the results of the study are encouraging and show that selected elements of closely-related Galliformes can be distinguished using geometric morphometrics. Undamaged archaeological specimens could be landmarked and included in the analysis in the same way that the unknown archaeological coracoids were in Section 6.7 and the probability of correct classification to species would be high. The reference database would be enhanced with the inclusion of unimproved,
wild-type guinea fowl. A further logical progression would be to modularise the landmark configurations to focus on, for example, proximal or distal ends of particular elements to investigate the application of the method to fragmented bones. It is not intended that separating these species using geometric morphometrics should replace qualitative methods of identification but rather be a supplementary method.

## 8 Discussion

## 8.I Introduction

The project objectives were to:

- Review historical records of poultry breeds;
- Compare bone shape variability between individuals from modern poultry breeds of reputed historical ancestry;
- Compare these modern datasets with archaeological datasets;
- Review historical records in light of the archaeological data.

A number of other questions arose and were addressed as the thesis progressed. These included explorations of:

- proportional limb bone lengths;
- identification of specific phenotypes, especially the creeper gene;
- sexual dimorphism;
- flight ability related to furcula shape.

These objectives were addressed by developing methods to identify chicken breeds in the archaeological record using elements of the post-cranial skeleton and an applied combination of traditional linear measurements and geometric morphometrics. No previous attempt had been made to develop and apply geometric morphometrics to identify breed-related bone shape variation in either ancient or modern chicken populations and the aim of the thesis was, in part, to evaluate the potential of these novel GMM methods.

### 8.2 Review historical records of poultry breeds

Chapter Two investigated historical records of poultry breeds, focusing on the documentary and archaeological evidence which strongly suggests that environmental adaptation and conscious selection contributed to the development of different morphotypes from as early as the Roman period and probably earlier. Classical authors described variations in body size and plumage colour as well as specific
phenotypes such as polydactyly, feathered crests and different comb types. Finding evidence for body shape and conformation is more difficult. Columella refers to the 'height of body' seen in Tanagran chickens and other breeds developed for fighting, which evokes the upright stance of extant English and Asian gamefowl (De Re Rustica 8.2.4). Aldrovandi quotes Albertus' description of Hadrianic hens - "of a big and rather long body" - and Longolius' account of "chickens with long legs" imported to Germany from Italy (Lind I963: 32-33) but these observations are rare: most descriptions highlight body size and plumage differences although temperament, egg-laying capabilities and other behavioural characteristics are frequently mentioned.

The review of the documentary evidence and interviews with poultry experts (Chapter Two) confirmed that the majority of chicken breeds seen today simply did not exist before I800 AD. Many of the newer breeds developed during the $19^{\text {th }}$ century were given names such as Light Sussex and Orpington which evoked a purely British heritage and a long association with particular geographical areas. However, most were produced by crossing with imported, Asian, soft-feather breeds, inbred to 'fix' desired characteristics. Of the older types, prior to the creation of breed standards, unregulated gene flow would have resulted in much more inter- and intrapopulation variability, even within flocks considered to be a particular 'breed' and it is impossible to be sure how closely the few, reputedly ancient, breeds recorded in pre1800 texts resembled their $19^{\text {th }}$-century counterparts or their modern representatives seen on today's exhibition circuit.

Section 2.7 summarised the evidence, concluding that the modern specimens obtained for the study should not be regarded as identical to historical and archaeological chickens from the same breed. However, many of the reference chickens could be categorised as 'types' and, in the context of this study, this is perhaps a more satisfactory way of classifying them than 'breeds'. After consultation with poultry experts, two additional groups were created comprising closely-related, morphologically similar chickens to supplement the three single-breed groups. For example, silver-spangled Hamburghs were combined with golden-pencilled Hamburghs and Old English Pheasant Fowl, while all the large Asian Game were grouped together. Several Red Junglefowl made up a sixth group, although the genetic purity of these was always in doubt and it is probable that those from private flocks, parks and zoos were
considerably removed, genetically and behaviourally, from their wild ancestors. These individuals were designated 'cross-bred Junglefowl' to avoid any unrealistic claims.

The six groups were used to investigate variation in bone-shape between types on the assumption that, if consistent differences could be identified between them, these differences may also be present in archaeological populations.

### 8.3 Compare bone shape variability between individuals from modern poultry breeds of reputed historical ancestry

The six 'type' groups were the subject of several comparative analyses, initially to establish whether consistent and reliable breed-related shape-variation could be identified. Combined measurement ratios (derived from standard linear measurements) were developed to complement geometric morphometrics as both compare the shape of objects while eliminating size. Selected observations from analyses for each element and method are presented below.

### 8.3.1.1 Coracoid

The ratio $\mathrm{Bf} / \mathrm{Bb}$ (Figure 39) revealed that Dorkings have a short sternal facet relative to the basal breadth whereas Hamburghs and Old English Game have an elongated facet. This may be a consequence of the entire coracoid being deeper and stouter in the heavier breeds - the facet becomes correspondingly 'fatter' and shorter. A further shape change is seen in the general outline of the coracoid, captured by the ratio $\mathrm{Bb} / \mathrm{GL}$ (Figure 39). The Hamburghs and cross-bred Junglefowl have a much narrower basal breadth relative to the greatest length than do the Dorkings and Asian Game. There are also variations in the shape of the sternal end: the lateral angle is more prominent in the light breeds, especially the Hamburghs, whereas the Asian breeds have a much 'flatter' articulation (ratio Lm/GL, illustrated in Figure 38). When these results are compared with those from the shape changes associated with principal component analysis of the superimposed landmarks, some similarities can be identified. The first principal component shows the narrow basal breadth relative to the greatest length (Figure IOI) and separates the breed/type groups in the same way as the measurement ratios (Figure 102). The second component (Figure I03) reflects the
same shape change in the lateral angle as the Lm/GL ratio and ranks the breed groups similarly.

### 8.3.1.2 Humerus

Shape-changes affecting the humerus were relatively simple: the Junglefowl and eggtype chickens had more gracile humeri than the heavier Dorkings and Asian breeds. Figure 48 , which plots the measurement ratios $\mathrm{Bp} / \mathrm{GL}$ and $\mathrm{Bd} / \mathrm{GL}$, shows that crossbred Junglefowl and Hamburghs have narrow proximal and distal ends relative to the greatest length. Dorking, Asian Game and Silkie have a broader proximal end relative to greatest length ( $\mathrm{Bp} / \mathrm{GL}$ ) and a broad distal end relative to the shaft breadth ( $\mathrm{SC} / \mathrm{Bd}$ ). The GMM study also identified these changes - Figure II5 shows the progression from robust to gracile on the first component axis while the second component identifies the straighter humeral shaft and broader proximal end of the Silkies and Dorkings. The Asian Game's position at the negative end of the axis is puzzling, given their score from the $\mathrm{Bp} / \mathrm{GL}$ measurement ratio, but it may be that the pronounced curve of the shaft in this type is masking a more subtle expansion at the proximal end.

### 8.3.1.3 Tibiotarsus

Figures 67 and 68 ( $\mathrm{Bd} / \mathrm{La}$ v Dip/La and $\mathrm{Bd} / \mathrm{Dip}$ v SC/GL) plot selected measurement ratio results. Both distal and proximal ends are narrow and shaft breadth is small compared to lateral length in cross-bred Junglefowl and Hamburghs but broad in Dorkings and Silkies. The Old English Game were very variable. In Figure 68, Old English Game, Hamburghs and cross-bred Junglefowl are seen to have narrow distal ends compared to proximal ends, as do Asian Game (the Asian Game result is somewhat surprising). The GMM results supported these findings, with the first and second principal components (Figures I33 and I34) both identifying the predictable progression from robust to gracile and the third component picking up the variation in comparative breadths of the proximal and distal ends (Figure 135). The Hamburghs and cross-bred Junglefowl, with negative scores, have a narrow distal and a broad proximal articulation while the Silkies showed the opposite morphology.

### 8.3.1.4 Tarsometatarsus

In Figure 78 (plotting measurement ratios SC/GL v Bp/GL), Junglefowl, Old English Game and Hamburghs have a narrow proximal end and shaft breadth relative to the greatest length whereas Silkies, Dorking and Asian Game have a broader proximal end
and shaft. Figure $79(\mathrm{Bd} / \mathrm{Bp} v \mathrm{Bd} / \mathrm{GL})$ shows that Hamburghs have the broadest distal end relative to the proximal end while Silkies have the narrowest. Silkie and Dorkings have the broadest distal end relative to greatest length and Junglefowl and Old English Game have the narrowest. This ratio combination (Figure 79) does not produce good separation between the groups. However, it does reveal that the distal articulation of the Hamburgh/egg-types is significantly larger relative to the proximal articulation (the tendency in most of the groups is towards parity). To interpret this in another way, it may be that the proximal articulation in the Hamburghs is small relative to the distal end.

The GMM results for the first PC largely confirm the measurement ratio results, with the Junglefowl and Hamburgh scores reflecting a narrow tarsometatarsus with small proximal and distal ends and the heavier chickens being much more robust. However, the second and third components identified changes that require further investigation and analysis: PC2 groups the gracile Junglefowl with the stockier Silkies and PC3 positions the Junglefowl and Hamburghs - types that usually show similarities - at opposite ends of the axis. PC3 successfully identified the broad distal end of the Hamburghs previously seen in the measurement ratio analysis.

### 8.3.2 Summary of modern bones comparison

The results from both the measurement ratio and GMM studies confirmed that, as anticipated, the lighter, egg-type chickens generally had more gracile bones and the heavier Dorkings and Asian breeds were more robust. Selected combinations of measurement ratios and principal component analysis of the Procrustes coordinates proved to be effective methods of ranking the chickens from light, Mediterranean-type to heavier table birds and individual specimens often grouped closely according to breed/type.

There may be several reasons for the consistent bone shape variability between the modern breed/type groups. Body weight is an obvious factor and it is likely that the robusticity seen in the bones of heavy table breeds such as Dorking and Indian/Cornish Game is related to weight-bearing. However, this correlation is not applicable in all cases as the bones of the Silkies regularly plotted with the heavier Asian Game and Dorkings. Both 'large' and bantam Silkies were used for the study but, although body weights were not recorded for most of the specimens, comparing the
greatest length measurements of the long bones suggests that none of the unrecorded carcasses had weighed over 2 kg . Although the standard for the bantam version of this breed stipulates a small size (the maximum bantam weights are 600 g males, 500 g females), a broad and stout body is also required and this stockiness may be related to the robust bones. It could be that the diminutive modern Silkies have retained the robust bones of a larger ancestor. Increasing the dataset using bones of different sized birds of this breed, including specimens from their native China, may reveal the origins of this trait.

Of all the groups, the Hamburgh/egg-type chicken bones were consistently most similarly shaped to the cross-bred Junglefowl, suggesting that these slender Mediterranean types are the most morphologically similar to the ancestral species, despite the increase in size. This concurred with a study by Moiseyeva et al (2003) which investigated the genetic relationship between four modern groups, including egg-types, and Red Junglefowl concluding that the egg-types and 'bantams' were closer to the Junglefowl.

The consistencies revealed in these comparisons are encouraging and show that either metrics method could be used to establish 'type characteristics' as a foundation for compiling defining characteristics for each breed or group. The DNA analyses carried out on feather samples from many of the modern reference chickens and archaeological coracoids have produced data which will complement and support these proposed characteristics.

### 8.4 Compare modern datasets with archaeological datasets and review historical records in light of archaeological data

Once it was established that breed-related variation was present and could be identified in the modern chicken bones, the intention was to compare these modern groups with ancient chicken remains to investigate their morphological resemblance. Domestic fowl remains were included from sites spanning approximately sixteen centuries. A change through time was anticipated - a progression from lighter, Junglefowl type chickens in the earlier sites to heavier types in the post-medieval and perhaps associated with increased shape-variation. It was also expected that any
discernible variability in the archaeological bones would be more subtle than the pronounced differences in the modern groups: the 'Species Differentiation’ study (Chapter 7) showed less shape-variation within the Uley and Lyminge bones relative to variation between a group of modern guinea fowl or pheasants, suggesting that ancient chickens from a single site may have been very much of a 'type'.

Several methods were tested to draw comparisons between archaeological and modern bones. The limb bone indices (Section 5.4) usefully established that Mediterranean breeds such as Hamburghs and Old English Game have short femora relative to tarsometatarsi while more 'developed' Dorkings show the opposite. This seems to validate Darwin's (1868) hypothesis that a long distal limb in Galliformes is a primitive characteristic, being a result of the ancestral species' adaptation to a cursorial lifestyle. That the shortness of Dorkings' tarsometatarsi is not simply an illusory effect caused by stance, fluffier plumage or fatter bodies/carcasses, reinforces the assertion that the "short-legged hens" mentioned by Shakespeare and Jonson (Section 3.3.4) were fattened table birds rather than creepers. The results are promising but the method is restricted to confidently identified articulated limbs, which limits application to archaeological remains. The measurements taken from one Roman and two Saxon associated bone groups did show a progression from a primitive, 'Bankiva' chicken with long tarsometatarsi to two more 'developed' types with proportionally shorter tarsometatarsi but these limited data can only show the potential of the method.

The modern/archaeological comparisons used between-groups principal component analysis, discriminant function analysis and DFA carried out on the scores from BGPCA, which addressed the issues raised by unequal data sets and small sample sizes. This technique was applied to the GPA scores for the coracoids and the results are presented in Sections 6.7 and 6.8.3. These illustrate the proportions of archaeological specimens per site classified as one of six, and then four, modern groups. The results table (Table 78) and stacked barchart (Figure 169) confirm that approximately a third of the Uley coracoids were of a heavier, 'Dorking-like' morphology, although the very high proportion of male birds at the site may have influenced the data. A sex-related shape variation in the tibiotarsus and tarsometatarsus (Sections 5.3.6.2 and 5.3.7.2) can be identified using measurement ratios in modern chickens and it is possible that this dimorphism extends to other elements. As a consequence, the robusticity seen in the
coracoids of the chickens sacrificed at Uley may be due, in part, to the majority being cocks or cockerels. The coracoids from Fishbourne were not included in the GMM study and have since been subjected to destructive analysis for DNA and isotope analysis; nevertheless, measurement ratios were able to identify significant differences which may be characteristic of 'primitive' types. The length of the basal facet of the coracoid is longer in less developed breeds relative to the greatest and medial lengths: this can be seen in the cross-bred Junglefowl and also in the Roman chickens from Fishbourne Palace. This is a potentially useful feature when analysing domestic fowl remains as coracoids are relatively robust bones which survive quite well in archaeological deposits. Even if the 'hook' at the humeral end is broken, Bf and Bb measurements from the basal end can reveal this information. The breadth of the basal facet is also significant, increasing as the corpus of the coracoid thickens in more developed, heavier breeds (for example, Dorkings and Indian Game). A correlation with body weight seems the most likely explanation - Junglefowl and lighter types have thinner, flatter coracoids - although genetics may also be a factor. It would therefore be worthwhile developing a metric to capture this variation and complement the Bf measurement.

The three Saxon-period sites are dominated by a type with similar coracoid morphology to a modern Old English Game with a lower but significant percentage of egg-types (Sections 6.7 and 6.8.3). However, the Lyminge assemblage also contained a small proportion of heavier types which concurs with the leg bone indices findings from this site. This may reflect chickens being brought in from satellite grange farms or as tithes from surrounding villages. The BGPCA graph of the measurement ratios for the coracoid (5.3.3.2) also shows a relatively broad range of 'types' at Lyminge. Unfortunately, more detailed analysis was not possible: the Lyminge assemblage was large and activity at the site covered several centuries but complete phasing was unavailable at the time of writing. Once phasing for those contexts yielding domestic fowl remains is confirmed, further investigation to determine the extent of the change and identify any within-site chronological variation is strongly recommended.

The most recent assemblage, the $16^{\text {th }}$-century feasting pit from Chester, showed the most variation: the coracoids from this (probable) single-event deposit showed characteristics similar to five of the six groups including the larger, meatier types.

Numbers of left-sided elements from the pit at Chester indicates a deposit of the disarticulated remains of at least I3 chickens. Although this is a small number, the broad spectrum of greatest length measurements in the kernel density estimates (Section 5.2) also indicate a wider variation compared to the earlier assemblages. This suggests evidence for the emergence of specialisation and possibly breed-development, perhaps managed by a respected pioneer such as Katherine Woodford, poultry raiser and supplier to Elizabeth I and subject of Mascall's dedication in his treatise on poultry (Mascall I58I).

No attempt was made to identify capons in any of the archaeological material, although it is possible they may have been present in the feasting pit at Chester. There is no convincing evidence that surgical castration was carried out on chickens in the Roman or Saxon period and there were too few bones from Chester for comparative analysis and confident identification of the characteristics described in Section 2.5.3.

A technique devised to investigate furcula shape (Section 5.5) found that flight ability did not appear to influence the shape of the furcula. However, a correlation was identified between the angle at the symphysis and body weight. The method was developed to be applicable to fragmented archaeological remains and may be an additional means of identifying increasing weight due to enlarged pectoral muscles in 'meatier' chickens. While the furcula is fragile and complete examples from excavations are rare, assemblages rich in domestic fowl remains may contain sufficient, relatively undamaged specimens for the application of the method.

Archaeological creeper chickens are most easily identified by either the deformation to the tibiotarsus or the extreme shortening effect on the tarsometatarsus. A number of creeper elements representing two chickens were recognised early in the data collection process: the articulating tibiotarsus and tarsometatarsus from the Chester pit previously reported upon by Gordon et al (2015) and a skeleton from Uley. At least two more individuals were identified during biometrical analysis evidenced by a further three wing elements from Uley (probably from the same individual) and a single femur from Lyminge. The identification of the femur is significant because, while the others were marked out as possible creepers during measuring, this specimen was initially classified as from a bantam. Comparison using measurement ratios showed it plotted convincingly with modern and archaeological creepers, demonstrating the
effectiveness of this method for confirming suspected creepers. It was hoped that the effect of the gene could also be seen on other elements, for example, the coracoid. Unfortunately, only three modern coracoids were available for comparison. Those from the two Japanese bantams plotted as outliers but this may have been a breed characteristic rather than a shape change associated with the creeper gene. The Krüper was too immature to include and the Scots Dumpy showed no variation outside the 'normal' range of morphologies (Figure IO0). Similarly, the coracoid from the Uley creeper ABG (U06I) was never an outlier in either the measurement ratio or the GMM study.

It appears that the creeper gene may have been more common in the past than previously thought and an increased awareness of the condition and assiduous checking, especially of those elements not so severely affected by the gene, will uncover more examples in other domestic fowl assemblages. Increased numbers of chickens with obvious phenotypic abnormalities such as crests and shortened limbs does not necessarily point to controlled, selective breeding, although it seems that they were certainly tolerated and perhaps favoured by some chicken keepers. Their obvious genetic characteristics may have been associated with real or imagined advantages but the possibility that they were kept simply as ornamental fowl or pets should not be discounted.

## 9 Conclusions

## 9.I GMM or Measurement Ratios? Advantages and disadvantages

This study has proved that significant bone shape differences exist in domestic fowl, that they are consistent to breed/type in modern specimens and can be identified using either measurement ratios or geometric morphometrics. The two methods are not interchangeable and frequently give results that, if not contradictory are often inconsistent: either can be used, however, if it is understood that the results are relative rather than absolute. Each approach has advantages and drawbacks which make them appropriate for some applications over others. The landmark GMM system of superimposing homologous anatomical points, enables much more of the shapevariations and diagnostic features common to the different breed groups/types to be captured - measurement ratios derived from the current suite of standard metrics often fail to detect these subtleties. For example, the two landmarks defining the medial and lateral edges of the humeral shaft (Figure 14) not only describe variation in the width but also changes to the curvature which distinguishes some breeds/types. Likewise, the hugely variable 'hook' at the humeral end of the coracoid (Figure 13) is not described by standard biometrics. However, GMM identifies subtle similarities as well as differences and this may mean that closely-related groups are sometimes confused (for example the cross-bred Junglefowl and Hamburgh humeri in Figure 121) when the simpler measurement ratios technique make a somewhat clearer distinction (Figure 49). Further disadvantages for 2D geometrics are the requirement for perfect specimens and the amount of time needed to photograph, landmark and check for measurement error before analysis begins. Fragmented bones could still be landmarked and the resulting configurations modularised but the risk of introduced error through incorrectly positioned objects would be a major problem. Finally, if sample sets are small the number of landmarks can frequently outnumber the number of specimens which means statistical analysis methods have to be adapted to prevent bias through overfitting.

The measurement ratios method has several advantages over geometric morphometrics, the most obvious being speed and simplicity of data collection. No expensive equipment is required for image capture and, while it is important that metrics are taken consistently by trained staff, gathering linear metrics data is a much more straightforward procedure. Furthermore, measurements derived from extant databases can be easily incorporated. Complete elements or more specific areas or features can be selected and investigated using simple $x-y$ plots to examine two ratio combinations or more comprehensive analysis through PCA incorporating all the data. The method could be expanded if required by devising novel metrics - for example, the depth as well as the breadth of the basal facet on the coracoid. Finally, there is increased potential to use measurement ratios with incomplete specimens providing at least two metrics can be taken. These factors make measurement ratios a better option for examining inter- and intra-site bone-shape variation in different archaeological populations.

The requirement for undamaged specimens with no pathologies is restrictive and can severely reduce the amount of archaeological material available for a GMM study and the process is undoubtedly more time-consuming and complex than analyses derived from linear metrics. However, the extra time and effort can be justified in some cases, particularly when investigating shape-changes related to domestication and evolutionary development. This GMM study has relied upon data from a single aspect of just four, relatively 'flat' post-cranial elements: the methodology would be much improved by using scanned 3D images which would enable all aspects to be landmarked and identify more complex shape variation.

### 9.2 The longue durée of chicken breeding

This thesis set out to investigate the changing shape of chickens. It has demonstrated that different modern types of chicken are indisputably associated with particular bone morphologies and these can be related to archaeological remains.

The coracoids of the chickens from the $I^{\text {st }}-2^{\text {nd }}$ century palace at Fishbourne Palace showed similarities to Junglefowl but at the other Roman site, the temple at Uley, a more robust type were being sacrificed. At Uley, though, the fact that most or all of the chickens were male may be influential. Of the three Saxon sites examined, the chickens at Lyminge had the highest proportion of heavier chickens, shown in the
geometric morphometrics coracoid study and also hinted at in the leg bone indices of two skeletons. The most recent assemblage, the $16^{\text {th }}$-century feasting pit from Chester, showed the greatest variation which may reflect a degree of specialisation and breed development.

The bone-shape analyses have reinforced the fact that pre-modern chickens were relatively gracile. Analysis of London chickens by Thomas et al (2013) shows a shift towards larger, heavier birds between the $14^{\text {th }}$ and $17^{\text {th }}$ centuries suggestive of increased specialisation of farming and a growing emphasis on meat production. This is supported by the ageing and sexing evidence of late medieval and early modern sites in England where increased proportions of juvenile birds and a more even representation of hens and cocks are observed (Albarella 1997).

The shape-variation seen in the $16^{\text {th }}$-century Chester pit-fill is persuasive evidence for the development of distinct morphotypes although the majority of flocks at this time almost certainly consisted of dual-purpose fowl. The Early-Modern period may mark the emergence of specialisation although this may well have earlier origins as yet not identified. The growing influence of the printing press meant that the advice of authors such as Prudent Le Choyselat (1577) and Leonard Mascall (158I) could be quickly and widely disseminated. The analysis of the Saxon assemblages has shown that in this earlier period chickens are by no means homogenous. Even the two Roman assemblages were shown to be markedly distinct from Junglefowl and from each other, signifying that the chickens introduced in the $I^{\text {st }}$ century had already been affected by selective breeding and/or environmental pressures and had diverged morphologically, as well as in terms of size, from the ancestral species.

Classification of the archaeological bones using discriminant function analysis indicates that most sites were dominated by morphotypes similar to Old English Game and Hamburgh/egg-types (Figure 169). However, scatterplots for the coracoid GMM analyses frequently show archaeological points plotting outside and beyond the convex hulls delineating the modern groups (for example, the BGPCA graphs of the Saxon coracoids (Figure 109)). This suggests that, although a proportion of the ancient chickens could have been similar to modern types, some of the morphologies may have been significantly different from those seen today and the coracoid shows these differences most effectively of the elements included in the study. Today's Hamburghs
and Old English Game fowl could be proposed as a proxy for pre-medieval chickens, although selection for size and husbandry regimes incorporating veterinary care and a more nutritious diet means the modern examples are considerably larger and arguably healthier. The Dorking has long been associated with the Roman period (Brown 1906:24-25; Hams 2004:I3; Scrivener 2009:6I) and a significant proportion of the coracoids from Uley were classified to this breed but this does not mean the Uley chickens closely resembled the large, five-toed fowl developed to supply the Victorian poultry meat markets. More data, both modern and archaeological, would improve the understanding of these similarities.

### 9.3 Implications for further research

Domestic fowl remains usually form a small percentage of faunal remains from excavations but occasionally, such as at Uley and Lyminge, large deposits are found. However, even small amounts of metrical data can be accrued from different sites to investigate change through time and morphological divergence. Additional data from modern chickens of relevant breeds is recommended to improve the datasets: reliably identified pure-bred Red Junglefowl specimens would be especially beneficial for comparison with the earliest assemblages. Experimentation with newly devised metrics to capture, for example, the shape of the coracoid basal facet or the distal articulation of the tarsometatarsus may reveal shape-differences associated with 'primitive' or polydactylous chickens.

The analytical methods described have the potential to further investigation into the development of different breeds or types of chicken in Britain, whether through identification of newly introduced exotics or long-term change through selective breeding. Investigation into all periods would be valuable in this under-researched area but further examination of the morphologies of Romano-British chickens particularly would advance understanding of the priorities and pressures involved in poultry husbandry at a time when the human-chicken relationship was arguably more complex. Remains from confidently-dated post-medieval deposits shape-variation may identify the development of specialisation and perhaps find evidence of early imports of foreign exotics such as the distinct Malayoid (Asian Game) type, reputedly brought to SouthWest Britain as early as the $18^{\text {th }}$ century (Scrivener 2009).

It is clear that the modern concept of chicken 'breeds' cannot be applied to past populations but it is equally certain that different morphologies, or 'types' existed. It is hoped that this thesis will provide a foundation for continuing research into shapevariation in domestic fowl bones, increasing understanding of the spatial and temporal origins of modern chicken breeds and the social and economic pressures driving selection and breed development.

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## Appendix A: Modern reference specimen catalogues

## Key

Collection: AF = Alison Foster; EA = Enid Allison; EH = English Heritage; JM = James Morris; KvG = Katrina van Grouw; NS = Naomi Sykes; PRS = Palaeoecology Research Services; SHD = Sheila Hamilton-Dyer; UoL = University of Leicester; UoS = University of Sheffield; UoY = University of York. Records of private donors have been edited to comply with the Data Protection Act.

Bone element: cmc= carpometacarpus; cor = coracoid; fem = femur; fur = furcula; hum = humerus; man = mandible; pel = pelvis; rad = radius; scp = scapula; skl = skull/cranium; ste = sternum; tbt = tibiotarsus; tmt = tarsometatarsus; uln =ulna.

Cells highlighted in bold indicate specimens which have been used in GMM study.

## I.I Chickens

| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Poland bantam, White Crested Black | m |  |  | $\begin{aligned} & >10 \\ & \mathrm{yrs} \end{aligned}$ | 935 |  | Kent | none | a001 | AF | Pet bantam. Died of old age. "Mr Pompey". |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Poland bantam | m | $\begin{aligned} & \text { ca. Jul } \\ & 2013 \end{aligned}$ | 03/03/2014 | 8 mths | 1205 |  | Lancashire | AF | a002 | AF |  |
| Dorking, Red | f |  | 25/10/2014 | $\begin{aligned} & \hline 18 \\ & \text { mths } \end{aligned}$ | 2045 |  | Herefordshire | AF | a003 | AF | Surplus stock. Spurred hen. Spurs not fused to tmt |
| Brahma | f |  |  | $\begin{aligned} & \sim 3 \\ & \text { years } \end{aligned}$ | 3777 |  | Kent | none | a005 | AF | "Sudden Brahma Death Syndrome" apparently this breed is prone to expiring suddenly and unexpectedly |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| ?Houdan | m |  | 25/10/2014 | $\begin{aligned} & 5.5 \\ & \text { mths } \end{aligned}$ | 1954 |  | Herefordshire | none | a006 | AF | Surplus stock. Fivetoed bird, plumage black and white. Not a good example of the breed. Crest is large and floppy, Skull is slightly herniated. |
| Dorking, Red | f | Jun-88 | Aug-91 | $3 \mathrm{yrs}$ <br> 2 mths | 1800 |  | Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WRII 5QJ | 2810 | e001 | EH | Spurred hen, spurs fused to the shields but shields are detached from the tmts. Rt tmt has fused accessory mt, other is detached. Path due to aggravation caused by extra toe? SBF narrow, sternum deviated, pelvis rounded. " V thin and wasted, eggs soft and dead inside, ovary decaying. Wattles, comb and ears pink". Presumed found dead but this was not recorded. |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Ross 308 | m | Sep-04 | 29/07/2005 | 43 wks | 5000 |  | Possibly West <br> End Poultry <br> Farm, <br> Allington Lane, <br> Southampton, <br> Hampshire <br> SO30 3HQ | 3870 | e002 | EH | Erosion to femoral head and distal artic, and prox tbt artic on both legs. Right cmc major mtc thickened - healed trauma? |
| Ross 308 | f | Oct-04 | 18/07/2005 | 38 wks | 3530 |  | Possibly West End Poultry Farm, Allington Lane, Southampton, Hampshire SO30 3HQ | 3871 | e003 | EH | Same paths on tbt and fem as 3870. In lay |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Old <br> English <br> Pheasant <br> Fowl | f | Apr-89 | Aug-91 | 2 yrs 4 mths | 2300 |  | Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WRII 5QJ | 2812 | e004 | EH | Dev sternum. Spongy growths infilling ribs/verts in pelvis. Perforations around partes glutaeae and acet (both sides). <br> Bone growth around distal tbt (left is the worst, also has enthysophyte) Bone growth around prox tmts. Cannot photograph either tbt. Not in lay. Carcass described as "very good, lots of flesh, lots of fat" |
| Scots Dumpy (mislabell ed Scots Grey) | f | May-89 | Sep-91 | $\begin{aligned} & 3 \mathrm{yrs} \\ & 4 \mathrm{mths} \end{aligned}$ | 2100 |  | Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WRII 5QJ | 2811 | e005 | EH | Dev and perforated sternum. Obviously a creeper, probably a Scots Dumpy. Right ulna broken and healed. Enlarged liver, interior of carcass filled with viscous liquid. Not in lay. |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc <br> no | ID | Collection | Notes |
| Poland bantam, Gold | m | 1991 | 04/02/I992 | $\begin{aligned} & 8-10 \\ & \text { mths } \end{aligned}$ | 1345 |  | Sussex | 2783 | e006 | EH | Perforated sternum. Surplus stock, culled |
| Sussex, Speckled | f | March '88 | May-91 | $\begin{aligned} & 3 \mathrm{yrs} \\ & 2 \mathrm{mths} \end{aligned}$ | 3100 |  | Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WRII 5QJ | 2813 | e007 | EH | Very fat, with fat deposits around internal organs. Very deviated sternum. Enthysophyte to distal tbt |
| Friesian bantam | m | 1990 | 04/02/I992 | $\begin{aligned} & 1 \mathrm{yr} \\ & 10 \\ & \text { mths } \end{aligned}$ | 1500 |  | Old Spot Sussex | 2785 | e008 | EH | Convex pelvis, slightly deviated sternum. Surplus stock, culled. |
| Araucana bantam, Lavender | m | 1991 | 04/02/1992 | $\begin{aligned} & 8-10 \\ & \text { mths } \end{aligned}$ | 1610 |  | Sussex | 2779 | e009 | EH | Surplus stock, culled. Pelvis poorly ossified, thin and fragile. "Testes much enlarged" |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc <br> no | ID | Collection | Notes |
| Red Jungle Fowl | f |  | 10/08/2006 | adult |  | Butser Iron Age Farm | West Sussex | 3982 | e010 | EH | No paths apparent, head not present, Fox kill. "Large gallinaceous bird" at top end of weight range for female RJF (max wild type is 1050 g ), this specimen weighed without the head. |
| Poland bantam, White Crested Black | m | 1989 | 04/02/1992 | $\begin{aligned} & \hline 2 \mathrm{yrs} \\ & 10 \\ & \text { mths } \end{aligned}$ | 1790 |  | Sussex | 2780 | e011 | EH | Surplus stock, culled |
| Poland bantam, Chamois | m | 1991 | 04/02/1992 | $\begin{aligned} & 8-10 \\ & \text { mths } \end{aligned}$ | 1455 |  | Sussex | 2781 | e012 | EH | Surplus stock, culled |
| Old <br> English Game | m | $\begin{aligned} & \hline 11 / 05 / 199 \\ & 3 \end{aligned}$ | 02/II/I995 | 6 mths | 2356g |  | Environmental Archaeology Unit, York | 47 | e013 | EH | Poss from Walled Garden flock. Prev acc no EAU 613. |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Dorking, Silver | m |  | Jul-76 | 2 yrs | 3628 | Dorking Breed Club | Dorking, Sussex. "R Jones Collection" | 450 | e014 | EH | Died of 'tumerous liver.' Both accessory metatarsals fused to the tmts. Spurs broken off. Furcula slightly malayoid. Possible bone growth around phalanges - is this pathology or associated with the spur shield? |
| Poland | ?f |  |  | Imm |  |  | Lampeter | 3044 | h001 | SHD | Recorded as female but has a spur scar. Recorded as a large fowl, not a bantam. Perforated sternum. Pelvis unfused on left side |
| Poland | m |  |  |  | 794 |  | Lancashire | 4221 | h002 | SHD | Weighed frozen. <br> Pelvis fused - adult. <br> Very small, probably <br> a bantam |
| Silkie, White with blue legs | f |  |  |  |  | Longdown Dairy Farm |  | 1307 | h003 | SHD | Small, very fragile spherical bone deposits on synsacrum. No perforation/vaulting at all on cranium but thinned to translucency at top |



| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Rosecomb bantam, brown | m |  | 21/03/1994 | $\begin{aligned} & 2 \mathrm{yrs} \\ & 8 \mathrm{mths} \end{aligned}$ |  | Sheila H-D | Southampton | 976 | h009 | SHD | Roadie'. Not breed standard. Brown, with 'redcap' type comb rather than rosecomb. Small projection on synsacrum |
| Maran, Blue Copper | m |  | May-14 | $\begin{aligned} & \hline 10 \\ & \text { mths } \end{aligned}$ |  | Sheila H-D | Southampton | 4470 | h010 | SHD | Perforated sternum. Culled due to aggressive nature |
| Dorking, Red | f |  | 15/08/2014 | $\begin{aligned} & 16 \\ & \text { mths } \end{aligned}$ | 2062 |  | Herefordshire. | unkno wn | h01I | SHD | Surplus stock. Very small bumps on tmts would probably develop into spurs |
| Poland bantam | m | $\begin{aligned} & \text { ca. Jul } \\ & 2013 \end{aligned}$ | 03/03/2014 | 8 mths | 1125 |  | Lancashire | none | j005 | JM | Donated to James Morris |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Poland bantam | m | $\begin{aligned} & \text { ca. Jul } \\ & 2013 \end{aligned}$ | 03/03/2014 | 8 mths | 1210 |  | Lancashire | none | j006 | JM | Donated to James Morris |
| Kruper | m |  |  | $\begin{aligned} & \hline 6.5 \\ & \text { mths } \end{aligned}$ |  | Enid Allison | Canterbury <br> Archaeological <br> Trust, 92a <br> Broad Street, Canterbury, Kent, CTI 2LU | unkno wn | kI64 | EA | From Germany? |
| Old <br> English Game Fowl | f |  |  |  | 1262 |  | University of York | KDI | n001 | PRS |  |
| Hamburg h Bantam, Silver Spangled | m | $\begin{aligned} & \text { ca. May } \\ & 2013 \end{aligned}$ | 22/02/2014 | $\begin{aligned} & 9-12 \\ & \text { mths } \end{aligned}$ | 1585 |  | Aberdeenshire | R65 I | r65 I | UoL |  |
| Japanese bantam, Blacktailed White | m | $\begin{aligned} & \hline \text { ca. Feb } \\ & 2009 \end{aligned}$ | 22/02/2014 | 5 yrs | 766 |  | Aberdeenshire | R652 | r652 | UoL |  |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Poland bantam | m | $\begin{aligned} & \text { ca. Jul } \\ & 2013 \end{aligned}$ | 03/03/2014 | 8 mths | 1080 |  | Lancashire | R653 | r653 | UoL |  |
| Poland bantam | m | $\begin{aligned} & \hline \text { ca. Jul } \\ & 2010 \end{aligned}$ | 03/03/2014 | 4 yrs | 1115 |  | Lancashire | R655 | r655 | UoL |  |
| Poland bantam | m | $\begin{aligned} & \text { ca. Jul } \\ & 2013 \end{aligned}$ | 03/03/2014 | 8 mths | 1370 |  | Lancashire | R656 | r656 | UoL |  |
| Shamo "Haji" Ring no. GI65 | m | $\begin{aligned} & 25 / 03 / 201 \\ & 2 \end{aligned}$ | 26/03/2014 | 2 yrs | 3860 |  | Isle of Man | R657 | r657 | UoL | Confined before culling due to aggressive nature |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Shamo <br> "Shobu" <br> Ring no. <br> GI75 | m | $\begin{aligned} & 15 / 04 / 20 \mid \\ & 2 \end{aligned}$ | 26/03/2014 | $\begin{aligned} & 23 \\ & \text { mths } \end{aligned}$ | 4320 |  | Isle of Man | R658 | r658 | UoL | Free range, larger, more muscular bird |
| Lakenvelder | m | $\begin{aligned} & \text { ca. Jun } \\ & 2013 \end{aligned}$ | 30/03/2014 | $\begin{aligned} & 9-12 \\ & \text { mths } \end{aligned}$ | 2220 |  | Herefordshire | R659 | r659 | UoL |  |
| Silkie, Lavender | f | $\begin{aligned} & \text { ca. Mar } \\ & 2008 \end{aligned}$ | 30/03/2014 | 6 yrs | 1455 |  | Herefordshire | R660 | r660 | UoL | Culled due to age and ear infection, hadn't laid since last year. Pronounced cerebral hernia, skin etc not particularly black |
| Silkie, Lavender | f | $\begin{aligned} & I 3 / I I / 20 I \\ & 2 \end{aligned}$ | 30/03/2014 | $\begin{aligned} & 16 \\ & \text { mths } \end{aligned}$ | 710 |  | Herefordshire | R66I | r661 | UoL | Green ring 448. No idea when last egg laid (freerange hen), been sickly for approx 3-4 weeks, poss Marek's disease. Small cerebral hernia, skin etc not particularly black |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Asil <br> (Reza) | f | $\begin{aligned} & \text { ca. Apr } \\ & 2012 \end{aligned}$ | 15/04/2014 | 2 yrs | 1705 |  | Oxfordshire | R662 | r662 | UoL | Excess stock, healthy bird in lay |
| Oxford Game | f | $\begin{aligned} & \text { ca. Apr } \\ & 2012 \end{aligned}$ | 15/04/2014 | 2 yrs | 1780 |  | Oxfordshire | R663 | r663 | UoL | Excess stock, healthy bird in lay. Black-red (partridge). Small spurs (normal for OEG hens). Shelled egg recovered during prepping |
| Buff Orpingto n | m | $\begin{aligned} & \text { ca. May } \\ & 2010 \end{aligned}$ | 17/05/2014 | $\sim 4 \mathrm{yrs}$ | 4480 |  | West Berkshire | R664 | r664 | UoL | Surplus stock |
| Vorwerk | f | $\begin{aligned} & 04 / 05 / 201 \\ & 3 \end{aligned}$ | 27/03/2014 | $\begin{aligned} & \text { II } \\ & \text { mths } \end{aligned}$ | 1900 | Gabrielle | Herefordshire | R665 | r665 | UoL | Last known egg laid $\sim 24 / 03 / 14$, was in regular egg production, hadn't got to her first moult, found dead, death probably associated with respiratory condition. Shelled egg |



| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Sussex, Light | f | 2007 | 17/05/2014 | 7 yrs | 2790 |  | West Berkshire | R669 | r669 | UoL | In lay but well past good productivity. Last egg: within the last three days, at least 4 eggs still developing. Advanced scaly leg, probably a heart condition too. Died when she was picked up, so neck not wrung. |
| Rumpless Araucana | m |  | 06/07/2014 | $\begin{aligned} & \hline 14 \\ & \text { mths } \end{aligned}$ | 2410 |  | County Durham | R670 | r670 | UoL | Wrong plumage |
| Dorking, Red | f |  | 06/07/2014 | $\begin{aligned} & 27 \\ & \text { mths } \end{aligned}$ | 2155 |  | Herefordshire | R723 | r723 | UoL | Bumble foot |



| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Dorking, White | m |  | 29/06/2014 | 16 wks | 1678 |  | Herefordshire | R727 | r727 | UoL | Single comb (wrong type of comb for breed standard) |
| Hamburg h Bantam, Silverspangled | $f$ |  |  | 2-3 yrs | 885 |  |  | R728 | r728 | UoL | Surplus stock. This hen has spurs |
| Hamburg h Bantam, Silverspangled | f |  |  | 2-3 yrs | 755 |  |  | R729 | r729 | UoL | Surplus stock |
| Hamburg h Bantam, Silverspangled | f |  |  | 2-3 yrs | 615 |  |  | R730 | r730 | UoL | Surplus stock |
| Hamburg h Bantam, Silverspangled | m |  |  | 2-3 yrs | 1020 |  |  | R73 I | r73I | UoL | Surplus stock. Perforation in sternum |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Oxford Game | m | $\begin{aligned} & \text { ca. Apr } \\ & 2012 \end{aligned}$ | 15/04/2014 | 2 yrs | 2565 |  | Oxfordshire | R732 | r732 | UoL | Excess stock, healthy bird, sawn spurs (in case of fighting within flock - sawn off halfway, not close to tmt) |
| Dorking, Dark | m |  | 06/07/2014 | 19 wks | 2750 |  | Herefordshire | R733 | r733 | UoL | Crooked breast bone |
| Dorking, Dark x White | m |  | II/II/2014 | 7 mths | 4050 |  | Herefordshire | R734 | r734 | UoL | Surplus stock. |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Oxford Game | m | $\begin{aligned} & \text { ca. Apr } \\ & 2013 \end{aligned}$ | 15/04/2014 | $\begin{aligned} & 12 \\ & \text { mths } \end{aligned}$ | 1605 |  | Oxfordshire | R735 | r735 | UoL | Excess stock, healthy bird, small spurs |
| Hamburg h, Silverspangled | m |  | 23/10/2014 | 2 yrs | 2690 |  | Essex | R736 | r736 | UoL | Full-size bird. Surplus breeding stock. Nonmetric trait - hole in sternum |
| Hamburg h, Silverspangled | m |  | 09/09/2014 | 5 mths | 2330 |  | Essex | R740 | r740 | UoL | Full-size bird, surplus stock. Wavy sternum crest and perforation in sternum |
| Hamburg h, Silverspangled | m |  | 09/09/2014 | 5 mths | 2335 |  | Essex | R74I | r74I | UoL | Full-size bird, surplus stock. Wavy sternum crest and perforation in sternum |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Hamburg h, Silverspangled | f |  | I3/01/2014 | 9 yrs | 1425 |  | Hampshire | R742 | r742 | UoL | Spurred hen. Ailing, found dead. Not in lay, last egg laid approx I year ago. Bone growth to prox tmts. |
| Maran | m |  |  | 9 mths |  | Naomi Sykes |  | unkno wn | s001 | NS | "Gunther". Culled due to aggression |
| Sussex, Black | f |  |  | 3-4 yrs |  | Naomi Sykes |  | unkno wn | s002 | NS |  |
| Welsum mer | f |  |  | 1 yr |  | Naomi Sykes |  | unkno wn | s003 | NS | "Redwick". Never <br> laid any eggs |
| Silkie | m |  |  |  |  |  |  | $\begin{aligned} & \text { S/2007. } \\ & 93.10 \end{aligned}$ | t007 | NHM |  |
| Rhode Island | m |  |  |  |  |  |  | $\begin{aligned} & \text { S/I999. } \\ & 43.53 \end{aligned}$ | t019 | NHM |  |
| Leghorn | m |  |  |  |  |  |  | $\begin{aligned} & \text { S/I } 999 \\ & 43.56 \end{aligned}$ | t022 | NHM |  |
| Kulm | m |  |  |  |  |  |  | $\begin{aligned} & \text { S/I952. } \\ & 3.5 \mathrm{I} \end{aligned}$ | t023 | NHM |  |
| Kulm | m |  |  |  |  |  |  | $\begin{aligned} & \mathrm{S} / \mathrm{I} 952 . \\ & 3.52 \end{aligned}$ | t024 | NHM |  |
| Sussex, Light | f |  |  |  |  |  |  | $\begin{aligned} & \text { S/I } 999 . \\ & 43.57 \end{aligned}$ | t026 | NHM |  |
| Sussex, Light | f |  |  |  |  |  |  | $\begin{aligned} & \text { S/2009. } \\ & \text { I. } 52 \end{aligned}$ | t027 | NHM |  |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Sussex, Light | f |  |  |  |  |  |  | $\begin{aligned} & \mathrm{S} / 1999 . \\ & 43.44 \end{aligned}$ | t028 | NHM |  |
| Silkie | f |  |  |  |  |  |  | $\begin{aligned} & \hline \text { S/I999. } \\ & 43.41 \end{aligned}$ | t032 | NHM |  |
| Silkie | m |  |  |  |  |  |  | $\begin{aligned} & \mathrm{S} / 1999 . \\ & 43.47 . \end{aligned}$ | t034 | NHM |  |
| Crested <br> Rump- <br> less <br> Turkish, <br> White | x |  |  |  |  |  |  | $\begin{aligned} & \mathrm{S} / 1952 . \\ & 2.104 \end{aligned}$ | t040 | NHM | Cannot find info on sex of this bird, despite lengthy search of Darwin's publications and correspondence. |
| Game | m |  |  |  |  |  |  | $\begin{aligned} & 1868.2 . \\ & 19.75 \end{aligned}$ | t04I | NHM |  |
| Sultan | f |  |  |  |  |  |  | $\begin{aligned} & \hline 1868.2 . \\ & 19.88 \\ & \hline \end{aligned}$ | t042 | NHM |  |
| Cochin | m |  |  |  |  |  |  | $\begin{aligned} & 1868.2 . \\ & 19.70 \end{aligned}$ | t046 | NHM |  |
| Sultan | m |  |  |  |  |  |  | $\begin{aligned} & \text { 1868.2. } \\ & \text { 19.72 } \end{aligned}$ | t048 | NHM |  |
| Spanish | m |  |  |  |  |  |  | $\begin{aligned} & \text { 1868.2. } \\ & \text { 19.71 } \end{aligned}$ | t049 | NHM |  |
| "wild" RJF | m |  |  |  |  |  |  | $\begin{aligned} & \hline 1868.2 . \\ & 19.59 \end{aligned}$ | t059 | NHM |  |
| Hamburg h, Gold- | m |  |  |  |  |  |  | $\begin{aligned} & 1868.2 . \\ & \text { 19.56 } \end{aligned}$ | t060 | NHM |  |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| pencilled |  |  |  |  |  |  |  |  |  |  |  |
| Dorking | m |  |  |  |  |  |  | $\begin{aligned} & \hline \text { I868.2. } \\ & 19.54 \end{aligned}$ | t065 | NHM |  |
| Red Jungle Fowl | f |  |  | 31 wks | 734 |  |  | $\begin{aligned} & \text { S/2009. } \\ & \text { I. } 42 \end{aligned}$ | t143 | NHM | Assessed as skeletally mature by Thomas 2014 |
| Red Jungle Fowl | m |  |  | 32 wks | 992 |  |  | $\begin{aligned} & \text { S/2009. } \\ & \text { I. } 43 \end{aligned}$ | tl44 | NHM |  |
| Red Jungle Fowl | f |  |  |  |  |  |  | $\begin{aligned} & \text { S/2009. } \\ & \text { I.5I } \end{aligned}$ | tl45 | NHM |  |
| Red Jungle Fowl | m |  |  |  |  |  |  | $\begin{aligned} & \text { S/I999. } \\ & 43.58 \end{aligned}$ | tl46 | NHM |  |
| Leghorn | f |  |  |  |  |  |  | $\begin{aligned} & \text { S/I999. } \\ & 43.36 \end{aligned}$ | t147 | NHM |  |
| Old English Game Fowl | f |  | $\begin{aligned} & \text { d. } 23 \text { Jul } \\ & 1992 \end{aligned}$ |  |  | From the Walled Garden, EAU | University of York | EAU5I <br> 8 | w5I8 | UoY |  |
| Red Jungle Fowl | f |  |  |  |  |  |  | EAU5I $9$ | w5I9 | UoY |  |
| Dorking, Dark | m | Mar-85 |  |  |  | Domestic <br> Fowl <br> Trust |  | $\begin{aligned} & \text { EAU52 } \\ & 8 \end{aligned}$ | w528 | UoY | Prepped May 1992 |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
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| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Dorking, Silvergrey | f |  |  |  |  |  |  | $\begin{aligned} & \text { EAU53 } \\ & 7 \end{aligned}$ | w537 | UoY |  |
| Sussex, Light | f | Apr-89 |  |  |  | Domestic Fowl Trust |  | $\begin{aligned} & \text { EAU53 } \\ & 8 \end{aligned}$ | w538 | UoY | Prepped May 1992. No date of death |
| Old <br> English <br> Game <br> Fowl | m |  |  |  |  | From the Walled Garden, EAU | University of York | EAU6I $1$ | w6II | UoY | "Jack Cock" 02II93 (cull/prep date?) |
| Old <br> English <br> Game <br> Fowl | m |  |  |  |  | From the Walled Garden, EAU | University of York | $\begin{aligned} & \text { EAU6I } \\ & 2 \end{aligned}$ | w612 | UoY | Bill the Chicken |
| Rhode Island Red | ?f |  |  |  |  |  |  | I401 | z002 | UoS | No spurs or spur scars, pelvis fused, smaller than Tring RIR |
| Modern broiler | m | $\begin{aligned} & \hline 15 / 0 I / 20 \mid \\ & 4 \end{aligned}$ | 19/02/2014 | $\begin{aligned} & \hline 35 \\ & \text { days } \end{aligned}$ |  |  | North Linconshire | R650 |  | UoL |  |


| All modern chickens |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed/ colour | Sex | Hatched | Culled/ died | Age | Wt (g) | Donor | Address | Acc no | ID | Collection | Notes |
| Red Jungle Fowl | m |  | 1978 |  |  | Whipsnade Zoo |  | 283 | z001 | UoS | Identified by B. Noddle. Recorded as "Jungle fowl" based on old label in the box that indicated Whipsnade Zoo as the origin of this specimen |
| Leghorn | f |  |  |  |  |  |  | $\begin{aligned} & \text { S/I } 999 . \\ & 43.36 \end{aligned}$ |  | NHM |  |
| Sultan | f |  |  |  |  |  |  | $\begin{aligned} & \hline \text { I868.2. } \\ & \text { I9.88 } \end{aligned}$ |  | NHM |  |
| Malay | m |  |  | 2 yrs |  |  |  |  | k001 | K v G | Part-assembled skeleton - could not measure/photograph all elements |

## I. 2 Non-chicken Galliformes

| All modern non-chicken Galliformes |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Species | Sex | Weight <br> $\mathbf{( g})$ | Collection | Acc no | GMM <br> ID | Notes |
| Common <br> pheasant | m |  | EH | 4292 | e015 | Collected from Nottingham area. Coracoids not present, TBTs <br> damaged, distal ends |
| Common <br> pheasant | f |  | EH | 4294 | e016 | Collected Bridge of Allan, Stirlingshire. Left coracoid damaged, right <br> used. L femur, prox sl damaged. TBTs broken, not photographed |
| Common <br> pheasant | m |  | EH | 4295 | e017 | Collected Longformacus, Berwickshire, I986. L femur broken, right <br> used |
| Common <br> pheasant | m | I250 | EH | 2139 | e018 | Road casualty (MII, just north of M25 junction), Epping, Essex. <br> I5/I2/1988. Right coracoid missing, left is damaged and has slight <br> lipping to cotyla scapularis |
| Common <br> pheasant | f |  | EH | 2531 | e019 | Cambridgeshire 'No details taken at time of recording' |
| Common <br> pheasant | m | I500 | EH | 2742 | e020 | Collected Audley End, Essex. 5/I0/9I. Road casualty? |
| Common <br> pheasant | f |  | EH | 2530 | e026 | Cambridgeshire |
| Common <br> pheasant | m |  | NHM | I904.2.2.I | t066 |  |


| All modern non-chicken Galliformes |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Species | Sex | Weight (g) | Collection | Acc no | $\begin{aligned} & \text { GMM } \\ & \text { ID } \end{aligned}$ | Notes |
| Common pheasant | m |  | NHM | S/I952.I.I96 | t067 |  |
| Common pheasant | m |  | NHM | S/1979.10.1 | t069 |  |
| Common pheasant | m |  | NHM | 1859.9.6.422 | t073 |  |
| Common pheasant | f |  | NHM | S/1953.14.1 | t074 |  |
| Common pheasant | f |  | NHM | S/I979.29.I | t079 |  |
| Common pheasant | f |  | NHM | S/1994.54.I | t080 |  |
| Common pheasant | f |  | NHM | S/201I/I8.I | t081 |  |
| Common pheasant | m |  | NHM | S/1997.77.I | t082 |  |
| Common pheasant | m |  | NHM | S/1999.43.207 | t083 |  |
| Common pheasant | f |  | NHM | S/1979.10.2 | t084 |  |
| Common pheasant | m |  | NHM | S/1999.43.200 | t085 |  |
| Common pheasant | m |  | NHM | S/2010.11.1 | t086 |  |


| All modern non-chicken Galliformes |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Species | Sex | Weight <br> (g) | Collection | Acc no | $\begin{aligned} & \hline \text { GMM } \\ & \text { ID } \end{aligned}$ | Notes |
| Common pheasant | f |  | NHM | S/I977.I07.I | t089 |  |
| Common pheasant | f |  | NHM | S/1999.43.210 | t090 |  |
| Common pheasant | f |  | NHM | S/I985.30.1 | t092 |  |
| Common pheasant | ? ${ }^{*}$ | 900 | UoS | 1264 | z003 | TMTs have spurs, probably male although recorded as female (not prepped at Sheffield, acquired from another collection - Creswell Crags C575) |
| Common pheasant | m | 1380 | UoS | 1067 | z004 | Source: Eastern Borders. Road casualty? |
| Common pheasant | f |  | UoS | 1274 | z005 | Creswell Crags Cl239 |
| Common pheasant | f |  | UoS | 1496 | z006 | Partial skeleton. Tony Legge collection PI. 2 |
| Common pheasant | m |  | UoS | 1498 | z007 | Partial skeleton. Tony Legge collection PI. 2 |
| Common pheasant | f |  | UoS | 1562 | z008 |  |
| Common pheasant | m |  | AF | AF | a004 | Road casualty, AI5 near Aswarby Park, Sleaford. NG34 8SA |
| Guinea fowl | f |  | EH | 1512 | e02I | Coracoid basal facet very broad and deep |


| All modern non-chicken Galliformes |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Species | Sex | Weight <br> (g) | Collection | Acc no | GMM ID | Notes |
| Guinea fowl | m | 2700 | EH | 2737 | e022 | TBTs very bowed, not suitable for GMM |
| Guinea fowl | m | 1200 | EH | 690 | e023 | Both coracoids missing |
| Guinea fowl | f | 3000 | EH | 2738 | e024 | Age unknown, pelvis unfused, healed trauma to furculum |
| Guinea fowl | f | 3000 | EH | 2740 | e025 | TBTs slightly bowed |
| Guinea fowl | m | 2600 | EH | 2741 | e027 | Med angle of coracoid slightly damaged? |
| Guinea fowl | f | 1060 | EH | 2849 | e028 | Unimproved |
| Black grouse | m |  | EH | 1475 | e029 | Shot in Scotland |
| Black grouse | f |  | EH | 3475 | e030 | Raptor kill |
| Black grouse | m | 1355 | EH | 1520 | e031 | Shot in the Borders region, Scotland. Humeri and femora broken or absent |
| Black grouse | f |  | EH | 3476 | e032 | Raptor kill, Widdybank, Teesdale. Femora, tbts and left tmt absent or broken |
| Black grouse | m | 1471 | EH | 1521 | e033 | Shot in the Borders region, Scotland. |
| Black grouse | m |  | NHM | S/1952.2.19 | t125 |  |


| All modern non-chicken Galliformes |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Species | Sex | Weight <br> $(\mathbf{g})$ | Collection | Acc no | GMM <br> ID | Notes |
| Black grouse | m |  | NHM | S/I984.54.I | tl26 |  |
| Black grouse | f |  | NHM | S/I952.2.20 | tl28 |  |
| Black grouse | f |  | NHM | 1905.10 .20 .1 | tl36 |  |
| Black grouse | m |  | UoY | EAU6/4 | w6/4 |  |
| Black grouse | f |  | UoY | EAU615 | w615 |  |
| Black grouse | m |  | UoY | EAU797 | w797 |  |
| Black grouse | f |  | UoS | I729 | z009 | Partial skeleton. |
| Black grouse | m |  | UoS | 266 | z010 |  |

## Appendix B: Biometrical data - modern chickens

### 2.1 Coracoid

## 2.I.I Standard metrics

| Modern breed coracoid metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | Bb | Bf | GL | Lm |
| Poland bantam | m | a001 | 14.92 | 11.55 | 58.59 | 55.78 |
| Poland bantam | m | a002 | 12.30 | 10.79 | 51.23 | 48.34 |
| Dorking | f | a003 | 19.49 | 14.55 | 68.36 | 65.27 |
| Brahma | f | a005 | 20.96 | 18.11 | 76.63 | 70.71 |
| Dorking | f | e001 | 20.63 | 15.57 | 67.63 | 63.86 |
| Ross 308 | m | e002 | 23.60 | 18.67 | 81.90 | 76.12 |
| Ross 308 | $f$ | e003 | 20.64 | 16.83 | 68.25 | 63.75 |
| Old English Pheasant Fowl | f | e004 | 17.38 | 14.57 | 59.67 | 59.51 |
| Scots Dumpy | f | e005 | 14.43 | 11.80 | 52.85 | 49.81 |
| Poland bantam | m | e006 | 14.25 | 12.53 | 56.09 | 52.44 |
| Sussex | f | e007 | 14.91 | 12.04 | 61.41 | 57.68 |
| Friesian bantam | m | e008 | 15.15 | 13.07 | 55.79 | 51.77 |
| Araucana bantam | m | e009 | 16.18 | 13.54 | 60.56 | 57.32 |
| Red Jungle Fowl | f | e010 | 11.28 | 9.41 | 45.54 | 42.99 |
| Poland bantam | m | e011 | 13.92 | 11.66 | 56.40 | 54.34 |


| Modern breed coracoid metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | Bb | Bf | GL | Lm |
| Poland bantam | m | e012 | 14.38 | 12.66 | 59.69 | 57.42 |
| Game Fowl | m | e013 | 17.76 | 14.75 | 65.23 | 61.76 |
| Dorking | m | e014 | 21.51 | 17.17 | 75.64 | 71.34 |
| Poland bantam | m | h001 | 15.88 | 12.82 | 59.34 | 55.71 |
| Poland bantam | m | h002 | 13.50 | 11.55 | 54.43 | 51.03 |
| Silkie bantam | f | h003 | 14.67 | 11.36 | 49.52 | 46.40 |
| Sussex | m | h004 | 17.02 | 15.18 | 63.21 | 59.92 |
| Poland bantam | ?f | h005 | 15.03 | 12.63 | 57.29 | 54.48 |
| Poland bantam | f | h006 | 12.15 | 10.00 | 49.37 | 47.17 |
| Maran | m | h007 | 17.15 | 16.35 | 66.17 | 63.38 |
| Sussex | f | h008 | 14.92 | 13.27 | 61.03 | 58.27 |
| Rosecomb bantam | m | h009 | 15.53 | 11.93 | 58.04 | 55.35 |
| Maran | m | h010 | 23.54 | 19.03 | 83.55 | 79.51 |
| Dorking | f | h01I | 20.93 | 17.83 | 68.54 | 64.19 |
| Poland bantam | m | j005 | 12.75 | 10.16 | 51.44 | 49.66 |
| Poland bantam | m | j006 | 12.50 | 11.15 | 52.84 | 50.06 |
| Malay | m | k001 | 24.73 | 20.58 | 87.99 | 80.03 |
| Game Fowl | f | n001 | 14.83 | 13.21 | 50.64 | 48.42 |
| Hamburgh bantam | m | r651 | 15.66 | 12.68 | 58.68 | 56.12 |
| Japanese Bantam | m | r652 | 12.12 | 9.62 | 40.08 | 37.01 |
| Poland bantam | m | r653 | 11.46 | 10.40 | 50.81 | 48.41 |


| Modern breed coracoid metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | Bb | Bf | GL | Lm |
| Poland bantam | m | r655 | 10.58 | 10.27 | 50.27 | 47.93 |
| Poland bantam | m | r656 | 13.78 | 11.72 | 56.71 | 54.00 |
| Shamo | m | r657 | 25.48 | 21.14 | 80.69 | 75.17 |
| Shamo | m | r658 | 28.20 | 21.58 | 88.33 | 83.70 |
| Lakenvelder | m | r659 | 16.72 | 15.23 | 66.13 | 63.01 |
| Silkie | f | r660 | 14.28 | 11.33 | 49.23 | 45.81 |
| Silkie | f | r661 | 13.55 | 10.77 | 46.34 | 42.30 |
| Asil | f | r662 | 16.95 | 13.37 | 53.60 | 49.87 |
| Game Fowl | f | r663 | 14.30 | 11.87 | 56.36 | 53.52 |
| Orpington | m | r664 | 21.82 | 17.43 | 73.16 | 68.76 |
| Vorwerk | f | r665 | 18.34 | 15.66 | 58.87 | 54.63 |
| Silkie | m | r666 | 15.33 | 12.39 | 52.24 | 49.30 |
| Game Fowl | f | r667 | 15.36 | 12.33 | 54.44 | 51.44 |
| Japanese Bantam | m | r668 | 11.46 | 8.76 | 38.52 | 34.68 |
| Sussex | f | r669 | 15.98 | 13.14 | 63.18 | 59.87 |
| Rumpless Araucana | m | r670 | 20.59 | 17.26 | 72.99 | 68.49 |
| Dorking | f | r723 | 18.01 | 14.15 | 61.63 | 57.86 |
| Dorking | $f$ | r724 | 21.15 | 16.00 | 68.12 | 64.32 |
| Indian Game | f | r725 | 17.05 | 12.95 | 62.76 | 59.72 |
| Hamburgh bantam | f | r728 | 11.88 | 10.18 | 45.13 | 43.02 |
| Hamburgh bantam | f | r729 | 10.12 | 7.96 | 41.28 | 39.58 |


| Modern breed coracoid metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | Bb | Bf | GL | Lm |
| Hamburgh bantam | f | r730 | 9.37 | 7.50 | 39.78 | 37.78 |
| Hamburgh bantam | m | r731 | 12.73 | 10.48 | 48.23 | 45.83 |
| Game Fowl | m | r732 | 19.32 | 16.59 | 62.03 | 58.94 |
| Game Fowl | m | r735 | 16.39 | 13.62 | 60.27 | 57.36 |
| Hamburgh | m | r736 | 19.30 | 16.30 | 66.03 | 63.17 |
| Hamburgh | m | r740 | 17.48 | 14.90 | 63.30 | 60.74 |
| Hamburgh | m | r741 | 18.13 | 15.53 | 62.70 | 60.77 |
| Hamburgh | f | r742 | 15.86 | 12.83 | 56.84 | 54.64 |
| Maran | m | s001 | 20.79 | 16.81 | 73.37 | 69.21 |
| Sussex | f | s002 | 18.24 | 15.57 | 68.46 | 63.84 |
| Welsummer | f | s003 | 15.92 | 13.42 | 59.21 | 56.08 |
| Silkie | m | t007 | 15.89 | 13.92 | 57.23 | 53.33 |
| Rhode Island | m | t019 | 20.86 | 17.67 | 69.44 | 64.43 |
| Leghorn | m | t022 | 18.21 | 14.61 | 63.93 | 60.65 |
| Kulm | m | t023 | 23.78 | 19.16 | 76.60 | 71.83 |
| Kulm | m | t024 | 23.35 | 19.37 | 76.40 | 71.84 |
| Sussex | f | t026 | 14.19 | 11.46 | 56.53 | 53.98 |
| Sussex | f | t028 | 17.19 | 13.60 | 59.06 | 54.96 |
| Silkie | f | t032 | 13.74 | 10.82 | 47.42 | 44.11 |
| Silkie | m | t034 | 17.21 | 14.99 | 57.95 | 53.83 |
| crested rumpless turkish | $\times$ | t040 | 11.87 | 9.90 | 47.42 | 44.50 |


| Modern breed coracoid metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | Bb | Bf | GL | Lm |
| Cochin | m | t046 | 19.91 | 17.52 | 72.82 | 68.53 |
| Sultan | m | t048 | 14.46 | 12.18 | 56.97 | 54.67 |
| Spanish | m | t049 | 19.37 | 17.01 | 72.28 | 68.07 |
| Red Jungle Fowl | m | t059 | 13.46 | 10.69 | 51.84 | 49.45 |
| Hamburgh | m | t060 | 15.52 | 13.75 | 60.05 | 57.20 |
| Dorking | m | t065 | 22.25 | 17.85 | 79.44 | 77.69 |
| Red Jungle Fowl | f | t143 | 12.00 | 9.66 | 44.38 | 42.10 |
| Red Jungle Fowl | m | t144 | 13.40 | 10.93 | 52.32 | 50.15 |
| Red Jungle Fowl | m | t146 | 13.34 | 11.45 | 50.60 | 48.03 |
| Game Fowl | f | w518 | 15.24 | 12.38 | 56.63 | 53.25 |
| Red Jungle Fowl | f | w519 | 10.23 | 7.96 | 42.15 | 40.04 |
| Dorking | m | w528 | 22.03 | 17.95 | 73.41 | 69.81 |
| Dorking | f | w537 | 17.88 | 13.77 | 64.42 | 62.33 |
| Sussex | f | w538 | 14.42 | 13.42 | 60.19 | 56.77 |
| Game Fowl | m | w611 | 15.46 | 13.60 | 59.98 | 57.30 |
| Game Fowl | m | w612 | 17.82 | 15.01 | 63.29 | 60.25 |
| Red Jungle Fowl | m | z001 | 15.57 | 12.47 | 57.14 | 53.78 |
| Rhode Island | ?f | z002 | 16.57 | 14.20 | 61.03 | 56.75 |
| Krüper | m | k164 | 17.21 | 15.38 | 58.47 | 55.35 |

## 2.I. 2 Measurement ratios

Modern coracoid measurement ratios

| ID | breed/type | sex | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| a003 | Dorking | f | 95.48 | 74.65 | 28.51 | 29.86 | 21.28 | 22.29 |
| e001 | Dorking | f | 94.43 | 75.47 | 30.50 | 32.31 | 23.02 | 24.38 |
| e004 | Hamburgh | f | 99.73 | 83.83 | 29.13 | 29.21 | 24.42 | 24.48 |
| e010 | RJF | f | 94.40 | 83.42 | 24.77 | 26.24 | 20.66 | 21.89 |
| e013 | O E Game | m | 94.68 | 83.05 | 27.23 | 28.76 | 22.61 | 23.88 |
| e014 | Dorking | m | 94.32 | 79.82 | 28.44 | 30.15 | 22.70 | 24.07 |
| h003 | Silkie | f | 93.70 | 77.44 | 29.62 | 31.62 | 22.94 | 24.48 |
| h011 | Dorking | f | 93.65 | 85.19 | 30.54 | 32.61 | 26.01 | 27.78 |
| k001 | Asian Game | m | 90.95 | 83.22 | 28.11 | 30.9 | 23.39 | 25.72 |
| n001 | O E Game | f | 95.62 | 89.08 | 29.29 | 30.63 | 26.09 | 27.28 |
| r651 | Hamburgh | m | 95.64 | 80.97 | 26.69 | 27.90 | 21.61 | 22.59 |
| r657 | Asian Game | m | 93.16 | 82.97 | 31.58 | 33.90 | 26.20 | 28.12 |
| r658 | Asian Game | m | 94.76 | 76.52 | 31.93 | 33.69 | 24.43 | 25.78 |
| r660 | Silkie | f | 93.05 | 79.34 | 29.01 | 31.17 | 23.01 | 24.73 |
| r661 | Silkie | f | 91.28 | 79.48 | 29.24 | 32.03 | 23.24 | 25.46 |
| r662 | Asian Game | f | 93.04 | 78.88 | 31.62 | 33.99 | 24.94 | 26.81 |
| r663 | O E Game | f | 94.96 | 83.01 | 25.37 | 26.72 | 21.06 | 22.18 |
| r666 | Silkie | m | 94.37 | 80.82 | 29.35 | 31.10 | 23.72 | 25.13 |
| r667 | O E Game | f | 94.49 | 80.27 | 28.21 | 29.86 | 22.65 | 23.97 |

Modern coracoid measurement ratios

| ID | breed/type | sex | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| :--- | :--- | :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| r723 | Dorking | f | 93.88 | 78.57 | 29.22 | 31.13 | 22.96 | 24.46 |
| r724 | Dorking | f | 94.42 | 75.65 | 31.05 | 32.88 | 23.49 | 24.88 |
| r732 | O E Game | m | 95.02 | 85.87 | 31.15 | 32.78 | 26.75 | 28.15 |
| r735 | O E Game | m | 95.17 | 83.10 | 27.19 | 28.57 | 22.6 | 23.74 |
| r736 | Hamburgh | m | 95.67 | 84.46 | 29.23 | 30.55 | 24.69 | 25.8 |
| r740 | Hamburgh | m | 95.96 | 85.24 | 27.61 | 28.78 | 23.54 | 24.53 |
| r74I | Hamburgh | m | 96.92 | 85.66 | 28.92 | 29.83 | 24.77 | 25.56 |
| r742 | Hamburgh | f | 96.13 | 80.90 | 27.9 | 29.03 | 22.57 | 23.48 |
| t007 | Silkie | m | 93.19 | 87.60 | 27.77 | 29.80 | 24.32 | 26.10 |
| t022 | Hamburgh | m | 94.87 | 80.23 | 28.48 | 30.02 | 22.85 | 24.09 |
| t023 | Asian Game | m | 93.77 | 80.57 | 31.04 | 33.11 | 25.01 | 26.67 |
| t024 | Asian Game | m | 94.03 | 82.96 | 30.56 | 32.50 | 25.35 | 26.96 |
| t032 | Silkie | f | 93.02 | 78.75 | 28.98 | 31.15 | 22.82 | 24.53 |
| t034 | Silkie | m | 92.89 | 87.10 | 29.70 | 31.97 | 25.87 | 27.85 |
| t059 | RJF | m | 95.39 | 79.42 | 25.96 | 27.22 | 20.62 | 21.62 |
| t060 | Hamburgh | m | 95.25 | 88.60 | 25.85 | 27.13 | 22.9 | 24.04 |
| t065 | Dorking | m | 97.80 | 80.22 | 28.0 I | 28.64 | 22.47 | 22.98 |
| t143 | RJF | f | 94.86 | 80.50 | 27.04 | 28.50 | 21.77 | 22.95 |
| t144 | RJF | m | 95.85 | 81.57 | 25.61 | 26.72 | 20.89 | 21.79 |
| t146 | RJF | m | 94.92 | 85.83 | 26.36 | 27.77 | 22.63 | 23.84 |
| w5I8 | O E Game | f | 94.03 | 81.23 | 26.91 | 28.62 | 21.86 | 23.25 |

Modern coracoid measurement ratios

| ID | breed/type | sex | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| :--- | :--- | :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| w5I9 | RJF | f | 94.99 | 77.8 I | 24.27 | 25.55 | 18.88 | 19.88 |
| w528 | Dorking | m | 95.10 | 81.48 | 30.01 | 31.56 | 24.45 | 25.71 |
| w537 | Dorking | f | 96.76 | 77.01 | 27.76 | 28.69 | 21.38 | 22.09 |
| w6II | O E Game | m | 95.53 | 87.97 | 25.78 | 26.98 | 22.67 | 23.73 |
| w6I2 | O E Game | m | 95.20 | 84.23 | 28.16 | 29.58 | 23.72 | 24.91 |
| z00I | RJF | m | 94.12 | 80.09 | 27.25 | 28.95 | 21.82 | 23.19 |

### 2.2 Humerus

### 2.2.I Standard metrics

| Modern breed humerus metrics |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| a00I | Poland bantam | m | 16.15 | 19.84 | 76.98 | 7.20 |
| a002 | Poland bantam | m | 14.94 | I 8.39 | 66.34 | 7.30 |
| a003 | Dorking | f | 19.66 | 24.19 | 84.84 | 8.43 |
| a005 | Brahma | f | 20.85 | 26.36 | 99.16 | 8.87 |
| a006 | Houdan | m | 18.54 | 22.30 | 87.84 | 7.88 |
| e001 | Dorking | f | 19.37 | 24.06 | 85.88 | 8.66 |
| e002 | Ross 308 | m | 25.87 | 30.89 | 104.76 | 10.29 |
| e003 | Ross 308 | f | 19.78 | 24.76 | 84.19 | 7.92 |


| Modern breed humerus metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| e004 | Old English Pheasant Fowl | $f$ | 16.79 | 21.48 | 80.74 | 7.28 |
| e005 | Scots Grey | f | 15.11 | 19.10 | 64.26 | 6.63 |
| e006 | Poland bantam | m | 16.82 | 20.02 | 75.35 | 7.59 |
| e007 | Sussex | f | 19.12 | 21.93 | 83.74 | 7.46 |
| e008 | Friesian bantam | m | 15.98 | 19.52 | 73.50 | 6.82 |
| e009 | Araucana bantam | m | 17.06 | 21.63 | 75.79 | 7.64 |
| e010 | Red Jungle Fowl | f | 12.84 | 15.70 | 61.07 | 5.98 |
| e011 | Poland bantam | m | 15.63 | 18.84 | 73.04 | 6.61 |
| e012 | Poland bantam | m | 16.28 | 19.89 | 77.70 | 7.65 |
| e013 | Game Fowl | m | 18.00 | 22.42 | 82.31 | 7.71 |
| e014 | Dorking | m | 21.90 | 26.43 | 99.08 | 8.96 |
| h001 | Poland bantam | m | 15.69 | 20.85 | 74.17 | 7.16 |
| h002 | Poland bantam | m | 15.54 | 19.14 | 71.60 | 7.02 |
| h003 | Silkie bantam | f | 15.15 | 18.58 | 67.59 | 7.08 |
| h004 | Sussex | m | 18.63 | 23.19 | 85.45 | 8.50 |
| h005 | Poland bantam | ?f | 15.12 | 19.68 | 70.91 | 7.05 |
| h006 | Poland bantam | f | 14.16 | 17.11 | 64.45 | 6.11 |
| h007 | Maran | m | 17.66 | 23.19 | 86.81 | 8.74 |
| h008 | Sussex | f | 17.49 | 21.77 | 80.67 | 7.53 |
| h009 | Rosecomb bantam | m | 15.43 | 19.18 | 73.19 | 6.67 |
| h0l0 | Maran | m | 23.17 | 29.72 | 105.77 | 10.17 |


| Modern breed humerus metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| h011 | Dorking | f | 19.86 | 25.48 | 88.39 | 9.29 |
| j005 | Poland bantam | m | 14.20 | 17.83 | 67.12 | 5.92 |
| j006 | Poland bantam | m | 15.23 | 18.57 | 67.76 | 6.71 |
| k001 | Malay | m | 24.85 | 31.92 | 118.87 | 11.20 |
| n001 | Game Fowl | f | 14.62 | 19.15 | 65.31 | 7.03 |
| r651 | Hamburgh bantam | m | 16.93 | 20.71 | 77.49 | 7.32 |
| r652 | Japanese Bantam | m | 12.87 | 16.22 | 47.97 | 6.19 |
| r653 | Poland bantam | m | 13.68 | 16.70 | 64.95 | 5.91 |
| r655 | Poland bantam | m | 13.74 | 16.35 | 66.04 | 5.79 |
| r656 | Poland bantam | m | 15.71 | 19.78 | 71.42 | 6.66 |
| r657 | Shamo | m | 23.37 | 29.67 | 105.12 | 9.67 |
| r658 | Shamo | m | 25.01 | 31.63 | 111.54 | 10.24 |
| r659 | Lakenvelder | m | 18.98 | 23.80 | 89.37 | 7.72 |
| r660 | Silkie | f | 14.11 | 17.93 | 64.73 | 6.18 |
| r661 | Silkie | f | 13.50 | 15.67 | 58.58 | 5.45 |
| r662 | Asil | f | 16.96 | 20.96 | 73.84 | 7.42 |
| r663 | Game Fowl | f | 15.14 | 20.01 | 70.75 | 7.42 |
| r664 | Orpington | m | 21.57 | 26.97 | 94.22 | 10.13 |
| r665 | Vorwerk | f | 17.67 | 21.82 | 79.75 | 7.70 |
| r666 | Silkie | m | 16.32 | 19.17 | 69.62 | 7.16 |
| r667 | Game Fowl | f | 15.08 | 18.97 | 72.19 | 7.22 |


| Modern breed humerus metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| r668 | Japanese Bantam | m | 14.08 | 16.37 | 44.80 | 6.63 |
| r669 | Sussex | f | 17.10 | 21.77 | 83.15 | 8.05 |
| r670 | Rumpless Araucana | m | 21.05 | 26.34 | 92.94 | 8.37 |
| r723 | Dorking | f | 17.37 | 23.17 | 79.01 | 7.88 |
| r724 | Dorking | f | 19.40 | 25.16 | 86.78 | 8.21 |
| r725 | Indian Game | f | 17.85 | 23.68 | 76.17 | 9.30 |
| r728 | Hamburgh bantam | f | 12.68 | 15.56 | 59.39 | 5.76 |
| r729 | Hamburgh bantam | f | 11.96 | 14.30 | 56.74 | 5.24 |
| r730 | Hamburgh bantam | f | 12.11 | 14.58 | 54.47 | 5.34 |
| r731 | Hamburgh bantam | m | 14.30 | 17.07 | 64.98 | 6.52 |
| r732 | Game Fowl | m | 17.58 | 23.41 | 81.30 | 8.17 |
| r735 | Game Fowl | m | 16.17 | 21.44 | 81.17 | 7.73 |
| r736 | Hamburgh | m | 18.54 | 23.25 | 89.21 | 8.09 |
| r740 | Hamburgh | m | 17.41 | 21.68 | 86.54 | 7.93 |
| r741 | Hamburgh | m | 17.38 | 21.45 | 86.52 | 7.46 |
| r742 | Hamburgh | f | 15.87 | 20.28 | 76.92 | 7.46 |
| s001 | Maran | m | 21.51 | 26.06 | 92.65 | 9.42 |
| s002 | Sussex | f | 19.32 | 23.33 | 86.68 | 7.93 |
| s003 | Welsummer | f | 17.06 | 21.12 | 77.46 | 7.47 |
| t007 | Silkie | m | 17.20 | 21.74 | 75.41 | 7.47 |
| t019 | Rhode Island | m | 21.12 | 24.80 | 93.61 | 8.61 |


| Modern breed humerus metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| t022 | Leghorn | m | 17.42 | 22.03 | 84.69 | 7.37 |
| t023 | Kulm | m | 22.86 | 27.77 | 98.24 | 9.71 |
| t024 | Kulm | m | 23.35 | 29.16 | 98.63 | 9.55 |
| t026 | Sussex | f | 14.80 | 18.70 | 73.67 | 6.53 |
| t027 | Sussex | f | 16.85 | 22.09 | 78.59 | 7.42 |
| t032 | Silkie | f | 13.86 | 17.85 | 63.27 | 5.81 |
| t034 | Silkie | m | 17.32 | 21.31 | 75.45 | 7.15 |
| t040 | crested rumpless turkish | x | 13.99 | 17.50 | 61.50 | 6.35 |
| t041 | Game Fowl | m | 17.62 | 21.98 | 83.56 | 7.98 |
| t042 | Sultan | f | 15.06 | 18.69 | 68.74 | 6.62 |
| t042 | Sultan | f | 15.10 |  | 68.63 | 6.71 |
| t046 | Cochin | m | 20.51 | 25.44 | 93.17 | 9.38 |
| t048 | Sultan | m | 15.56 | 19.40 | 72.04 | 6.95 |
| t049 | Spanish | m | 18.91 | 24.21 | 91.21 | 8.01 |
| t059 | Red Jungle Fowl | m | 14.38 | 17.75 | 71.74 | 6.77 |
| t060 | Hamburgh | m | 16.58 | 20.64 | 77.86 | 7.66 |
| t060 | Hamburgh | m | 16.50 | 20.62 | 77.51 | 7.43 |
| t065 | Dorking | m | 23.50 | 30.24 | 104.66 | 9.79 |
| t143 | Red Jungle Fowl | f | 12.25 | 15.22 | 58.78 | 5.67 |
| t144 | Red Jungle Fowl | m | 14.60 | 18.33 | 68.58 | 7.04 |
| t145 | Red Jungle Fowl | f | 13.00 | 16.24 | 62.53 | 6.10 |


| Modern breed humerus metrics |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC |
| t146 | Red Jungle Fowl | m | 13.73 | 17.67 | 69.78 | 5.99 |
| t147 | Leghorn | f | 14.59 | 18.75 | 70.26 | 6.53 |
| w518 | Game Fowl | f | 15.05 | 18.86 | 69.49 | 7.34 |
| w519 | Red Jungle Fowl | f | 10.89 | 12.98 | 53.16 | 4.86 |
| w528 | Dorking | m | 22.28 | 27.16 | 97.58 | 9.15 |
| w537 | Dorking | f | 18.06 | 23.68 | 82.19 | 8.34 |
| w538 | Sussex | f | 16.98 | 21.07 | 80.14 | 8.13 |
| w611 | Game Fowl | m | 16.40 | 21.14 | 81.15 | 7.78 |
| w612 | Game Fowl | m | 17.42 | 21.79 | 82.25 | 7.91 |
| z001 | Red Jungle Fowl | m | 15.07 | 18.85 | 73.40 | 6.94 |
| z002 | Rhode Island | ?f | 17.18 | 21.48 | 79.08 | 8.04 |
| kI64 | Krüper | m | 18.65 | 22.57 | 70.69 | 8.09 |

### 2.2.2 Measurement ratios

Modern humeri measurement ratios

| ID | breed/type | sex | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| :--- | :--- | :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| a003 | Dorking | f | 81.27 | 9.94 | 28.5 I | 23.17 | 34.85 | 42.88 |
| e00I | Dorking | f | 80.5 I | 10.08 | 28.02 | 22.55 | 35.99 | 44.71 |
| e004 | Hamburgh | f | 78.17 | 9.02 | 26.6 | 20.8 | 33.89 | 43.36 |
| e010 | RJF | f | 81.78 | 9.79 | 25.71 | 21.03 | 38.09 | 46.57 |

## Modern humeri measurement ratios

| ID | breed/type | sex | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| e013 | O E Game | m | 80.29 | 9.37 | 27.24 | 21.87 | 34.39 | 42.83 |
| e014 | Dorking | m | 82.86 | 9.04 | 26.68 | 22.1 | 33.9 | 40.91 |
| h003 | Silkie | f | 81.54 | 10.47 | 27.49 | 22.41 | 38.11 | 46.73 |
| h011 | Dorking | f | 77.94 | 10.51 | 28.83 | 22.47 | 36.46 | 46.78 |
| k001 | Asian Game | m | 77.85 | 9.42 | 26.85 | 20.91 | 35.09 | 45.07 |
| n001 | O E Game | f | 76.34 | 10.76 | 29.32 | 22.39 | 36.71 | 48.08 |
| r651 | Hamburgh | m | 81.75 | 9.45 | 26.73 | 21.85 | 35.35 | 43.24 |
| r657 | Asian Game | m | 78.77 | 9.20 | 28.22 | 22.23 | 32.59 | 41.38 |
| r658 | Asian Game | m | 79.07 | 9.18 | 28.36 | 22.42 | 32.37 | 40.94 |
| r660 | Silkie | f | 78.69 | 9.55 | 27.7 | 21.8 | 34.47 | 43.80 |
| r661 | Silkie | f | 86.15 | 9.30 | 26.75 | 23.05 | 34.78 | 40.37 |
| r662 | Asian Game | f | 80.92 | 10.05 | 28.39 | 22.97 | 35.4 | 43.75 |
| r663 | O E Game | f | 75.66 | 10.49 | 28.28 | 21.4 | 37.08 | 49.01 |
| r666 | Silkie | m | 85.13 | 10.28 | 27.54 | 23.44 | 37.35 | 43.87 |
| r667 | O E Game | f | 79.49 | 10.00 | 26.28 | 20.89 | 38.06 | 47.88 |
| r723 | Dorking | f | 74.97 | 9.97 | 29.33 | 21.98 | 34.01 | 45.37 |
| r724 | Dorking | f | 77.11 | 9.46 | 28.99 | 22.36 | 32.63 | 42.32 |
| r732 | O E Game | m | 75.10 | 10.05 | 28.79 | 21.62 | 34.9 | 46.47 |
| r735 | O E Game | m | 75.42 | 9.52 | 26.41 | 19.92 | 36.05 | 47.80 |
| r736 | Hamburgh | m | 79.74 | 9.07 | 26.06 | 20.78 | 34.8 | 43.64 |
| r740 | Hamburgh | m | 80.30 | 9.16 | 25.05 | 20.12 | 36.58 | 45.55 |

## Modern humeri measurement ratios

| ID | breed/type | sex | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| r741 | Hamburgh | m | 81.03 | 8.62 | 24.79 | 20.09 | 34.78 | 42.92 |
| r742 | Hamburgh | f | 78.25 | 9.70 | 26.37 | 20.63 | 36.79 | 47.01 |
| t007 | Silkie | m | 79.12 | 9.91 | 28.83 | 22.81 | 34.36 | 43.43 |
| t022 | Hamburgh | m | 79.07 | 8.7 | 26.01 | 20.57 | 33.45 | 42.31 |
| t023 | Asian Game | m | 82.32 | 9.88 | 28.27 | 23.27 | 34.97 | 42.48 |
| t024 | Asian Game | m | 80.08 | 9.68 | 29.57 | 23.67 | 32.75 | 40.9 |
| t032 | Silkie | f | 77.65 | 9.18 | 28.21 | 21.91 | 32.55 | 41.92 |
| t034 | Silkie | m | 81.28 | 9.48 | 28.24 | 22.96 | 33.55 | 41.28 |
| t041 | O E Game | m | 80.16 | 9.55 | 26.3 | 21.09 | 36.31 | 45.29 |
| t059 | RJF | m | 81.01 | 9.44 | 24.74 | 20.04 | 38.14 | 47.08 |
| t060 | Hamburgh | m | 80.33 | 9.84 | 26.51 | 21.29 | 37.11 | 46.2 |
| t065 | Dorking | m | 77.71 | 9.35 | 28.89 | 22.45 | 32.37 | 41.66 |
| t143 | RJF | f | 80.49 | 9.65 | 25.89 | 20.84 | 37.25 | 46.29 |
| t144 | RJF | m | 79.65 | 10.27 | 26.73 | 21.29 | 38.41 | 48.22 |
| t145 | RJF | f | 80.05 | 9.76 | 25.97 | 20.79 | 37.56 | 46.92 |
| t146 | RJF | m | 77.7 | 8.58 | 25.32 | 19.68 | 33.9 | 43.63 |
| t147 | Hamburgh | f | 77.81 | 9.29 | 26.69 | 20.77 | 34.83 | 44.76 |
| w518 | O E Game | f | 79.8 | 10.56 | 27.14 | 21.66 | 38.92 | 48.77 |
| w519 | RJF | f | 83.90 | 9.14 | 24.42 | 20.49 | 37.44 | 44.63 |
| w528 | Dorking | m | 82.03 | 9.38 | 27.83 | 22.83 | 33.69 | 41.07 |
| w537 | Dorking | f | 76.27 | 10.15 | 28.81 | 21.97 | 35.22 | 46.18 |

## Modern humeri measurement ratios

| ID | breed/type | sex | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| :--- | :--- | :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| w6II | O E Game | m | 77.58 | 9.59 | 26.05 | 20.21 | 36.8 | 47.44 |
| w6I2 | O E Game | m | 79.94 | 9.62 | 26.49 | 21.18 | 36.3 | 45.4 I |
| z00I | RJF | m | 79.95 | 9.46 | 25.68 | 20.53 | 36.82 | 46.05 |

### 2.3 Femur

### 2.3.I Standard metrics

| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| a001 | Poland bantam | m | 15.75 | 15.98 | 13.34 | 11.03 | 81.58 | 75.68 | 7.72 |
| a002 | Poland bantam | m | 14.92 | 14.72 | 12.87 | 10.38 | 72.19 | 66.88 | 8.07 |
| a003 | Dorking | f | 19.82 | 19.81 | 16.02 | 13.99 | 92.76 | 85.32 | 8.32 |
| a005 | Brahma | f | 22.40 | 22.05 | $17.90$ | $15.99$ | 106.98 | 100.21 | 11.06 |
| a006 | Houdan | m | 18.91 | 18.82 | 15.30 | 12.38 | 96.46 | 89.57 | 8.65 |
| e001 | Dorking | f | 20.12 | 20.60 | 16.15 | 15.27 | 97.64 | 90.40 | 9.11 |
| e002 | Ross 308 | m | 28.36 | 27.58 | 24.52 | 18.28 | 116.06 | 107.23 | 10.98 |
| e003 | Ross 308 | f | 21.28 | 20.20 | 16.92 | 15.51 | 95.12 | 89.76 | 9.48 |
| e004 | Old English Pheasant Fowl | f | 17.27 | 16.77 | 14.02 | 12.06 | 89.66 | 83.89 | 7.61 |
| e005 | Scots Grey | f | 15.29 | 15.71 | 13.58 | 10.36 | 68.19 | 63.62 | 6.41 |
| e006 | Poland bantam | m | 16.55 | 16.36 | 14.25 | 11.43 | 81.90 | 75.64 | 8.05 |


| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| e007 | Sussex | f | 19.77 | 18.92 | 18.30 | 13.32 | 96.02 | 88.84 | 8.10 |
| e008 | Friesian bantam | m | 16.44 | 15.51 | 13.67 | 11.35 | 79.07 | 73.10 | 6.93 |
| e009 | Araucana bantam | m | 18.12 | 16.67 | 15.13 | 11.27 | 83.70 | 77.81 | 8.53 |
| e010 | Red Jungle Fowl | f | 13.15 | 12.77 | 10.68 | 8.74 | 66.51 | 62.39 | 5.80 |
| e011 | Poland bantam | m | 15.45 | 16.04 | 13.51 | 11.26 | 79.32 | 73.97 | 6.67 |
| e012 | Poland bantam | m | 16.43 | 16.83 | 13.53 | 11.17 | 94.66 | 77.91 | 8.16 |
| e013 | Game Fowl | m | 18.34 | 19.17 | 15.99 | 13.13 | 92.72 | 86.61 | 8.15 |
| e014 | Dorking | m | 23.52 | 22.52 | 19.81 | 16.18 | 108.92 | 100.70 | 10.64 |
| h001 | Poland bantam | m | 16.67 | 17.46 | 14.85 | 11.50 | 81.63 | 75.93 | 7.51 |
| h002 | Poland bantam | m | 16.69 | 17.27 | 13.99 | $11.73$ | 80.53 | 74.57 | 8.11 |
| h003 | Silkie bantam | f | 15.71 | 15.29 | 12.83 | 10.26 | 73.29 | 68.08 | 6.97 |
| h004 | Sussex | m | 20.50 | 20.03 | 16.33 | 13.48 | 97.32 | 90.82 | 8.81 |
| h005 | Poland bantam | ?f | 16.05 | 17.18 | 13.52 | 10.79 | 81.19 | 75.44 | 7.32 |
| h006 | Poland bantam | f | 13.78 | 13.40 | 11.82 | 8.95 | 70.27 | 65.74 | 5.71 |
| h007 | Maran | m | 20.52 | 19.82 | 16.86 | 12.49 | 101.05 | 94.52 | 8.93 |
| h008 | Sussex | f | 17.93 | 17.65 | 14.91 | 12.51 | 87.84 | 82.21 | 8.63 |
| h009 | Rosecomb bantam | m | 15.90 | 16.33 | 13.66 | 10.42 | 80.91 | 75.89 | 7.03 |
| h010 | Maran | m | 26.12 | 25.48 | 21.74 | 17.22 | 120.00 | 112.52 | 11.36 |
| h01l | Dorking | f | 20.03 | 19.32 | 16.14 | 14.35 | 95.78 | 87.82 | 8.73 |
| j005 | Poland bantam | m | 14.63 | 15.50 | 12.79 | 10.57 | 74.02 | 69.08 | 6.05 |
| j006 | Poland bantam | m | 14.90 | 14.74 | 12.92 | 10.33 | 74.66 | 69.27 | 6.14 |


| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| k001 | Malay | m | 28.65 | 27.88 | 21.99 | 20.07 | 134.40 | 125.10 | 11.97 |
| n001 | Game Fowl | f | 15.04 | 15.30 | 13.18 | 11.01 | 71.86 | 66.62 | 7.22 |
| r651 | Hamburgh bantam | m | 18.06 | 17.79 | 14.60 | 12.89 | 84.79 | 77.56 | 8.31 |
| r652 | Japanese Bantam | m | 13.25 | 12.34 | 10.74 | 9.36 | 47.47 | 43.79 | 6.11 |
| r653 | Poland bantam | m | 13.07 | 13.41 | 11.68 | 9.61 | 72.55 | 67.01 | 6.11 |
| r655 | Poland bantam | m | 14.29 | 14.70 | 12.56 | 9.98 | 74.12 | 69.17 | 6.20 |
| r656 | Poland bantam | m | 16.07 | 17.29 | 13.80 | 11.83 | 78.62 | 74.03 | 7.08 |
| r657 | Shamo | m | 26.32 | 25.77 | 21.28 | 17.55 | 117.36 | 109.29 | 11.35 |
| r658 | Shamo | m | 27.86 | 26.48 | 24.43 | 17.99 | 127.68 | 118.74 | 12.10 |
| r659 | Lakenvelder | m | 20.07 | 21.00 | 16.48 | 15.25 | 98.71 | 90.77 | 9.28 |
| r660 | Silkie | f | 14.21 | 14.00 | 12.03 | 9.56 | 70.68 | 65.56 |  |
| r661 | Silkie | f | 13.16 | 13.10 | 10.84 | 8.52 | 63.57 | 59.20 | 5.68 |
| r662 | Asil | f | 16.55 | 17.71 | 14.75 | 12.29 | 84.11 | 78.19 | 8.05 |
| r663 | Game Fowl | f | 15.49 | 15.74 | 12.85 | 10.70 | 78.24 | 72.79 | 7.10 |
| r664 | Orpington | m | 24.26 | 23.53 | 20.28 | 15.61 | 103.11 | 96.33 | 11.36 |
| r665 | Vorwerk | f | 19.94 | 18.34 | 15.46 | 13.77 | 89.13 | 82.56 | 8.23 |
| r666 | Silkie | m | 15.77 | 16.13 | 12.93 | 10.76 | 73.76 | 68.20 | 7.40 |
| r667 | Game Fowl | f | 15.98 | 15.92 | 13.50 | 10.85 | 78.98 | 73.94 | 7.10 |
| r668 | Japanese Bantam | m | 13.52 | 12.59 | 11.43 | 7.83 | 45.41 | 42.27 | 6.20 |
| r669 | Sussex | f | 19.15 | 18.92 | 15.62 | 12.18 | 89.30 | 82.52 | 10.23 |
| r670 | Rumpless Araucana | m | 23.41 | 22.96 | 18.81 | 14.62 | 103.41 | 96.21 | 9.73 |


| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| r723 | Dorking | f | 18.25 | 17.50 | 15.48 | 12.34 | 85.66 | 78.67 | 8.30 |
| r724 | Dorking | f | 20.93 | 19.21 | 16.58 | 13.88 | 93.62 | 85.96 | 8.54 |
| r725 | Indian Game | f | 18.89 | 17.78 | 16.02 | 13.10 | 81.50 | 74.80 | 8.80 |
| r728 | Hamburgh bantam | f | 12.19 | 12.54 | 9.79 | 7.89 | 65.83 | 60.95 | 5.76 |
| r729 | Hamburgh bantam | f | 11.67 | 12.10 | 9.31 | 7.32 | 62.13 | 57.20 | 5.39 |
| r730 | Hamburgh bantam | f | 11.58 | 11.68 | 9.74 | 7.69 | 58.52 | 54.30 | 5.12 |
| r731 | Hamburgh bantam | m | 13.63 | 14.79 | 11.09 | 9.00 | 71.19 | 65.53 | 6.43 |
| r732 | Game Fowl | m | 18.97 | 19.41 | 15.80 | 13.56 | 89.14 | 82.65 | 8.95 |
| r735 | Game Fowl | m | 17.08 | 17.58 | 14.81 | 12.01 | 88.59 | 82.47 | 8.05 |
| r736 | Hamburgh | m | 18.60 | 19.86 | 16.77 | 13.72 | 96.49 | 90.62 | 9.15 |
| r740 | Hamburgh | m | 18.18 | 19.11 | 15.31 | 12.37 | 94.40 | 88.02 | 8.48 |
| r741 | Hamburgh | m | 17.85 | 18.70 | 14.58 | 12.25 | 94.31 | 88.01 | 8.40 |
| r742 | Hamburgh | f | 15.60 | 15.92 | 13.37 | 11.28 | 82.63 | 76.98 | 7.56 |
| s001 | Maran | m | 24.76 | 24.22 | 20.37 | 16.34 | 106.79 | 98.13 | 9.41 |
| s002 | Sussex | f | 20.12 | 19.12 | 16.39 | 13.19 | 97.15 | 90.85 | 8.40 |
| s003 | Welsummer | f | 17.27 | 17.26 | 14.02 | 12.00 | 85.03 | 80.12 | 7.75 |
| t007 | Silkie | m | 17.31 | 17.64 | 14.26 | 11.60 | 81.41 | 75.87 | 8.25 |
| t019 | Rhode Island | m | 23.57 | 22.14 | 20.19 | 15.50 | 106.08 | 99.78 | 9.89 |
| t022 | Leghorn | m | 18.33 | 18.82 | 16.02 | 12.43 | 95.64 | 89.81 | 8.20 |
| t023 | Kulm | m | 25.56 | 24.39 | 21.44 | 17.80 | 115.27 | 105.03 | 11.04 |
| t024 | Kulm | m | 25.15 | 23.95 | 21.72 | 16.86 | 110.32 | 103.70 | 10.20 |


| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| t026 | Sussex | f | 16.19 | 15.82 | 13.50 | 10.42 | 82.07 | 77.17 | 7.14 |
| t027 | Sussex | f | 17.49 | 16.91 | 14.47 | 12.38 | 86.27 | 80.39 | 8.04 |
| t032 | Silkie | f | 14.03 | 13.96 | 12.31 | 9.63 | 69.66 | 64.70 | 6.01 |
| t034 | Silkie | m | 17.35 | 17.31 | 14.54 | 11.75 | 83.36 | 77.39 | 7.42 |
| t040 | crested rumpless turkish | $\times$ | 14.35 | 13.63 | 11.61 | 9.70 | 67.09 | 63.57 | 6.94 |
| t041 | Game Fowl | m | 18.02 | 17.69 | 15.89 | 12.63 | 94.82 | 87.90 | 8.53 |
| t042 | Sultan | f | 15.67 | 15.44 |  | 11.58 | 74.86 | 69.35 | 7.36 |
| t046 | Cochin | m | 21.93 | 22.43 | 19.12 | 15.31 | 105.59 | 98.40 | 9.87 |
| t048 | Sultan | m | 17.74 | 15.84 | 12.86 | 11.43 | 78.60 | 74.00 | 7.43 |
| t049 | Spanish | m | 21.39 | 21.07 | 17.55 | 15.50 | 104.61 | 96.11 | 8.93 |
| t059 | Red Jungle Fowl | m | 13.46 | 14.59 | 11.15 | 8.84 | 76.60 | 71.53 | 6.09 |
| t060 | Hamburgh | m | 17.13 | 17.67 | 14.66 | 12.47 | 87.04 | 82.23 | 7.56 |
| t065 | Dorking | m | 25.53 | 25.64 | 22.18 | 18.11 | 119.90 | 111.69 | 10.58 |
| t143 | Red Jungle Fowl | f | 11.85 | 12.47 | 9.39 | 8.13 | 62.44 | 58.42 | 5.53 |
| t144 | Red Jungle Fowl | m | 14.10 | 14.82 | 10.96 | 9.89 | 72.39 | 69.50 | 6.82 |
| t145 | Red Jungle Fowl | f | 12.66 | 12.86 | 10.74 | 8.48 | 67.38 | 62.92 | 6.15 |
| t146 | Red Jungle Fowl | m | 14.28 | 14.27 | 11.78 | 10.04 | 74.48 | 70.14 | 6.36 |
| t147 | Leghorn | f | 15.45 | 15.31 | 12.85 | 11.15 | 78.39 | 74.06 | 6.77 |
| w518 | Game Fowl | f | 16.00 | 15.13 | 12.60 | 10.80 | 79.55 | 74.34 | 7.59 |
| w519 | Red Jungle Fowl | f | 10.38 | 11.03 | 9.94 | 7.67 | 60.71 | 58.35 | 4.85 |
| w528 | Dorking | m | 22.84 | 23.72 | 19.68 | 15.94 | 108.34 | 100.40 | 9.61 |


| Modern breed femur metrics |  |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| GMM ID | Breed | Sex | Bd | Bp | Dd | Dp | GL | Lm | SC |
| w537 | Dorking | f | 18.38 | 19.05 | 15.40 | 13.17 | 87.84 | 80.19 | 9.08 |
| w538 | Sussex | f | 17.16 | 17.50 | 14.26 | 11.84 | 86.01 | 8 I .65 | 8.77 |
| w6II | Game Fowl | m | 17.58 | 18.01 | 14.48 | 11.97 | 89.57 | 83.61 | 8.06 |
| w6I2 | Game Fowl | m | 18.28 | 19.04 | 15.68 | 13.42 | 93.11 | 86.90 | 8.42 |
| z00I | Red Jungle Fowl | m | 15.29 | 15.23 | 12.31 | 10.05 | 81.27 | 76.29 | 6.67 |
| z002 | Rhode Island | ?f | 17.81 | 17.94 | 14.92 | 12.93 | 87.95 | 82.05 | 9.04 |
| kI64 | Krüper | m | 19.57 | 19.37 | 16.57 | 14.20 | 79.49 | 73.69 | 7.85 |

### 2.3.2 Measurement ratios

| Modern femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/type | sex | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| a003 | Dorking | $f$ | 80.83 | 41.98 | 8.97 | 21.37 | 21.36 | 23.23 | 23.22 | 9.75 | 42.00 | 80.87 | 87.33 | 17.27 | 18.78 | 51.94 |
| e001 | Dorking | f | 80.27 | 45.28 | 9.33 | 20.61 | 21.10 | 22.26 | 22.79 | 10.08 | 44.22 | 78.40 | 94.55 | 16.54 | 17.87 | 56.41 |
| e004 | Hamburgh | f | 81.18 | 44.06 | 8.49 | 19.26 | 18.70 | 20.59 | 19.99 | 9.07 | 45.38 | 83.6 | 86.02 | 15.64 | 16.71 | 54.28 |
| e010 | RJF | f | 81.22 | 44.11 | 8.72 | 19.77 | 19.20 | 21.08 | 20.47 | 9.30 | 45.42 | 83.63 | 81.84 | 16.06 | 17.12 | 54.31 |
| e013 | O E Game | m | 87.19 | 44.44 | 8.79 | 19.78 | 20.68 | 21.18 | 22.13 | 9.41 | 42.51 | 83.41 | 82.11 | 17.25 | 18.46 | 50.97 |
| e014 | Dorking | m | 84.23 | 45.24 | 9.77 | 21.59 | 20.68 | 23.36 | 22.36 | 10.57 | 47.25 | 87.97 | 81.68 | 18.19 | 19.67 | 53.71 |
| h003 | Silkie | f | 81.67 | 44.37 | 9.51 | 21.44 | 20.86 | 23.08 | 22.46 | 10.24 | 45.59 | 83.91 | 79.97 | 17.51 | 18.85 | 54.33 |
| h01l | Dorking | f | 80.58 | 43.58 | 9.11 | 20.91 | 20.17 | 22.81 | 22.00 | 9.94 | 45.19 | 83.54 | 88.91 | 16.85 | 18.38 | 54.09 |
| k001 | Asian Game | m | 76.75 | 41.78 | 8.91 | 21.32 | 20.74 | 22.90 | 22.29 | 9.57 | 42.93 | 78.87 | 91.27 | 16.36 | 17.58 | 54.43 |
| n001 | O E Game | f | 87.63 | 48.01 | 10.05 | 20.93 | 21.29 | 22.58 | 22.97 | 10.84 | 47.19 | 86.14 | 83.54 | 18.34 | 19.78 | 54.78 |


| Modern femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/type | sex | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| r651 | Hamburgh | m | 80.84 | 46.01 | 9.80 | 21.30 | 20.98 | 23.29 | 22.94 | 10.71 | 46.71 | 82.07 | 88.29 | 17.22 | 18.82 | 56.92 |
| r657 | Asian Game | m | 80.85 | 43.12 | 9.67 | 22.43 | 21.96 | 24.08 | 23.58 | 10.39 | 44.04 | 82.58 | 82.47 | 18.13 | 19.47 | 53.34 |
| r658 | Asian Game | m | 87.69 | 43.43 | 9.48 | 21.82 | 20.74 | 23.46 | 22.30 | 10.19 | 45.69 | 92.26 | 73.64 | 19.13 | 20.57 | 49.53 |
| r660 | Silkie | f | 84.66 | 42.08 | 8.46 | 20.10 | 19.81 | 21.67 | 21.35 | 9.12 | 42.71 | 85.93 | 79.47 | 17.02 | 18.35 | 49.71 |
| r661 | Silkie | f | 82.37 | 43.16 | 8.94 | 20.70 | 20.61 | 22.23 | 22.13 | 9.59 | 43.36 | 82.75 | 78.60 | 17.05 | 18.31 | 52.40 |
| r662 | Asian Game | f | 89.12 | 48.64 | 9.57 | 19.68 | 21.06 | 21.17 | 22.65 | 10.30 | 45.45 | 83.29 | 83.32 | 17.54 | 18.86 | 54.58 |
| r663 | O E Game | f | 82.96 | 45.84 | 9.07 | 19.80 | 20.12 | 21.28 | 21.62 | 9.75 | 45.11 | 81.64 | 83.27 | 16.42 | 17.65 | 55.25 |
| r666 | Silkie | m | 81.99 | 46.92 | 10.03 | 21.38 | 21.87 | 23.12 | 23.65 | 10.85 | 45.88 | 80.16 | 83.22 | 17.53 | 18.96 | 57.23 |
| r667 | O E Game | f | 84.48 | 44.43 | 8.99 | 20.23 | 20.16 | 21.61 | 21.53 | 9.60 | 44.60 | 84.80 | 80.37 | 17.09 | 18.26 | 52.59 |
| r723 | Dorking | f | 84.82 | 45.48 | 9.69 | 21.31 | 20.43 | 23.20 | 22.24 | 10.55 | 47.43 | 88.46 | 79.72 | 18.07 | 19.68 | 53.62 |
| r724 | Dorking | f | 79.22 | 40.80 | 9.12 | 22.36 | 20.52 | 24.35 | 22.35 | 9.93 | 44.46 | 86.31 | 83.72 | 17.71 | 19.29 | 51.51 |
| r732 | O E Game | m | 83.29 | 47.18 | 10.04 | 21.28 | 21.77 | 22.95 | 23.48 | 10.83 | 46.11 | 81.40 | 85.82 | 17.72 | 19.12 | 56.65 |
| r735 | O E Game | m | 86.71 | 47.13 | 9.09 | 19.28 | 19.84 | 20.71 | 21.32 | 9.76 | 45.79 | 84.24 | 81.09 | 16.72 | 17.96 | 54.36 |
| r736 | Hamburgh | m | 90.16 | 49.19 | 9.48 | 19.28 | 20.58 | 20.53 | 21.92 | 10.10 | 46.07 | 84.44 | 81.81 | 17.38 | 18.51 | 54.56 |
| r740 | Hamburgh | m | 84.21 | 46.64 | 8.98 | 19.26 | 20.24 | 20.65 | 21.71 | 9.63 | 44.37 | 80.12 | 80.80 | 16.22 | 17.39 | 55.39 |
| r741 | Hamburgh | m | 81.68 | 47.06 | 8.91 | 18.93 | 19.83 | 20.28 | 21.25 | 9.54 | 44.92 | 77.97 | 84.02 | 15.46 | 16.57 | 57.61 |
| r742 | Hamburgh | f | 85.71 | 48.46 | 9.15 | 18.88 | 19.27 | 20.27 | 20.68 | 9.82 | 47.49 | 83.98 | 84.37 | 16.18 | 17.37 | 56.54 |
| t007 | Silkie | m | 82.38 | 47.66 | 10.13 | 21.26 | 21.67 | 22.82 | 23.25 | 10.87 | 46.77 | 80.84 | 81.35 | 17.52 | 18.80 | 57.85 |
| t022 | Hamburgh | m | 87.40 | 44.74 | 8.57 | 19.17 | 19.68 | 20.41 | 20.96 | 9.13 | 43.57 | 85.12 | 77.59 | 16.75 | 17.84 | 51.19 |
| t023 | Asian Game | m | 83.88 | 43.19 | 9.58 | 22.17 | 21.16 | 24.34 | 23.22 | 10.51 | 45.26 | 87.90 | 83.02 | 18.60 | 20.41 | 51.49 |
| t024 | Asian Game | m | 86.36 | 40.56 | 9.25 | 22.80 | 21.71 | 24.25 | 23.10 | 9.84 | 42.59 | 90.69 | 77.62 | 19.69 | 20.95 | 46.96 |
| t032 | Silkie | f | 87.74 | 42.84 | 8.63 | 20.14 | 20.04 | 21.68 | 21.58 | 9.29 | 43.05 | 88.18 | 78.23 | 17.67 | 19.03 | 48.82 |
| t034 | Silkie | m | 83.80 | 42.77 | 8.90 | 20.81 | 20.77 | 22.42 | 22.37 | 9.59 | 42.87 | 84.00 | 80.81 | 17.44 | 18.79 | 51.03 |
| t041 | O E Game | m | 88.18 | 47.34 | 9.00 | 19.00 | 18.66 | 20.50 | 20.13 | 9.70 | 48.22 | 89.82 | 79.48 | 16.76 | 18.08 | 53.68 |


| Modern femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/type | sex | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| t059 | RJF | m | 82.84 | 45.25 | 7.95 | 17.57 | 19.05 | 18.82 | 20.40 | 8.51 | 41.74 | 76.42 | 79.28 | 14.56 | 15.59 | 54.62 |
| t060 | Hamburgh | m | 85.58 | 44.13 | 8.69 | 19.68 | 20.30 | 20.83 | 21.49 | 9.19 | 42.78 | 82.97 | 85.06 | 16.84 | 17.83 | 51.57 |
| t065 | Dorking | m | 86.88 | 41.44 | 8.82 | 21.29 | 21.38 | 22.86 | 22.96 | 9.47 | 41.26 | 86.51 | 81.65 | 18.50 | 19.86 | 47.70 |
| t143 | RJF | f | 79.24 | 46.67 | 8.86 | 18.98 | 19.97 | 20.28 | 21.35 | 9.47 | 44.35 | 75.30 | 86.58 | 15.04 | 16.07 | 58.89 |
| t144 | RJF | m | 77.73 | 48.37 | 9.42 | 19.48 | 20.47 | 20.29 | 21.32 | 9.81 | 46.02 | 73.95 | 90.24 | 15.14 | 15.77 | 62.23 |
| t145 | RJF | f | 84.83 | 48.58 | 9.13 | 18.79 | 19.09 | 20.12 | 20.44 | 9.77 | 47.82 | 83.51 | 78.96 | 15.94 | 17.07 | 57.26 |
| t146 | RJF | m | 82.49 | 44.54 | 8.54 | 19.17 | 19.16 | 20.36 | 20.35 | 9.07 | 44.57 | 82.55 | 85.23 | 15.82 | 16.79 | 53.99 |
| t147 | Hamburgh | f | 83.17 | 43.82 | 8.64 | 19.71 | 19.53 | 20.86 | 20.67 | 9.14 | 44.22 | 83.93 | 86.77 | 16.39 | 17.35 | 52.68 |
| w518 | O E Game | f | 78.75 | 47.44 | 9.54 | 20.11 | 19.02 | 21.52 | 20.35 | 10.21 | 50.17 | 83.28 | 85.71 | 15.84 | 16.95 | 60.24 |
| w519 | RJF | f | 95.76 | 46.72 | 7.99 | 17.10 | 18.17 | 17.79 | 18.90 | 8.31 | 43.97 | 90.12 | 77.16 | 16.37 | 17.04 | 48.79 |
| w528 | Dorking | m | 86.16 | 42.08 | 8.87 | 21.08 | 21.89 | 22.75 | 23.63 | 9.57 | 40.51 | 82.97 | 81.00 | 18.17 | 19.60 | 48.83 |
| w537 | Dorking | f | 83.79 | 49.40 | 10.34 | 20.92 | 21.69 | 22.92 | 23.76 | 11.32 | 47.66 | 80.84 | 85.52 | 17.53 | 19.20 | 58.96 |
| w611 | O E Game | m | 82.37 | 45.85 | 9.00 | 19.63 | 20.11 | 21.03 | 21.54 | 9.64 | 44.75 | 80.40 | 82.67 | 16.17 | 17.32 | 55.66 |
| w612 | O E Game | m | 85.78 | 46.06 | 9.04 | 19.63 | 20.45 | 21.04 | 21.91 | 9.69 | 44.22 | 82.35 | 85.59 | 16.84 | 18.04 | 53.70 |
| z001 | RJF | m | 80.51 | 43.62 | 8.21 | 18.81 | 18.74 | 20.04 | 19.96 | 8.74 | 43.80 | 80.83 | 81.64 | 15.15 | 16.14 | 54.18 |

### 2.4 Tibiotarsus

### 2.4.I Standard metrics

| Modern breed tibiotarsus metrics |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Dd | Dip | GL | La | SC |
| a001 | Poland bantam | m | 11.37 | 13.28 | 21.44 | 119.01 | 114.32 | 7.26 |
| a002 | Poland bantam | m | 10.41 | 11.36 | 19.97 | 106.45 | 102.03 | 6.32 |
| a003 | Dorking | f | 15.99 | 14.66 | 26.36 | 127.67 | 122.77 | 8.01 |
| a005 | Brahma | f | 16.41 | 18.14 | 30.31 | 158.00 | 153.98 | 10.10 |
| a006 | Houdan | m | 14.57 | 14.74 | 23.97 | 136.34 | 131.00 | 7.54 |
| e001 | Dorking | f | 15.59 | 15.48 | 26.74 | 131.54 | 126.20 | 8.33 |
| e002 | Ross 308 | m | 22.26 | 23.31 | 39.94 | 160.60 | 151.60 | 10.96 |
| e003 | Ross 308 | f | 17.17 | 17.32 | 28.67 | 130.24 | 123.72 | 8.59 |
| e005 | Scots Grey | f | 12.29 | 12.38 | 21.59 | 88.24 | 83.11 | 7.65 |
| e006 | Poland bantam | m | 12.55 | 12.95 | 22.61 | 116.64 | 112.01 | 6.87 |
| e007 | Sussex | f | 13.86 | 16.15 | 26.81 | 135.51 | 131.04 | 7.41 |
| e008 | Friesian bantam | m | 12.10 | 13.30 | 21.74 | 113.06 | 107.82 | 6.80 |
| e009 | Araucana bantam | m | 12.32 | 14.22 | 23.51 | 120.05 | 115.93 | 7.90 |
| e010 | Red Jungle Fowl | $f$ | 10.19 | 9.68 | 17.14 | 95.54 | 92.61 | 5.30 |
| e017 | Poland bantam | m | 11.56 | 12.49 | 21.21 | 116.60 | 109.25 | 6.02 |
| e012 | Poland bantam | m | 12.10 | 12.52 | 21.82 | 120.56 | 115.86 | 6.74 |
| e013 | Game Fowl | m | 12.73 | 14.66 | 25.68 | 135.98 | 131.34 | 7.61 |
| e014 | Dorking | m | 18.31 | 17.64 | 31.30 | 155.63 | 148.96 | 9.28 |


| Modern breed tibiotarsus metrics |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Dd | Dip | GL | La | SC |
| h001 | Poland bantam | m | 11.82 | 13.18 | 22.96 | 118.99 | 113.23 | 6.92 |
| h002 | Poland bantam | m | 11.25 | 12.65 | 22.26 | 108.57 | 104.08 | 6.63 |
| h003 | Silkie bantam | f | $12.04$ | $12.49$ | 20.15 | 100.91 | 97.77 | 6.81 |
| h004 | Sussex | m | 13.95 | 15.61 | 26.86 | 138.04 | 133.46 | 9.09 |
| h005 | Poland bantam | ?f | 11.91 | 12.59 | 20.72 | 111.14 | 107.28 | 6.50 |
| h006 | Poland bantam | f | 11.33 | 10.85 | 17.46 | 94.80 | 91.04 | 5.62 |
| h007 | Maran | m | 13.95 | 16.03 | 26.48 | 142.42 | 138.69 | 8.89 |
| h008 | Sussex | f | 13.06 | 14.52 | 23.80 | 124.60 | 119.13 | 7.61 |
| h009 | Rosecomb bantam | m | 11.39 | 12.86 | 22.05 | 112.59 | 108.13 | 6.91 |
| h010 | Maran | m | 17.42 | 20.12 | 33.38 | 170.00 | 165.40 | 10.35 |
| h01l | Dorking | f | 15.88 | 15.46 | 26.28 | 131.36 | 124.79 | 8.89 |
| j005 | Poland bantam | m | 10.70 | 12.23 | 19.80 | 105.33 | 99.77 | 5.44 |
| j006 | Poland bantam | m | 10.58 | 11.29 | 19.83 | 108.16 | 103.91 | 6.22 |
| k001 | Malay | m | 21.98 | 22.34 | 39.12 | 197.40 | 187.80 | 12.49 |
| n001 | Game Fowl | f | 12.17 | 11.62 | 20.42 | 101.73 | 97.04 | 6.45 |
| r65 I | Hamburgh bantam | m | 12.23 | 14.63 | 23.83 | 120.06 | 116.23 | 7.70 |
| r652 | Japanese Bantam | m | 9.77 | 10.47 | 18.66 | 61.35 | 57.78 | 5.98 |
| r653 | Poland bantam | m | 9.86 | 11.03 | 18.24 | 106.34 | 102.37 | 5.50 |
| r655 | Poland bantam | m | 10.58 | 11.12 | 19.20 | 104.72 | 100.50 | 5.70 |
| r656 | Poland bantam | m | 10.93 | 12.94 | 21.04 | 114.80 | 109.95 | 6.15 |
| r657 | Shamo | m | 19.20 | 19.35 | 34.89 | 170.80 | 164.89 | 11.26 |


| Modern breed tibiotarsus metrics |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Dd | Dip | GL | La | SC |
| r658 | Shamo | m | 20.32 | 20.93 | 39.96 | 185.20 | 177.16 | 11.97 |
| r659 | Lakenvelder | m | 14.21 | 15.11 | 27.14 | 140.44 | 135.57 | 7.94 |
| r660 | Silkie | f | 12.01 | 11.32 | 18.39 | 94.69 | 91.17 | 6.37 |
| r661 | Silkie | f | 10.65 | 10.50 | 17.21 | 87.98 | 85.19 | 5.86 |
| r662 | Asil | f | 12.77 | 13.33 | 23.39 | 119.52 | 115.13 | 7.51 |
| r663 | Game Fowl | f | 11.72 | 11.73 | 21.59 | 108.36 | 104.41 | 6.50 |
| r664 | Orpington | m | 18.33 | 18.89 | 33.46 | 151.63 | 144.97 | 11.30 |
| r665 | Vorwerk | f | 13.93 | 14.72 | 23.90 | 123.45 | 120.14 | 7.07 |
| r666 | Silkie | m | 12.75 | 13.10 | 21.28 | 105.80 | 101.49 | 7.62 |
| r667 | Game Fowl | f | 12.10 | 11.94 | 21.46 | 111.07 | 106.80 | 6.21 |
| r668 | Japanese Bantam | m | 9.87 | 10.23 | 18.25 | 58.25 | 55.33 | 5.29 |
| r669 | Sussex | f | 16.08 | 14.11 | 26.32 | 128.27 | 123.15 | 8.75 |
| r670 | Rumpless Araucana | m | 16.13 | 17.15 | 31.53 | 149.23 | 144.43 | 8.89 |
| r723 | Dorking | f | 13.59 | 13.89 | 24.57 | 116.65 | 112.75 | 7.34 |
| r724 | Dorking | f | 15.64 | 14.80 | 26.68 | 130.07 | 124.71 | 7.78 |
| r725 | Indian Game | f | 14.38 | 15.48 | 26.82 | 113.91 | 110.19 | 9.25 |
| r728 | Hamburgh bantam | f | 9.51 | 9.87 | 15.66 | 92.00 | 88.61 | 5.20 |
| r729 | Hamburgh bantam | f | 8.84 | 9.50 | 15.49 | 86.12 | 82.37 | 4.85 |
| r730 | Hamburgh bantam | f | 9.10 | 9.63 | 15.18 | 81.92 | 78.45 | 4.70 |
| r731 | Hamburgh bantam | m | 10.25 | 11.46 | 18.07 | 104.36 | 99.66 | 6.05 |
| r732 | Game Fowl | m | 14.01 | 14.55 | 26.07 | 125.62 | 120.48 | 7.80 |


| Modern breed tibiotarsus metrics |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Dd | Dip | GL | La | SC |
| r735 | Game Fowl | m | 12.58 | 12.88 | 23.84 | 123.05 | 118.42 | 7.36 |
| r736 | Hamburgh | m | 13.95 | 15.08 | 27.67 | 142.93 | 137.16 | 8.55 |
| r740 | Hamburgh | m | 12.90 | 14.70 | 26.15 | 140.16 | 135.12 | 7.72 |
| r741 | Hamburgh | m | 12.91 | 14.47 | 25.16 | 138.06 | 133.26 | 7.98 |
| r742 | Hamburgh | f | 11.67 | 12.20 | 22.26 | 118.12 | 113.74 | 6.53 |
| s001 | Maran | m | 16.63 | 18.49 | 32.66 | 150.13 | 144.93 | 9.55 |
| s002 | Sussex | f | 14.93 | 16.75 | 27.32 | 139.28 | 134.68 |  |
| s003 | Welsummer | f | 13.44 | 14.03 | 23.14 | 120.13 | 116.63 | 7.39 |
| t007 | Silkie | m | 13.72 | 13.95 | 23.54 | 113.76 |  | 8.27 |
| t019 | Rhode Island | m | 17.49 | 18.46 | 30.88 | 151.96 | 145.45 | 9.64 |
| t022 | Leghorn | m | 14.29 | 14.25 | 25.39 | 138.53 | 133.78 | 7.65 |
| t023 | Kulm | m | 19.06 | 19.74 | 35.24 | 171.20 | 165.60 | 10.84 |
| t024 | Kulm | m | 18.42 | 18.78 | 33.75 | 159.50 | 152.93 | 11.12 |
| t026 | Sussex | f | 12.48 | 12.61 | 20.87 | 117.28 | 114.39 | 6.43 |
| t027 | Sussex | f | 13.83 | 14.58 | 24.52 | 120.58 | 116.45 | 7.53 |
| t032 | Silkie | f | 12.08 | 11.08 | 19.35 | 95.31 | 92.16 | 5.99 |
| t034 | Silkie | m | 14.43 | 13.75 | 23.83 | 119.53 | 115.16 | 7.26 |
| t040 | crested rumpless turkish | $\times$ | 10.97 | 10.74 | 18.12 | 94.52 | 91.17 | 5.56 |
| t041 | Game Fowl | m | 12.90 | 14.46 | 24.49 | 133.06 | 127.35 | 7.59 |
| t046 | Cochin | m | 16.71 | 16.81 | 29.66 | 154.22 | 149.07 | 9.80 |
| t048 | Sultan | m | 13.29 | 12.16 | 21.39 | 113.64 | 109.44 | 6.38 |


| Modern breed tibiotarsus metrics |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Dd | Dip | GL | La | SC |
| t049 | Spanish | m | 14.85 | 15.17 | 27.19 | 157.11 | 151.91 | 8.38 |
| t059 | Red Jungle Fowl | m | 10.17 | 10.86 | 18.84 | 107.94 | 104.97 | 5.81 |
| t060 | Hamburgh | m | 12.15 | 13.80 | 23.25 | 128.05 | 122.87 | 7.08 |
| t065 | Dorking | m | 18.65 | 19.23 | 33.23 | 165.70 | 159.10 | 10.34 |
| t143 | Red Jungle Fowl | f | 9.09 | 9.44 | 15.99 | 88.57 | 85.26 | 5.12 |
| t144 | Red Jungle Fowl | m | 10.94 | 11.18 | 18.92 | 106.40 | 102.53 | 6.31 |
| t145 | Red Jungle Fowl | f | 9.86 | 10.52 | 17.22 | 95.29 | 91.65 | 5.53 |
| t146 | Red Jungle Fowl | m | 10.56 | 11.23 | 19.71 | 108.46 | 103.78 | 6.12 |
| t147 | Leghorn | f | 12.35 | 12.18 | 19.93 | 113.27 | 108.61 | 6.35 |
| w518 | Game Fowl | f | 11.68 | 12.10 | 21.60 | 109.25 | 105.64 | 6.72 |
| w519 | Red Jungle Fowl | f | 8.68 | 9.90 | 14.62 | 86.35 | 83.68 | 4.55 |
| w528 | Dorking | m | 17.36 | 18.23 | 31.49 | 147.69 | 141.49 | 9.35 |
| w537 | Dorking | f | 15.44 | 14.30 | 24.99 | 124.14 | 118.02 | 7.53 |
| w538 | Sussex | f | 13.80 | 14.70 | 23.93 | 122.62 | 118.09 | 7.97 |
| w611 | Game Fowl | m | 12.28 | 14.18 | 23.28 | 131.37 | 126.76 | 7.26 |
| w612 | Game Fowl | m | 13.10 | 14.78 | 25.03 | 134.82 | 131.37 | 7.53 |
| z001 | Red Jungle Fowl | m | 11.74 | 12.20 | 20.63 | 113.29 | 108.41 | 7.00 |
| z002 | Rhode Island | ?f | 13.08 | 14.59 | 24.49 | 128.14 | 122.35 | 7.94 |
| k164 | Krüper | m | 13.83 | 15.01 | 26.66 | 101.85 | 95.19 | 9.10 |

### 2.4.2 Measurement ratios

| Modern tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/ type | sex | $\begin{array}{\|l\|} \hline \text { Bd/ } \\ \text { Dip } \\ \hline \end{array}$ | $\begin{aligned} & \mathbf{B d} / \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \text { Dd/ } \\ & \text { GL } \end{aligned}$ | $\begin{aligned} & \mathrm{SCl} \end{aligned}$ | $\begin{aligned} & \hline \mathbf{S C /} \\ & \mathbf{G L} \end{aligned}$ | $\begin{array}{\|l\|} \hline \mathbf{B d} / \\ \mathrm{La} \\ \hline \end{array}$ | $\begin{aligned} & \mathrm{Dd} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{SC} / \\ & \mathbf{L a} \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathbf{D d} \end{aligned}$ | $\begin{aligned} & \hline \mathrm{Dd} / \\ & \mathrm{Dip} \\ & \hline \end{aligned}$ | $\begin{array}{\|l\|} \hline \text { Dip/ } \\ \text { GL } \\ \hline \end{array}$ | $\begin{array}{\|l\|} \hline \mathbf{S C} / \\ \mathbf{D i p} \\ \hline \end{array}$ | $\begin{aligned} & \hline \text { Dip/ } \\ & \text { La } \\ & \hline \end{aligned}$ | $\begin{aligned} & \mathrm{La} / \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \mathrm{SC} / \\ & \mathrm{Dd} \end{aligned}$ |
| a003 | Dorking | f | 60.66 | 12.52 | 11.48 | 50.09 | 6.27 | 13.02 | 11.94 | 6.52 | 109.07 | 55.61 | 20.65 | 30.39 | 21.47 | 96.16 | 54.64 |
| e001 | Dorking | f | 58.30 | 11.85 | 11.77 | 53.43 | 6.33 | 12.35 | 12.27 | 6.60 | 100.71 | 57.89 | 20.33 | 31.15 | 21.19 | 95.94 | 53.81 |
| e010 | RJF | f | 59.45 | 10.67 | 10.13 | 52.01 | 5.55 | 11.00 | 10.45 | 5.72 | 105.27 | 56.48 | 17.94 | 30.92 | 18.51 | 96.93 | 54.75 |
| e013 | O E Game | m | 49.57 | 9.36 | 10.78 | 59.78 | 5.60 | 9.69 | 11.16 | 5.79 | 86.83 | 57.09 | 18.89 | 29.63 | 19.55 | 96.59 | 51.91 |
| e014 | Dorking | m | 58.50 | 11.77 | 11.33 | 50.68 | 5.96 | 12.29 | 11.84 | 6.23 | 103.8 | 56.36 | 20.11 | 29.65 | 21.01 | 95.71 | 52.61 |
| h003 | Silkie | f | 59.75 | 11.93 | 12.38 | 56.56 | 6.75 | 12.31 | 12.77 | 6.97 | 96.40 | 61.99 | 19.97 | 33.80 | 20.61 | 96.89 | 54.52 |
| h011 | Dorking | f | 60.43 | 12.09 | 11.77 | 55.98 | 6.77 | 12.73 | 12.39 | 7.12 | 102.72 | 58.83 | 20.01 | 33.83 | 21.06 | 95.00 | 57.50 |
| k001 | Asian Game | m | 56.19 | 11.13 | 11.32 | 56.82 | 6.33 | 11.70 | 11.90 | 6.65 | 98.39 | 57.11 | 19.82 | 31.93 | 20.83 | 95.14 | 55.91 |
| n001 | O E Game | f | 59.60 | 11.96 | 11.42 | 53.00 | 6.34 | 12.54 | 11.97 | 6.65 | 104.73 | 56.90 | 20.07 | 31.59 | 21.04 | 95.39 | 55.51 |
| r651 | Hamburgh | m | 51.32 | 10.19 | 12.19 | 62.96 | 6.41 | 10.52 | 12.59 | 6.62 | 83.60 | 61.39 | 19.85 | 32.31 | 20.50 | 96.81 | 52.63 |
| r657 | Asian Game | m | 55.03 | 11.24 | 11.33 | 58.65 | 6.59 | 11.64 | 11.74 | 6.83 | 99.22 | 55.46 | 20.43 | 32.27 | 21.16 | 96.54 | 58.19 |
| r658 | Asian Game | m | 50.85 | 10.97 | 11.30 | 58.91 | 6.46 | 11.47 | 11.81 | 6.76 | 97.09 | 52.38 | 21.58 | 29.95 | 22.56 | 95.66 | 57.19 |
| r660 | Silkie | f | 65.31 | 12.68 | 11.95 | 53.04 | 6.73 | 13.17 | 12.42 | 6.99 | 106.10 | 61.56 | 19.42 | 34.64 | 20.17 | 96.28 | 56.27 |
| r661 | Silkie | f | 61.88 | 12.11 | 11.93 | 55.02 | 6.66 | 12.50 | 12.33 | 6.88 | 101.43 | 61.01 | 19.56 | 34.05 | 20.2 | 96.83 | 55.81 |
| r662 | Asian Game | f | 54.60 | 10.68 | 11.15 | 58.81 | 6.28 | 11.09 | 11.58 | 6.52 | 95.80 | 56.99 | 19.57 | 32.11 | 20.32 | 96.33 | 56.34 |
| r663 | O E Game | f | 54.28 | 10.82 | 10.83 | 55.46 | 6.00 | 11.22 | 11.23 | 6.23 | 99.91 | 54.33 | 19.92 | 30.11 | 20.68 | 96.35 | 55.41 |
| r666 | Silkie | m | 59.92 | 12.05 | 12.38 | 59.76 | 7.20 | 12.56 | 12.91 | 7.51 | 97.33 | 61.56 | 20.11 | 35.81 | 20.97 | 95.93 | 58.17 |
| r667 | O E Game | f | 56.38 | 10.89 | 10.75 | 51.32 | 5.59 | 11.33 | 11.18 | 5.81 | 101.34 | 55.64 | 19.32 | 28.94 | 20.09 | 96.16 | 52.01 |
| r723 | Dorking | f | 55.31 | 11.65 | 11.91 | 54.01 | 6.29 | 12.05 | 12.32 | 6.51 | 97.84 | 56.53 | 21.06 | 29.87 | 21.79 | 96.66 | 52.84 |
| r724 | Dorking | f | 58.62 | 12.02 | 11.38 | 49.74 | 5.98 | 12.54 | 11.87 | 6.24 | 105.68 | 55.47 | 20.51 | 29.16 | 21.39 | 95.88 | 52.57 |
| r732 | O E Game | m | 53.74 | 11.15 | 11.58 | 55.67 | 6.21 | 11.63 | 12.08 | 6.47 | 96.29 | 55.81 | 20.75 | 29.92 | 21.64 | 95.91 | 53.61 |
| r735 | O E Game | m | 52.77 | 10.22 | 10.47 | 58.51 | 5.98 | 10.62 | 10.88 | 6.22 | 97.67 | 54.03 | 19.37 | 30.87 | 20.13 | 96.24 | 57.14 |


| Modern tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/ type | sex | Bd/ <br> Dip | $\begin{aligned} & \mathbf{B d} / \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \hline \mathbf{D d} / \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \hline \mathbf{S C l} \\ & \mathbf{B d} \end{aligned}$ | $\begin{aligned} & \hline \mathbf{S C /} \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{Dd} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{SC} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathbf{D d} \end{aligned}$ | $\begin{array}{\|l\|} \hline \mathbf{D d} / \\ \text { Dip } \\ \hline \end{array}$ | $\begin{aligned} & \hline \text { Dip/ } \\ & \text { GL } \end{aligned}$ | $\begin{aligned} & \mathrm{SCl} \\ & \mathrm{Dip} \\ & \hline \end{aligned}$ | $\begin{aligned} & \hline \text { Dip/ } \\ & \text { La } \end{aligned}$ | $\begin{aligned} & \mathrm{La} / \\ & \mathrm{GL} \end{aligned}$ | $\begin{aligned} & \hline \mathbf{S C /} \\ & \mathbf{D d} \end{aligned}$ |
| r736 | Hamburgh | m | 50.42 | 9.76 | 10.55 | 61.29 | 5.98 | 10.17 | 10.99 | 6.23 | 92.51 | 54.50 | 19.36 | 30.90 | 20.17 | 95.96 | 56.70 |
| r740 | Hamburgh | m | 49.33 | 9.20 | 10.49 | 59.84 | 5.51 | 9.55 | 10.88 | 5.71 | 87.76 | 56.21 | 18.66 | 29.52 | 19.35 | 96.40 | 52.52 |
| r741 | Hamburgh | m | 51.31 | 9.35 | 10.48 | 61.81 | 5.78 | 9.69 | 10.86 | 5.99 | 89.22 | 57.51 | 18.22 | 31.72 | 18.88 | 96.52 | 55.15 |
| r742 | Hamburgh | f | 52.43 | 9.88 | 10.33 | 55.96 | 5.53 | 10.26 | 10.73 | 5.74 | 95.66 | 54.81 | 18.85 | 29.34 | 19.57 | 96.29 | 53.52 |
| t007 | Silkie | m | 58.28 | 12.06 | 12.26 | 60.28 | 7.27 | 12.70 | 12.39 | 6.86 | 98.35 | 59.26 | 20.69 | 35.13 | 20.60 | 96.49 | 59.28 |
| t022 | Hamburgh | m | 56.28 | 10.32 | 10.29 | 53.53 | 5.52 | 10.68 | 10.65 | 5.72 | 100.28 | 56.12 | 18.33 | 30.13 | 18.98 | 96.57 | 53.68 |
| t023 | Asian Game | m | 54.09 | 11.13 | 11.53 | 56.87 | 6.33 | 11.51 | 11.92 | 6.55 | 96.56 | 56.02 | 20.58 | 30.76 | 21.28 | 96.73 | 54.91 |
| t024 | Asian Game | m | 54.58 | 11.55 | 11.77 | 60.37 | 6.97 | 12.04 | 12.28 | 7.27 | 98.08 | 55.64 | 21.16 | 32.95 | 22.07 | 95.88 | 59.21 |
| t032 | Silkie | f | 62.43 | 12.67 | 11.63 | 49.59 | 6.28 | 13.11 | 12.02 | 6.50 | 109.03 | 57.26 | 20.30 | 30.96 | 21.00 | 96.69 | 54.06 |
| t034 | Silkie | m | 60.55 | 12.07 | 11.50 | 50.31 | 6.07 | 12.53 | 11.94 | 6.30 | 104.95 | 57.70 | 19.94 | 30.47 | 20.69 | 96.34 | 52.80 |
| t041 | O E Game | m | 52.67 | 9.69 | 10.87 | 58.84 | 5.70 | 10.13 | 11.35 | 5.96 | 89.21 | 59.04 | 18.41 | 30.99 | 19.23 | 95.71 | 52.49 |
| t059 | RJF | m | 53.98 | 9.42 | 10.06 | 57.13 | 5.38 | 9.69 | 10.35 | 5.53 | 93.65 | 57.64 | 17.45 | 30.84 | 17.95 | 97.25 | 53.50 |
| t060 | Hamburgh | m | 52.26 | 9.49 | 10.78 | 58.27 | 5.53 | 9.89 | 11.23 | 5.76 | 88.04 | 59.35 | 18.16 | 30.45 | 18.92 | 95.95 | 51.30 |
| t065 | Dorking | m | 56.12 | 11.26 | 11.61 | 55.44 | 6.24 | 11.72 | 12.09 | 6.50 | 96.98 | 57.87 | 20.05 | 31.12 | 20.89 | 96.02 | 53.77 |
| t143 | RJF | f | 56.85 | 10.26 | 10.66 | 56.33 | 5.78 | 10.66 | 11.07 | 6.01 | 96.29 | 59.04 | 18.05 | 32.02 | 18.75 | 96.26 | 54.24 |
| t144 | RJF | m | 57.82 | 10.28 | 10.51 | 57.68 | 5.93 | 10.67 | 10.90 | 6.15 | 97.85 | 59.09 | 17.78 | 33.35 | 18.45 | 96.36 | 56.44 |
| t145 | RJF | f | 57.26 | 10.35 | 11.04 | 56.09 | 5.80 | 10.76 | 11.48 | 6.03 | 93.73 | 61.09 | 18.07 | 32.11 | 18.79 | 96.18 | 52.57 |
| tl46 | RJF | m | 53.58 | 9.74 | 10.35 | 57.95 | 5.64 | 10.18 | 10.82 | 5.90 | 94.03 | 56.98 | 18.17 | 31.05 | 18.99 | 95.69 | 54.50 |
| t147 | Hamburgh | f | 61.97 | 10.90 | 10.75 | 51.42 | 5.61 | 11.37 | 11.21 | 5.85 | 101.4 | 61.11 | 17.60 | 31.86 | 18.35 | 95.89 | 52.13 |
| w518 | O E Game | f | 54.07 | 10.69 | 11.08 | 57.53 | 6.15 | 11.06 | 11.45 | 6.36 | 96.53 | 56.02 | 19.77 | 31.11 | 20.45 | 96.7 | 55.54 |
| w519 | RJF | f | 59.37 | 10.05 | 11.46 | 52.42 | 5.27 | 10.37 | 11.83 | 5.44 | 87.68 | 67.72 | 16.93 | 31.12 | 17.47 | 96.91 | 45.96 |
| w528 | Dorking | m | 55.13 | 11.75 | 12.34 | 53.86 | 6.33 | 12.27 | 12.88 | 6.61 | 95.23 | 57.89 | 21.32 | 29.69 | 22.26 | 95.8 | 51.29 |
| w537 | Dorking | f | 61.78 | 12.44 | 11.52 | 48.77 | 6.07 | 13.08 | 12.12 | 6.38 | 107.97 | 57.22 | 20.13 | 30.13 | 21.17 | 95.07 | 52.66 |
| w611 | O E Game | m | 52.75 | 9.35 | 10.79 | 59.12 | 5.53 | 9.69 | 11.19 | 5.73 | 86.60 | 60.91 | 17.72 | 31.19 | 18.37 | 96.49 | 51.20 |


| Modern tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | breed/ type | sex | $\begin{aligned} & \mathrm{Bd} / \\ & \mathrm{Dip} \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathbf{G L} \end{aligned}$ | $\begin{aligned} & \mathrm{Dd} / \\ & \mathrm{GL} \\ & \hline \end{aligned}$ | $\begin{array}{\|l\|} \hline \mathbf{S C l} \\ \mathbf{B d} \\ \hline \end{array}$ | $\begin{aligned} & \hline \mathbf{S C l} \\ & \mathbf{G L} \\ & \hline \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathrm{La} \\ & \hline \end{aligned}$ | $\begin{aligned} & \mathrm{Dd} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{SC} / \\ & \mathrm{La} \end{aligned}$ | $\begin{aligned} & \mathrm{Bd} / \\ & \mathrm{Dd} \end{aligned}$ | $\begin{array}{\|l\|} \hline \mathbf{D d} / \\ \text { Dip } \\ \hline \end{array}$ | $\begin{aligned} & \hline \text { Dip/ } \\ & \text { GL } \end{aligned}$ | $\begin{aligned} & \mathrm{SCl} \\ & \mathrm{Dip} \\ & \hline \end{aligned}$ | $\begin{aligned} & \hline \text { Dip/ } \\ & \text { La } \\ & \hline \end{aligned}$ | $\begin{aligned} & \mathrm{La} \\ & \mathrm{GL} \end{aligned}$ | $\begin{aligned} & \mathrm{SC} / \\ & \mathrm{Dd} \end{aligned}$ |
| w612 | O E Game | m | 52.34 | 9.72 | 10.96 | 57.48 | 5.59 | 9.97 | 11.25 | 5.73 | 88.63 | 59.05 | 18.57 | 30.08 | 19.05 | 97.44 | 50.95 |
| z001 | RJF | m | 56.91 | 10.36 | 10.77 | 59.63 | 6.18 | 10.83 | 11.25 | 6.46 | 96.23 | 59.14 | 18.21 | 33.93 | 19.03 | 95.69 | 57.38 |

### 2.5 Tarsometatarsus

### 2.5.I Standard metrics

| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| a001 | Poland bantam | m | 13.68 | 14.86 | 80.79 | 6.84 | 24.42 |
| a002 | Poland bantam | m | 13.77 | 12.55 | 73.00 | 6.98 | 9.07 |
| a003 | Dorking | f | 16.88 | 17.22 | 84.93 | 8.27 |  |
| a005 | Brahma | f | 17.89 | 19.94 | 103.42 | 10.24 |  |
| a006 | Houdan | m | 15.87 | $15.79$ | 96.80 | 7.46 |  |
| e001 | Dorking | f | 17.33 | 17.07 | 86.31 | 8.29 |  |
| e002 | Ross 308 | m | 23.67 | 25.75 | 109.58 | 11.08 | 17.89 |
| e003 | Ross 308 | $f$ | 17.69 | $19.34$ | 85.60 | 8.95 |  |
| e004 | Old English Pheasant Fowl | f | 16.01 | 15.51 | 88.36 | 7.40 |  |
| e005 | Scots Grey | $f$ | 12.86 | 13.89 | 56.71 | 7.16 |  |
| e006 | Poland bantam | m | 13.56 | 14.26 | 79.34 | 6.73 |  |
| e007 | Sussex | f | 17.04 | 17.84 | 91.43 | 7.96 |  |


| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| e008 | Friesian bantam | m | 14.17 | 13.92 | 77.73 | 6.95 |  |
| e009 | Araucana bantam | m | 14.42 | 15.10 | 75.97 | 7.51 |  |
| e010 | Red Jungle Fowl | f | 10.83 | 10.95 | 59.29 | 5.41 |  |
| e011 | Poland bantam | m | 12.94 | 13.95 | 78.30 | 6.02 | 22.36 |
| e012 | Poland bantam | m | 13.67 | 13.78 | 80.31 | 6.52 |  |
| e013 | Game Fowl | m | 16.50 | 15.78 | 97.96 | 7.94 |  |
| e014 | Dorking | m | 18.97 | 20.45 | 109.61 | 10.42 |  |
| h001 | Poland bantam | m | 14.94 | 14.45 | 78.34 | 6.77 |  |
| h002 | Poland bantam | m | 13.80 | 13.50 | 72.50 | 7.07 | 22.11 |
| h003 | Silkie bantam | $f$ | 13.12 | 14.05 | 64.54 | 6.74 |  |
| h004 | Sussex | m | 16.80 | 17.18 | 93.47 | 9.07 | 37.28 |
| h005 | Poland bantam | ?f | 14.48 | 13.78 | 72.68 | 7.64 |  |
| h006 | Poland bantam | f | 12.62 | 12.49 | 63.52 | $6.53$ |  |
| h007 | Maran | m | 17.45 | 18.11 | 99.84 | 9.76 | 31.82 |
| h008 | Sussex | f | 15.49 | 15.42 | 80.72 | $7.64$ |  |
| h009 | Rosecomb bantam | m | 12.92 | 13.29 | 75.34 | 6.87 | 18.66 |
| h010 | Maran | m | 19.98 | 21.17 | 114.41 | 10.62 | 12.83 |
| h0ll | Dorking | $f$ | 17.83 | 17.02 | 87.16 | 8.79 |  |
| j005 | Poland bantam | m | 12.83 | 12.75 | 71.79 | 6.10 |  |
| j006 | Poland bantam | m | 12.94 | 12.29 | 72.09 | 6.28 |  |
| k00l | Malay | m | 25.97 | 26.05 | 146.74 | 14.13 |  |


| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| n001 | Game Fowl | f | 12.84 | 13.55 | 70.98 | 6.54 |  |
| r651 | Hamburgh bantam | m | 16.05 | 14.34 | 80.24 | 7.62 | 10.58 |
| r652 | Japanese Bantam | m | 10.32 | 10.81 | 35.67 | 6.81 |  |
| r653 | Poland bantam | m | 12.18 | 11.75 | 72.60 | 5.67 |  |
| r655 | Poland bantam | m | 12.85 | 11.94 | 69.74 | 5.99 | 20.30 |
| r656 | Poland bantam | m | 12.62 | 13.28 | 75.48 | 6.11 |  |
| r657 | Shamo | m | 22.85 | 22.22 | 118.52 | 11.53 | 16.4 |
| r658 | Shamo | m | 23.70 | 24.56 | 131.06 | 12.47 | 19.75 |
| r659 | Lakenvelder | m | 17.38 | 16.52 | 98.98 | 8.68 | 15.83 |
| r660 | Silkie | f | 12.89 | 12.97 | 63.62 | 6.51 |  |
| r661 | Silkie | f | 12.00 | 11.86 | 56.67 | 5.47 |  |
| r662 | Asil | f | 14.91 | 14.90 | 77.08 | 7.92 |  |
| r663 | Game Fowl | f | 14.16 | 13.52 | 74.10 | 7.15 | 16.48 |
| r664 | Orpington | m | 20.06 | 22.23 | 100.59 | 12.15 | 26.46 |
| r665 | Vorwerk | f | 16.23 | 16.19 | 84.08 | 7.44 |  |
| r666 | Silkie | m | 13.76 | 14.55 | 71.38 | 7.69 | 20.47 |
| r667 | Game Fowl | f | 13.79 | 13.62 | 74.75 | 6.54 |  |
| r668 | Japanese Bantam | m | 10.08 | 11.64 | 35.45 | 6.54 |  |
| r669 | Sussex | f | 16.91 | 17.68 | 91.25 | 9.48 |  |
| r670 | Rumpless Araucana | m | 18.86 | 19.42 | 98.88 | 9.39 |  |
| r723 | Dorking | f | 15.30 | 14.68 | 77.88 | 7.74 |  |


| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| r724 | Dorking | f | 17.45 | 16.72 | 86.25 | 8.09 |  |
| r725 | Indian Game | f | 16.60 | 18.62 | 74.90 | 10.20 |  |
| r728 | Hamburgh bantam | f | 11.68 | 10.40 | 62.63 | 5.41 | 18.09 |
| r729 | Hamburgh bantam | f | 10.64 | 10.30 | 54.24 | 4.96 |  |
| r730 | Hamburgh bantam | f | 10.81 | 10.26 | 51.31 | 4.87 |  |
| r731 | Hamburgh bantam | m | 12.69 | 12.03 | 70.97 | 6.05 | 20.12 |
| r732 | Game Fowl | m | 16.53 | 16.07 | 87.12 | 8.33 | 23.65 |
| r735 | Game Fowl | m | 14.55 | 14.25 | 85.49 | 7.63 | 10.48 |
| r736 | Hamburgh | m | 18.25 | 16.13 | 100.18 | 8.50 | 25.37 |
| r740 | Hamburgh | m | 16.85 | 15.27 | 97.36 | 7.55 |  |
| r741 | Hamburgh | m | 17.51 | 14.85 | 96.36 | 7.38 |  |
| r742 | Hamburgh | f | 15.55 | 14.75 | 80.23 | 6.79 | 24.37 |
| s001 | Maran | m | 19.52 | 19.96 | 105.29 | 9.95 |  |
| s003 | Welsummer | f | 15.45 | 15.53 | 79.96 | 7.80 |  |
| t007 | Silkie | m | 13.18 | 15.06 | 77.4I | $7.75$ | 17.46 |
| t019 | Rhode Island | m | 20.05 | 20.13 | 100.26 | 11.28 |  |
| t022 | Leghorn | m | 17.09 | 16.71 | 95.50 | 8.28 |  |
| t023 | Kulm | m | 21.48 | 22.41 | 122.02 | 11.51 |  |
| t024 | Kulm | m | 21.10 | 23.42 | 113.39 | 12.80 | 21.34 |
| t026 | Sussex | f | 13.98 | 14.20 | 74.58 | 6.75 |  |
| t028 | Sussex | f | 16.21 | 15.69 | 80.38 | 8.09 |  |


| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| t032 | Silkie | f | 11.83 | 12.82 | 64.08 | 5.85 |  |
| t034 | Silkie | m | 13.76 | 15.84 | 79.23 | 8.36 | 22.14 |
| t040 | crested rumpless turkish | $\times$ | 11.99 | 11.93 | 63.16 | 6.54 |  |
| t04I | Game Fowl | m | 16.56 | 15.98 | 90.50 | 8.39 | 20.64 |
| t046 | Cochin | m | $19.97$ | 20.86 | 105.72 | 11.62 | 15.01 |
| t048 | Sultan | m | 14.19 | 14.59 | 74.00 | 7.60 |  |
| t049 | Spanish | m | 19.12 | 17.11 | 114.50 | 8.40 | 26.00 |
| t059 | Red Jungle Fowl | m | 11.89 | 11.99 | 76.20 | 5.63 |  |
| t065 | Dorking | m | 20.58 | 20.94 | 113.53 | 10.51 | 24.21 |
| t143 | Red Jungle Fowl | f | 10.70 | 10.15 | 60.20 | 4.97 |  |
| t144 | Red Jungle Fowl | m | 12.49 | 12.17 | 73.30 | 6.32 |  |
| t145 | Red Jungle Fowl | f | 10.93 | 11.60 | 62.46 | 5.61 |  |
| t146 | Red Jungle Fowl | m | 12.41 | 12.29 | 72.55 | 6.29 | 16.29 |
| t147 | Leghorn | f | 13.45 | 13.85 | 78.05 | 6.69 |  |
| w518 | Game Fowl | f | 13.92 | 13.68 | 74.33 | $6.79$ |  |
| w519 | Red Jungle Fowl | f | 9.67 | 10.42 | 56.37 | 4.33 |  |
| w528 | Dorking | m | 19.95 | 19.85 | 99.13 | 9.41 |  |
| w537 | Dorking | f | 16.85 | 15.94 | 82.56 | 8.13 |  |
| w538 | Sussex | f | 15.47 | 16.21 | 82.87 | 8.42 |  |
| w611 | Game Fowl | m | 15.21 | 14.51 | 92.66 | 7.26 |  |
| w612 | Game Fowl | m | 15.93 | 16.16 | 97.95 | 8.28 |  |


| Modern breed tarsometatarsus metrics |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| GMM ID | Breed | Sex | Bd | Bp | GL | SC | Spur Length |
| z001 | Red Jungle Fowl | m | 13.09 | 14.65 | 73.5 I | 7.10 |  |
| z002 | Rhode Island | ?f | 16.59 | 16.23 | 82.83 | 8.57 |  |

### 2.5.2 Measurement ratios

## Modern tarsometatarsi measurement ratios

| ID | Breed/type | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| a003 | Dorking | f | 98.03 | 48.99 | 9.74 | 20.28 | 19.88 | 48.03 |
| e001 | Dorking | f | 101.52 | 47.84 | 9.60 | 19.78 | 20.08 | 48.56 |
| e004 | Hamburgh | f | 103.22 | 46.22 | 8.37 | 17.55 | 18.12 | 47.71 |
| e010 | RJF | f | 98.9 | 49.95 | 9.12 | 18.47 | 18.27 | 49.41 |
| e013 | O E Game | m | 104.56 | 48.12 | 8.11 | 16.11 | 16.84 | 50.32 |
| e014 | Dorking | m | 92.76 | 54.93 | 9.51 | 18.66 | 17.31 | 50.95 |
| h003 | Silkie | f | 93.38 | 51.37 | 10.44 | 21.77 | 20.33 | 47.97 |
| h011 | Dorking | f | 104.76 | 49.30 | 10.08 | 19.53 | 20.46 | 51.65 |
| k001 | Asian Game | m | 99.69 | 54.41 | 9.63 | 17.75 | 17.70 | 54.24 |
| n001 | O E Game | f | 94.76 | 50.93 | 9.21 | 19.09 | 18.09 | 48.27 |
| r651 | Hamburgh | m | 111.92 | 47.48 | 9.50 | 17.87 | 20.00 | 53.14 |
| r657 | Asian Game | m | 102.84 | 50.46 | 9.73 | 18.75 | 19.28 | 51.89 |
| r658 | Asian Game | m | 96.50 | 52.62 | 9.51 | 18.74 | 18.08 | 50.77 |

Modern tarsometatarsi measurement ratios

| ID | Breed/type | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| r660 | Silkie | f | 99.38 | 50.50 | 10.23 | 20.39 | 20.26 | 50.19 |
| r661 | Silkie | f | 101.18 | 45.58 | 9.65 | 20.93 | 21.18 | 46.12 |
| r662 | Asian Game | f | 100.07 | 53.12 | 10.28 | 19.33 | 19.34 | 53.15 |
| r663 | O E Game | f | 104.73 | 50.49 | 9.65 | 18.25 | 19.11 | 52.88 |
| r666 | Silkie | m | 94.57 | 55.89 | 10.77 | 20.38 | 19.28 | 52.85 |
| r667 | O E Game | f | 101.25 | 47.43 | 8.75 | 18.22 | 18.45 | 48.02 |
| r723 | Dorking | f | 104.22 | 50.59 | 9.94 | 18.85 | 19.65 | 52.72 |
| r724 | Dorking | f | 104.37 | 46.36 | 9.38 | 19.39 | 20.23 | 48.39 |
| r732 | O E Game | m | 102.86 | 50.39 | 9.56 | 18.45 | 18.97 | 51.84 |
| r735 | O E Game | m | 102.11 | 52.44 | 8.93 | 16.67 | 17.02 | 53.54 |
| r736 | Hamburgh | m | 113.14 | 46.58 | 8.48 | 16.10 | 18.22 | 52.70 |
| r740 | Hamburgh | m | 110.35 | 44.81 | 7.75 | 15.68 | 17.31 | 49.44 |
| r741 | Hamburgh | m | 117.91 | 42.15 | 7.66 | 15.41 | 18.17 | 49.70 |
| r742 | Hamburgh | f | 105.42 | 43.67 | 8.46 | 18.38 | 19.38 | 46.03 |
| t007 | Silkie | m | 87.52 | 58.80 | 10.01 | 19.45 | 17.03 | 51.46 |
| t022 | Hamburgh | m | 102.27 | 48.45 | 8.67 | 17.50 | 17.90 | 49.55 |
| t023 | Asian Game | m | 95.85 | 53.58 | 9.43 | 18.37 | 17.60 | 51.36 |
| t024 | Asian Game | m | 90.09 | 60.66 | 11.29 | 20.65 | 18.61 | 54.65 |
| t032 | Silkie | f | 92.28 | 49.45 | 9.13 | 20.01 | 18.46 | 45.63 |
| t034 | Silkie | m | 86.87 | 60.76 | 10.55 | 19.99 | 17.37 | 52.78 |
| t04I | O E Game | m | 103.63 | 50.66 | 9.27 | 17.66 | 18.30 | 52.50 |

## Modern tarsometatarsi measurement ratios

| ID | Breed/type | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| :--- | :--- | :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| t059 | RJF | m | 99.17 | 47.35 | 7.39 | 15.73 | 15.60 | 46.96 |
| t065 | Dorking | m | 98.28 | 51.07 | 9.26 | 18.44 | 18.13 | 50.19 |
| tl43 | RJF | f | 105.42 | 46.45 | 8.26 | 16.86 | 17.77 | 48.97 |
| tl44 | RJF | m | 102.63 | 50.60 | 8.62 | 16.60 | 17.04 | 51.93 |
| tl45 | RJF | f | 94.22 | 51.33 | 8.98 | 18.57 | 17.50 | 48.36 |
| tl46 | RJF | m | 100.98 | 50.68 | 8.67 | 16.94 | 17.1 II | 51.18 |
| tl47 | Hamburgh | f | 97.1 I | 49.74 | 8.57 | 17.75 | 17.23 | 48.30 |
| w5I8 | O E Game | f | 101.75 | 48.78 | 9.13 | 18.40 | 18.73 | 49.63 |
| w5I9 | RJF | f | 92.80 | 44.78 | 7.68 | 18.49 | 17.15 | $4 \mathrm{II.55}$ |
| w528 | Dorking | m | 100.50 | 47.17 | 9.49 | 20.02 | 20.13 | 47.4 I |
| w537 | Dorking | f | 105.7 I | 48.25 | 9.85 | 19.31 | 20.4 I | 5 II .00 |
| w6II | O E Game | m | 104.82 | 47.73 | 7.84 | 15.66 | 16.4 I | 50.03 |
| w6I2 | O E Game | m | 98.58 | 51.98 | 8.45 | 16.50 | 16.26 | 51.24 |
| z00I | RJF | m | 89.35 | 54.24 | 9.66 | 19.93 | 17.8 I | 48.46 |

### 2.6 Pelvis metrics

| Modern breed pelvis measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | AA | BA | CB | DiA | GL | LS | LV | SB | Bsdi | Bpti |
| Indian Game | f | r725 | 54.62 | 65.99 | 43.19 | 11.33 | 100.93 | 96.58 | 73.52 | 38.76 | 37.61 | 61.31 |
| Hamburgh bantam | f | r730 | 34.43 | 43.48 | 25.51 | 6.17 | 70.38 | 64.16 | 54.22 | 22.26 | 20.24 | 36.47 |
| Hamburgh bantam | f | r728 | 36.90 | 46.84 | 28.11 | 7.31 | 79.42 | 72.72 | 61.30 | 24.88 | 23.85 | 37.59 |
| Brahma | f | a005 | 55.89 | 72.68 | 47.52 | 11.14 | 124.84 | 110.64 | 88.55 | 40.19 | 41.87 | 54.05 |
| Game Fowl | f | r667 | 43.06 | 54.82 | 33.24 | 8.96 | 93.35 | 85.75 | 67.46 | 29.78 | 27.37 | 45.07 |
| Sussex | f | r669 | 49.02 | 64.62 | 37.04 | 10.18 | 107.13 | 98.44 | 80.71 | 34.05 | 43.94 | 61.27 |
| Hamburgh | f | r742 | 46.93 | 58.93 | 39.18 | 9.31 | 103.12 | 94.43 | 73.35 | 31.50 | 29.60 | 43.59 |
| Orpington | m | r664 | 57.15 | 74.59 | 47.24 | 13.64 | 126.53 | 116.57 | 87.25 | 38.17 | 36.32 | 54.87 |
| Silkie | f | r661 | 35.20 | 44.97 | 25.87 | 7.55 | 77.98 | 71.97 | 61.39 | 22.21 | 24.06 | 37.29 |
| Dorking | f | a003 | 49.76 | 66.36 | 37.97 | 11.69 | 107.62 | 102.92 | 73.61 | 34.65 | 30.52 | 53.80 |
| Poland bantam | m | r655 | 39.82 | 48.87 | 28.83 | 9.24 | 91.18 | 82.72 | 68.89 | 25.49 | 24.85 | 30.90 |
| Game Fowl | m | r732 | 47.92 | 63.01 | 39.43 | 11.25 | 110.32 | 100.04 | 78.01 | 32.93 | 30.32 | 49.94 |
| Hamburgh bantam | m | r651 | 45.30 | 58.47 | 38.09 | 9.84 | 101.10 | 94.96 | 79.14 | 31.89 | 27.09 | 42.57 |
| Dorking | f | r723 | 46.73 | 60.80 | 37.78 | 10.93 | 102.36 | 98.40 | 78.11 | 32.13 | 30.78 | 45.01 |
| Japanese Bantam | m | r652 | 31.18 | 40.39 | 25.40 | 7.09 | 70.57 | 65.80 | 52.80 | 21.85 | 13.91 | 33.38 |
| Hamburgh | m | r736 | 52.24 | 65.52 | 47.21 | 11.33 | 119.20 | 111.30 | 84.09 | 35.53 | 32.85 | 39.71 |
| Hamburgh bantam | m | r731 | 37.25 | 48.06 | 32.12 | 7.41 | 87.98 | 80.57 | 64.16 | 25.37 | 19.02 | 34.14 |
| Poland bantam | m | a001 | 43.74 | 56.33 | 35.85 | 9.14 | 104.21 | 96.25 | 74.01 | 27.78 | 19.30 | 38.42 |
| Game Fowl | m | r735 | 44.07 | 57.47 | 39.59 | 9.70 | 105.55 | 97.58 | 77.50 | 31.71 | 26.19 | 37.32 |


| Modern breed pelvis measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | Sex | GMM ID | AA | BA | CB | DiA | GL | LS | LV | SB | Bsdi | Bpti |
| Silkie | m | r666 | 37.93 | 50.07 | 31.67 | 9.00 | 90.13 | 86.71 | 65.95 | 25.86 | 17.32 | 37.22 |
| Lakenvelder | m | r659 | 43.04 | 60.47 | 40.04 | 11.93 | 118.46 | 107.98 | 79.14 | 29.60 | 26.48 | 38.13 |
| Tigray ecotype | m | dI50 | 45.02 | 59.45 | 38.60 | 9.01 | 110.43 | 99.21 | 75.84 | 29.75 | 25.23 | 38.47 |
| Tigray ecotype | m | dI48 | 43.76 | 57.49 | 36.53 | 9.86 | 108.10 | 97.47 | 73.85 | 28.58 | 24.00 | 35.17 |
| Tigray ecotype | m | dI75 | 41.10 | 54.08 | 36.54 | 9.41 | 99.45 | 93.81 | 80.64 | 28.26 | 22.14 | 37.25 |
| Tigray ecotype | m | dI3I | 51.75 | 63.50 | 43.72 | 9.39 | 119.46 | 112.97 | 84.43 | 34.49 | 29.80 | 38.41 |
| Tigray ecotype | m | dI56 | 42.35 | 54.81 | 54.81 | 9.79 | 105.56 | 100.96 | 75.26 | 28.21 | 28.91 | 44.32 |
| Tigray ecotype | m | dI72 | 43.73 | 57.67 | 40.97 | 8.99 | 107.72 | 105.05 | 79.37 | 30.84 | 27.42 | 37.22 |
| Tigray ecotype | m | d109 | 42.75 | 54.31 | 38.66 | 9.17 | 107.62 | 98.90 | 79.42 | 29.11 | 25.51 | 36.63 |
| Tigray ecotype | f | dI78 | 45.82 | 58.93 | 37.58 | 8.71 | 104.97 | 95.49 | 74.47 | 29.44 | 25.33 | 43.31 |
| Tigray ecotype | m | dI80 | 42.29 | 53.22 | 37.91 | 9.28 | 103.43 | 98.95 | 74.90 | 28.85 | 22.76 | 37.55 |
| Tigray ecotype | f | dI05 | 42.62 | 52.73 | 33.81 | 7.28 | 92.78 | 88.32 | 71.66 | 30.25 | 25.76 | 38.95 |
| Tigray ecotype | f | dl45 | 43.46 | 55.66 | 31.04 | 8.44 | 97.49 | 90.07 | 69.8 | 26.47 | 34.11 | 44.66 |
| Tigray ecotype | f | dI63 | 42.99 | 53.90 | 32.34 | 8.42 | 101.06 | 90.23 | 73.11 | 28.53 | 31.20 | 42.08 |
| Tigray ecotype | m | dI35 | 44.46 | 56.26 | 35.61 | 9.11 | 106.97 | 100.66 | 84.26 | 28.10 | 28.19 | 36.92 |
| Tigray ecotype | f | dI77 | 39.34 | 48.35 | 33.34 | 7.88 | 91.06 | 85.71 | 64.97 | 27.23 | 28.01 | 41.97 |
| Tigray ecotype | m | dI46 | 47.86 | 59.96 | 43.54 | 9.30 | 114.45 | 108.32 | 84.93 | 32.67 | 28.14 | 40.95 |
| Tigray ecotype | m | d166 | 40.27 | 55.33 | 36.88 | 9.15 | 102.93 | 96.93 | 72.50 | 30.04 | 27.31 | 36.45 |

### 2.6.I MANOVA test results

| MANOVA test results of three pelvic metric analyses |  |  |  |
| :--- | :--- | :--- | :--- |
|  | Metrics Group A | Metrics Group B | Metric Group C |
| Wilks' lambda: | 0.594 I | 0.367 | 0.2794 |
| dfI: | 5 | 8 | 10 |
| df2: | 32 | 29 | 27 |
| F stat: | 4.372 | 6.253 | 4.893 |
| F value: | 2.5122 | 2.2783 | 2.2042 |
| P (same): | $0.0038 I^{* *}$ | $0.000103 I^{* * *}$ | $0.00003^{* * *}$ |

### 2.7 Furcula

$\left.\begin{array}{|l|l|l|l|l|l|c|c|c|c|c|c|c|c|}\hline \text { Modern breed furcula measurements } \\ \hline \text { Breed } & \text { ID } & \text { Type } & \text { Sex } & \text { Wt (g) } & \text { Wt cat. } & \text { Flying } \\ \text { ability }\end{array}\right)$

| Modern breed furcula measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | ID | Type | Sex | Wt (g) | Wt cat. | Flying ability | 10\% | 50\% | 100\% | 10mm | Length | Width |
| Poland | e012 | Crested | m | 1455 | I | I | 108.22 | 49.75 | 31.33 | 82.84 | 51.26 | 33.04 |
| Dorking | r727 | DPH | m | 1678 | 1 | 2 | 88.54 | 49.89 | 31.68 | 72.04 | 45.04 | 31.29 |
| OE Game | r667 | OE Game | $f$ | 1500 | 1 | 2 | 92.31 | 46.46 | 34.87 | 70.83 | 47.38 | 33.85 |
| OE Game | r735 | OE Game | m | 1605 | I | 2 | 97.10 | 50.50 | 38.95 | 77.08 | 50.12 | 38.20 |
| Houdan | a006 | DPH | m | 1954 | 1 | 2 | 81.54 | 46.21 | 28.75 | 68.97 | 48.81 | 30.35 |
| Silver-Spangled Hamburgh | r65I | Egg-type | m | 1585 | 1 | 3 | 91.87 | 51.01 | 40.38 | 73.90 | 45.35 | 37.48 |
| Silver-Spangled Hamburgh | r742 | Egg-type | $f$ | 1425 | 1 | 3 | 90.16 | 48.40 | 33.44 | 72.94 | 47.47 | 32.62 |
| Poland | r655 | Crested | m | 1115 | 1 | 1 | 99.04 | 45.77 | 28.23 | 71.87 | 41.79 | 24.00 |
| Poland | r653 | Crested | m | 1080 | I | I | 97.64 | 57.54 | 36.99 | 79.63 | 40.84 | 30.55 |
| Vorwerk | r665 | Egg-type | $f$ | 1900 | 1 | 3 | 93.27 | 41.64 | 27.01 | 75.32 | 52.68 | 30.07 |
| Poland | r656 | Crested | m | 1370 | I | I | 102.07 | 52.60 | 27.92 | 82.71 | 47.72 | 30.03 |
| Poland | a002 | Crested | m | 1205 | 1 | 1 | 87.67 | 50.39 | 33.57 | 71.96 | 41.89 | 30.14 |
| Poland | j005 | Crested | m | 1125 | 1 | 1 | 94.95 | 51.21 | 32.18 | 74.77 | 42.07 | 28.23 |
| Silkie | r660 | Silkie | $f$ | 1455 | 1 | 0 | 93.20 | 47.96 | 29.94 | 71.71 | 41.20 | 26.15 |
| Poland | j006 | Crested | m | 1210 | 1 | 1 | 102.00 | 56.29 | 32.62 | 83.33 | 43.52 | 28.93 |
| Hamburg bantam | r731 | Bantam | m | 1020 | 1 | 3 | 101.80 | 57.30 | 37.37 | 78.03 | 39.80 | 31.41 |
| Silkie | r666 | Silkie | m | 1625 | I | 0 | 98.75 | 55.34 | 35.84 | 79.77 | 42.04 | 31.36 |
| Poland | h006 | Crested | f |  | 1 | I | 104.80 | 46.49 | 32.50 | 74.67 | 40.93 | 27.86 |
| Poland | h005 | Crested | f |  | I | I | 90.00 | 46.02 | 34.47 | 68.92 | 43.96 | 31.71 |
| Poland | e006 | Crested | m |  | 1 | 1 | 93.96 | 50.77 | 36.19 | 73.86 | 45.44 | 33.04 |


| Modern breed furcula measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | ID | Type | Sex | Wt (g) | Wt cat. | Flying ability | 10\% | 50\% | 100\% | 10mm | Length | Width |
| Gold-Pencilled Hamburgh | t060 | Egg-type | m |  | 2 | 3 | 107.00 | 53.50 | 36.97 | 86.56 | 48.26 | 36.97 |
| Sultan | t048 | Crested | m |  | 2 | 3 | 118.89 | 51.98 | 33.05 | 94.71 | 47.46 | 32.14 |
| Scots Dumpy | e005 | DPH | $f$ | 2100 | 2 | 2 | 94.04 | 46.74 | 29.74 | 75.57 | 45.76 | 28.02 |
| Old English Pheasant Fowl | e004 | Egg-type | $f$ | 2300 | 2 | 3 | 94.11 | 48.35 | 37.09 | 75.92 | 51.15 | 38.54 |
| Old English Game | e013 | OE Game | m | 2356 | 2 | 2 | 105.39 | 50.33 | 37.51 | 85.18 | 52.36 | 40.73 |
| Rumpless Araucana | r670 | DPH | m | 2410 | 2 | 2 | 92.39 | 45.15 | 32.82 | 75.93 | 56.04 | 37.02 |
| Silver-Spangled Hamburgh | r740 | Egg-type | m | 2330 | 2 | 3 | 100.47 | 47.76 | 33.63 | 83.01 | 55.56 | 37.28 |
| Silver-Spangled Hamburgh | r74I | Egg-type | m | 2335 | 2 | 3 | 96.28 | 45.18 | 34.89 | 75.69 | 54.44 | 37.23 |
| Lakenvelder | r659 | Egg-type | m | 2220 | 2 | 3 | 101.06 | 46.02 | 28.60 | 82.91 | 55.38 | 34.66 |
| Dorking | r723 | DPH | $f$ | 2155 | 2 | 2 | 91.93 | 43.25 | 29.70 | 74.88 | 52.94 | 30.18 |
| Old English Game | r732 | OE Game | m | 2565 | 2 | 2 | 88.59 | 52.50 | 40.14 | 75.00 | 51.01 | 42.90 |
| Dorking | r733 | DPH | m | 2750 | 2 | 2 | 86.98 | 44.72 | 27.77 | 73.82 | 56.43 | 33.55 |
| Indian Game | r725 | Meat | $f$ | 2610 | 2 | I | 105.90 | 54.78 | 38.35 | 87.43 | 52.14 | 41.83 |
| Dorking | r724 | DPH | $f$ | 2365 | 2 | 2 | 93.05 | 45.07 | 32.13 | 78.87 | 58.62 | 37.93 |
| Dorking | a003 | DPH | f | 2045 | 2 | 2 | 91.30 | 47.13 | 35.46 | 74.37 | 52.98 | 38.02 |
| Silver-Spangled Hamburgh | r736 | Egg-type | m | 2690 | 2 | 3 | 102.91 | 48.37 | 35.85 | 83.55 | 52.93 | 38.81 |
| Indian Game | r726 | Meat | m | 2935 | 2 | 1 | 98.49 | 52.18 | 35.69 | 84.10 |  |  |
| Old English Game | w518 | OE Game | $f$ |  | 2 | 2 | 96.51 | 47.71 | 31.03 | 76.86 | 47.00 | 31.01 |
| Old English Game | w612 | OE Game | m |  | 2 | 2 | 106.26 | 48.76 | 32.53 | 85.91 | 56.23 | 37.35 |
| Old English Game | w6II | OE Game | m |  | 2 | 2 | 104.45 | 50.17 | 35.56 | 84.07 | 49.30 | 37.63 |


| Modern breed furcula measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | ID | Type | Sex | Wt (g) | Wt cat. | Flying ability | 10\% | 50\% | 100\% | 10 mm | Length | Width |
| Spanish | t049 | Egg-type | m |  | 3 | I | 100.71 | 53.34 | 38.31 | 82.40 | 57.56 | 44.39 |
| Sussex | t028 | DPH | $f$ |  | 3 | 1 | 103.06 | 48.32 | 32.62 | 75.95 | 45.72 | 31.30 |
| Kulm | t023 | Asian G | m |  | 4 | 1 | 104.89 | 60.06 | 48.09 | 91.36 | 56.76 | 54.22 |
| Sussex | t026 | DPH | $f$ |  | 3 | I | 92.20 | 46.83 | 34.24 | 73.28 | 43.25 | 30.59 |
| Kulm | t024 | Asian G | m |  | 4 | I | 114.78 | 58.80 | 42.59 | 101.39 | 57.68 | 52.22 |
| Leghorn | t022 | Egg-type | m |  | 3 | 3 | 88.36 | 43.49 | 26.60 | 74.26 | 53.98 | 30.52 |
| Dorking | t065 | DPH | m |  | 3 | 2 | 85.47 | 43.73 | 37.15 | 75.94 | 66.25 | 48.22 |
| Malay | k001 | Asian G | m |  | 3 | I | 104.76 | 52.27 | 41.97 | 93.13 | 70.11 | 58.62 |
| Sussex | e007 | DPH | $f$ | 3100 | 3 | I | 96.77 | 47.03 | 35.40 | 75.36 | 50.05 | 37.58 |
| Ross broiler | e003 | Meat | $f$ | 3530 | 3 | 0 | 104.57 | 51.72 | 39.84 | 82.87 | 51.72 | 39.92 |
| Ross broiler | e002 | Meat | m | 5000 | 4 | 0 | 95.57 | 48.91 | 33.92 | 78.66 | 56.45 | 40.11 |
| Dorking | e014 | DPH | m | 3628 | 3 | 2 | 87.88 | 45.31 | 32.08 | 74.29 | 63.90 | 43.13 |
| Dorking | r734 | DPH | m | 4050 | 4 | 2 | 93.78 | 41.16 | 32.22 | 80.20 | 64.28 | 43.90 |
| Brahma | a005 | DPH | $f$ | 3777 | 3 | 1 | 83.07 | 42.59 | 30.65 | 71.56 | 58.37 | 39.42 |
| Shamo | r658 | Asian G | m | 4320 | 4 | 1 | 106.71 | 59.71 | 48.34 | 96.26 | 66.21 | 64.46 |
| Shamo | r657 | Asian G | m | 3860 | 4 | 1 | 90.41 | 54.88 | 44.77 | 82.27 | 59.92 | 54.26 |
| Dorking | w528 | DPH | m |  | 3 | 2 | 97.28 | 47.20 | 35.37 | 81.24 | 61.53 | 44.42 |
| Dorking | w537 | DPH | f |  | 3 | 2 | 96.93 | 48.10 | 32.34 | 79.76 | 54.05 | 36.55 |
| Sussex | h004 | DPH | m |  | 3 | I | 101.55 | 42.78 | 24.50 | 74.44 | 51.32 | 30.24 |
| Sussex | h008 | DPH | f |  | 3 | 1 | 98.15 | 46.89 | 27.46 | 75.91 | 49.68 | 29.57 |


| Modern breed furcula measurements |  |  |  |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Breed | ID | Type | Sex | Wt (g) | Wt cat. | Flying <br> ability | $\mathbf{1 0 \%}$ | $\mathbf{5 0 \%}$ | $\mathbf{1 0 0 \%}$ | 10mm | Length | Width |
| Marans | h007 | DPH | m |  | 3 | I | 94.36 | 52.92 | 41.44 | 78.63 | 51.91 | 46.03 |
| Marans | h 010 | DPH | m |  | 3 | I | 98.59 | 49.96 | 35.70 | 87.69 | 62.31 | 48.37 |

(Key: Asian G = Asian Game; DPH = Dual-purpose, heavy; OE Game = Old English Game)

| Permanova summary statistics - furcula study |  |  |
| :--- | ---: | ---: |
|  | Weight | Flying ability |
| Permutations N. | 9999 | 9999 |
| Total no of sums of squares | 3891 | 3891 |
| Within-group sums of squares | 2515 | 3633 |
| F | 10.25 | 1.802 |
| P-value (same) | 0.0001 | 0.15 |

### 2.8 Warren-ranger standard chicken GL measurements

| Warren-Ranger standard (UoL Acc. no. RI59) |  |  |
| :--- | :---: | :---: |
| Element | GL | LogI0 |
| humerus | 74.00 | I .8692 |
| coracoid | 57.30 | I .7582 |
| ulna | 75.00 | I .875 I |
| femur | 85.20 | I .9304 |
| tibiotarsus | II 6.40 | 2.0660 |
| tarsometatarsus | 76.90 | I .8859 |

## Appendix C: Biometrical data - archaeological chickens

### 3.1 Uley

### 3.1.I Uley coracoid

3.1.1.1 Standard metrics - coracoid

| Uley - coracoids |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Meas. ratio | GMM | Side | Bb | Bf | GL | Lm |
| WH77 B2 | 12 | 6b | U004 | $y$ | $y$ | r | 15.52 | 12.67 | 52.73 | 50.03 |
| WH77 | 22 | 5 e | U023 | $y$ | y | r | 15.76 | 12.31 | 55.28 | 52.32 |
| WH77 | 37 | 5 e | U025 | $y$ | $y$ | 1 | 14.44 | 12.18 | 52.68 | 49.87 |
| WH77 | 47 | ? | U03I | $y$ |  | $r$ | 15.36 | 12.9 | 57.8 | 55.42 |
| WH77 | 72 | 5 e | U040 | y | y | $r$ | 15.59 | 12.73 | 59.38 | 56.86 |
| WH77 | 126 | 5a-d | U043 | $y$ | $y$ | r | 15.94 | 12.71 | 58.86 | 56.24 |
| WH77 | 136 | 5 e | U050 | y | $y$ | 1 | 15.78 | 12.07 | 54.91 | 52.36 |
| WH77 | 136 | 5 e | U05 I |  |  | r | 15.14 | 12.23 | 56.38 | 53.66 |
| WH77 | 155 | 5 e | U057 | $y$ | y | r | 14.8 | 12.12 | 57.85 | 55.21 |
| WH77 | 164 | 5 e | U061 | $y$ | $y$ | 1 | 15.43 | 12.34 | 52.03 | 49.52 |
| WH77 | 164 | 5 e | U062 |  |  | r | 15.57 | 12.73 | 51.75 | 49.14 |
| WH77 | 187 | 5 e | U075 | $y$ | $y$ | 1 | 15.02 | 12.51 | 56.54 | 52.93 |
| WH77 | 320 | 4a | U091 | $y$ |  | r | 15.91 | 12.77 | 53.22 | 50.54 |


| Uley - coracoids |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Meas. ratio | GMM | Side | Bb | Bf | GL | Lm |
| WH77 | 331 | 6b | U096 | $y$ |  | $r$ | 15.39 | 12.69 | 54.25 | 51.92 |
| WH77 | 348 | 4b | UIIO | y | y | r | 14.83 | 11.66 | 58.71 | 56.33 |
| WH77 | 369 | 4b | UII7 | $y$ | $y$ | r | 15.36 | 13.69 | 57 | 54.46 |
| WH78 | 681 | 5b | U121 | $y$ |  | 1 | 14.17 | 11.88 | 53.2 | 51.03 |
| WH78 | 820a | 4b | UI27 | y | $y$ | 1 | 11.54 | 9.79 | 46.86 | 44.69 |
| WH78 | 616 | ? | UI39 | y | y | I | 13.99 | 11.01 | 52.19 | 49.38 |
| WH78 | 634 | 5a-c | UI5I | $y$ | y | 1 | 14.94 | 12.35 | 54.79 | 52.22 |
| WH79 | 02 layer | ? | U163 | $y$ |  | r | 13.22 | 10.99 | 50.9 | 47.91 |
| WH79 | 1191 | 5d-6b | UI80 | y | $y$ | 1 | 15.09 | 12.68 | 57.47 | 55.22 |
| WH79 | 1191 | 5d-6b | UI86 | $y$ | $y$ | 1 | 14.63 | 12.31 | 58.79 | 55.98 |
| WH78 | 820a | 4b | U198 | y |  | r | 14.41 | 11.48 | 56.18 | 54.08 |

### 3.1.1.2 Measurement ratios - coracoid

| Uley coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| U4 | 94.88 | 81.64 | 29.43 | 31.02 | 24.03 | 25.32 |
| U23 | 94.65 | 78.1 I | 28.5 I | 30.12 | 22.27 | 23.53 |
| U25 | 94.67 | 84.35 | 27.4 I | 28.96 | 23.12 | 24.42 |
| U3I | 95.88 | 83.98 | 26.57 | 27.72 | 22.32 | 23.28 |


| Uley coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| U40 | 95.76 | 81.65 | 26.25 | 27.42 | 21.44 | 22.39 |
| U43 | 95.55 | 79.74 | 27.08 | 28.34 | 21.59 | 22.60 |
| U50 | 95.36 | 76.49 | 28.74 | 30.14 | 21.98 | 23.05 |
| U57 | 95.44 | 81.89 | 25.58 | 26.8 I | 20.95 | 21.95 |
| U6I | 95.18 | 79.97 | 29.66 | 31.16 | 23.72 | 24.92 |
| U75 | 93.62 | 83.29 | 26.57 | 28.38 | 22.13 | 23.63 |
| U9I | 94.96 | 80.26 | 29.89 | 31.48 | 23.99 | 25.27 |
| U96 | 95.7 I | 82.46 | 28.37 | 29.64 | 23.39 | 24.44 |
| UII0 | 95.95 | 78.62 | 25.26 | 26.33 | 19.86 | 20.70 |
| UII7 | 95.54 | 89.13 | 26.95 | 28.20 | 24.02 | 25.14 |
| UI2I | 95.92 | 83.84 | 26.64 | 27.77 | 22.33 | 23.28 |
| UI27 | 95.37 | 84.84 | 24.63 | 25.82 | 20.89 | 21.91 |
| UI39 | 94.62 | 78.70 | 26.81 | 28.33 | 21.10 | 22.30 |
| UI5I | 95.3 I | 82.66 | 27.27 | 28.61 | 22.54 | 23.65 |
| UI63 | 94.13 | 83.13 | 25.97 | 27.59 | 21.59 | 22.94 |
| UI80 | 96.08 | 84.03 | 26.26 | 27.33 | 22.06 | 22.96 |
| UI86 | 95.22 | 84.14 | 24.89 | 26.13 | 20.94 | 21.99 |
| UI98 | 96.26 | 79.67 | 25.65 | 26.65 | 20.43 | 21.23 |

### 3.1.2 Uley humerus

### 3.1.2.1 Standard metrics - humerus

| Uley - humeri |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| WH77 B2 | 12 | 6b | U003 | $r$ | $y$ | $y$ | 14.28 | 18.85 | 69.99 | 6.34 |
| WH77 B2 | 148 | 5c-d | U007 | $r$ | y |  | 15.77 | 19.65 | 73.51 | 7.39 |
| WH77 B2 | 148 | 5c-d | U010 | I | $y$ | $y$ | 16.66 | 20.45 | 76.47 | 7.07 |
| WH77 | 22 | 5 e | U02I | I | $y$ |  | 14.60 | 18.57 | 71.77 | 7.32 |
| WH77 BI | 69 | 5 e | U034 | 1 | $y$ | $y$ | 13.60 | 17.48 | 68.03 | 6.89 |
| WH77 BI | 69 | 5 e | U035 | r | $y$ | $y$ | 14.78 | 19.01 | 72.43 | 6.82 |
| WH77 | 155 | 5 e | U055 | I | $y$ | $y$ | 16.64 | 20.07 | 73.42 | 8.08 |
| WH77 | 164 | 5 e | U063 | I |  |  | 14.95 | 19.26 | 58.74 | 6.80 |
| WH77 | 164 | 5 e | U064 | $r$ |  |  | 14.93 | 20.79 | 58.64 | 6.86 |
| WH77 | 165 | 5a-b | U07I | $r$ | $y$ | $y$ | 15.66 | 19.78 | 69.77 | 7.09 |
| WH77 | 165 | 5a-b | U072 | r | $y$ | $y$ | 16.97 | 21.31 | 78.48 | 7.38 |
| WH77 | 187 | 5 e | U076 | 1 |  |  | 15.26 | 18.68 | 60.63 | 7.01 |
| WH77 | 300 | 6b | U077 | $r$ | $y$ | y | 16.32 | 19.92 | 74.84 | 7.08 |
| WH77 | 302 | 4a | U08I | I | $y$ | $y$ | 16.39 | 20.19 | 75.83 | 7.83 |
| WH77 | 331 | 6b | U097 | r | $y$ | $y$ | 16.12 | 20.36 | 73.60 | 6.91 |
| WH77 | 348 | 4b | U109 | $r$ | y | $y$ | 15.51 | 19.43 | 73.32 | 7.20 |
| WH78 | 878 | ? | UI24 | 1 | $y$ | $y$ | 14.94 | 18.80 | 69.58 | 6.83 |


| Uley - humeri |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| WH78 | 820a | 4b | UI28 | I | $y$ | $y$ | 15.32 | 18.78 | 70.30 | 6.70 |
| WH78 | 820a | 4b | UI29 | 1 | $y$ | $y$ | 14.44 | 17.44 | 66.73 | 6.23 |
| WH78 | 634 | 5a-c | UI48 | $r$ | $y$ | $y$ | $16.72$ | $21.29$ | $76.45$ | 7.71 |
| WH78 | 634 | 5a-c | UI49 | 1 | $y$ | $y$ | 15.48 | 18.88 | 72.54 | 6.77 |
| WH78 | 726 | 3 | UI55 | 1 | $y$ | $y$ | 13.48 | 17.24 | 63.29 | 5.97 |
| WH78 | 813 | 4b | UI58 | 1 | $y$ | $y$ | $13.27$ | $16.78$ | 63.20 | 6.01 |
| WH79 | 406 | 7 | U167 | $r$ | $y$ | $y$ | 15.13 | 19.77 | 71.82 | 7.16 |
| WH79 | 1228 | 5a-b | UI75 | $r$ | $y$ |  | 14.71 | 18.52 | 72.35 | 6.89 |
| WH79 | 1224 | 4b | UI78 | $r$ | $y$ |  | 15.90 | 19.63 | 75.49 | 7.14 |
| WH79 | 1191 | 5d-6b | U187 | I | $y$ |  | 14.70 | 18.81 | 72.75 | 7.16 |

### 3.1.2.2 Measurement ratios - humerus

| Uley humerus measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| U3 | 75.76 | 9.06 | 26.93 | 20.40 | 33.63 | 44.40 |
| U7 | 80.25 | 10.05 | 26.73 | 21.45 | 37.61 | 46.86 |
| U10 | 81.47 | 9.25 | 26.74 | 21.79 | 34.57 | 42.44 |
| U2I | 78.62 | 10.20 | 25.87 | 20.34 | 39.42 | 50.14 |
| U34 | 77.80 | 10.13 | 25.69 | 19.99 | 39.42 | 50.66 |


| Uley humerus measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| U35 | 77.75 | 9.42 | 26.25 | 20.4 I | 35.88 | 46.14 |
| U55 | 82.91 | 11.0 I | 27.34 | 22.66 | 40.26 | 48.56 |
| U7I | 79.17 | 10.16 | 28.35 | 22.45 | 35.84 | 45.27 |
| U72 | 79.63 | 9.40 | 27.15 | 21.62 | 34.63 | 43.49 |
| U77 | 81.93 | 9.46 | 26.62 | 21.81 | 35.54 | 43.38 |
| U8I | 81.18 | 10.33 | 26.63 | 21.61 | 38.78 | 47.77 |
| U97 | 79.17 | 9.39 | 27.66 | 21.90 | 33.94 | 42.87 |
| UI09 | 79.83 | 9.82 | 26.50 | 21.15 | 37.06 | 46.42 |
| UI24 | 79.47 | 9.82 | 27.02 | 21.47 | 36.33 | 45.72 |
| UI28 | 81.58 | 9.53 | 26.71 | 21.79 | 35.68 | 43.73 |
| UI29 | 82.80 | 9.34 | 26.14 | 21.64 | 35.72 | 43.14 |
| UI48 | 78.53 | 10.09 | 27.85 | 21.87 | 36.21 | 46.11 |
| UI49 | 81.99 | 9.33 | 26.03 | 21.34 | 35.86 | 43.73 |
| UI55 | 78.19 | 9.43 | 27.24 | 21.30 | 34.63 | 44.29 |
| UI58 | 79.08 | 9.51 | 26.55 | 21.00 | 35.82 | 45.29 |
| UI67 | 76.53 | 9.97 | 27.53 | 21.07 | 36.22 | 47.32 |
| UI75 | 79.43 | 9.52 | 25.60 | 20.33 | 37.20 | 46.84 |
| UI78 | 81.00 | 9.46 | 26.00 | 21.06 | 36.37 | 44.91 |
| UI87 | 78.15 | 9.84 | 25.86 | 20.21 | 38.06 | 48.71 |
|  |  |  |  |  |  |  |

### 3.1.3 Uley femur

### 3.1.3.1 Standard metrics - femur

| Uley - femora |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| WH77 B2 | 148 | 5c-d | U013 | 1 | y | 15.71 | 16.07 | 12.88 | 10.93 | 83.92 | 78.81 | 7.28 |
| WH77 B2 | 148 | 5c-d | U014 | $r$ |  | 15.51 | 16.01 | 12.96 | 10.69 | 83.94 | 79.17 | 7.23 |
| WH77 | 22 | 5 e | U022 | r | $y$ | 16.37 | 16.50 | 13.15 | 11.30 | 80.20 | 76.07 | 7.19 |
| WH77 | 136 | 5 e | U048 | r | $y$ | 15.86 | 15.79 | 12.79 | 9.92 | 81.13 | 76.60 | 6.93 |
| WH77 | 136 | 5 e | U049 | 1 | y | 15.51 | 15.37 | 12.73 | 10.43 | 79.72 | 74.56 | 7.30 |
| WH77 | 164 | 5 e | U065 | 1 |  | 15.14 | 14.47 | 12.33 | 10.65 | 65.32 | 60.48 | 5.95 |
| WH77 | 164 | 5 e | U066 | r |  | 15.09 | 14.55 | 12.61 | 10.63 | 65.92 | 60.84 | 6.15 |
| WH77 | 302 | 4a | U082 | r | $y$ | 16.30 | 16.66 | 13.68 | 11.34 | 84.59 | 78.53 | 7.70 |
| WH77 | 348 | 4b | U089 | r | y | 16.51 | 16.38 | 12.72 | 11.23 | 84.07 | 79.25 | 7.24 |
| WH77 | 325 | 4b | U094 | r | $y$ | 14.78 | 15.27 | 11.73 | 10.27 | 77.72 | 73.28 | 6.65 |
| WH77 | 341 | 6 to 7 | UI04 | r | $y$ | 15.26 | 15.95 | 13.48 | 10.34 | 82.75 | 77.77 | 7.25 |
| WH77 | 348 | 4b | UIII | $r$ | $y$ | 14.97 | 15.50 | 11.96 | 10.51 | 79.79 | 74.95 | 7.02 |
| WH77 | 354 | 4b | UII3 | r | y | 15.97 | 15.94 | 12.49 | 10.82 | 81.08 | 75.22 | 7.28 |
| WH77 | 368 | 6b | UII6 | r | $y$ | 15.64 | 14.94 | 12.23 | 10.33 | 77.17 | 71.89 | 6.66 |
| WH78 | 682 | 4a | UI23 | 1 | $y$ | 14.76 | 15.67 | 12.27 | 10.54 | 81.75 | 76.44 | 6.55 |
| WH78 | 823 | 4a | UI45 | 1 | $y$ | 16.70 | 16.25 | 13.71 | 11.30 | 81.65 | 76.47 | 7.61 |
| WH79 | 1191 | 5d-6b | U165 | r | $y$ | 15.86 | 15.61 | 12.65 | 10.74 | 79.43 | 74.47 | 7.24 |


| Uley - femora |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| WH79 | 180 | 3b | UI73 | $r$ | $y$ | 14.65 | 15.53 | 12.79 | 10.06 | 77.86 | 72.10 | 7.05 |
| WH79 | 1191 | 5d-6b | U190 | $r$ | $y$ | 14.94 | 15.76 | 12.22 | 10.23 | 79.93 | 75.22 | 7.03 |
| WH77 | 386 | ? | U194 | $r$ | $y$ | 14.85 | 14.45 | 12.35 | 10.22 | 76.87 | 72.09 | 6.57 |

### 3.1.3.2 Measurement ratios-femur

| Uley femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| U013 | 81.99 | 46.34 | 8.67 | 18.72 | 19.15 | 19.93 | 20.39 | 9.24 | 45.30 | 80.15 | 84.86 | I 5.35 | 16.34 | 56.52 |
| U022 | 80.33 | 43.92 | 8.97 | 20.41 | 20.57 | 21.52 | 21.69 | 9.45 | 43.58 | 79.70 | 85.93 | 16.40 | 17.29 | 54.68 |
| U048 | 80.64 | 43.69 | 8.54 | 19.55 | 19.46 | 20.70 | 20.61 | 9.05 | 43.89 | 81.00 | 77.56 | I 5.76 | 16.70 | 54.18 |
| U049 | 82.08 | 47.07 | 9.16 | 19.46 | 19.28 | 20.80 | 20.61 | 9.79 | 47.50 | 82.82 | 81.93 | I 5.97 | 17.07 | 57.34 |
| U082 | 83.93 | 47.24 | 9.10 | 19.27 | 19.69 | 20.76 | 21.21 | 9.81 | 46.22 | 82.11 | 82.89 | 16.17 | 17.42 | 56.29 |
| U089 | 77.04 | 43.85 | 8.61 | 19.64 | 19.48 | 20.83 | 20.67 | 9.14 | 44.20 | 77.66 | 88.29 | 15.13 | 16.05 | 56.92 |
| U094 | 79.36 | 44.99 | 8.56 | 19.02 | 19.65 | 20.17 | 20.84 | 9.07 | 43.55 | 76.82 | 87.55 | I 5.09 | I6.01 | 56.69 |
| UIO4 | 88.34 | 47.51 | 8.76 | 18.44 | 19.27 | 19.62 | 20.5 I | 9.32 | 45.45 | 84.51 | 76.71 | 16.29 | 17.33 | 53.78 |
| UIII | 79.89 | 46.89 | 8.80 | 18.76 | 19.43 | 19.97 | 20.68 | 9.37 | 45.29 | 77.16 | 87.88 | 14.99 | 15.96 | 58.70 |
| UII3 | 78.21 | 45.59 | 8.98 | 19.70 | 19.66 | 21.23 | 21.19 | 9.68 | 45.67 | 78.36 | 86.63 | 15.40 | 16.60 | 58.29 |
| UII6 | 78.20 | 42.58 | 8.63 | 20.27 | 19.36 | 21.76 | 20.78 | 9.26 | 44.58 | 81.86 | 84.46 | 15.85 | I7.01 | 54.46 |
| UI23 | 83.13 | 44.38 | 8.01 | 18.06 | 19.17 | I9.31 | 20.50 | 8.57 | 41.80 | 78.30 | 85.90 | I5.01 | 16.05 | 53.38 |


| Uley femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| UI45 | 82.10 | 45.57 | 9.32 | 20.45 | 19.90 | 21.84 | 21.25 | 9.95 | 46.83 | 84.37 | 82.42 | 16.79 | 17.93 | 55.51 |
| UI65 | 79.76 | 45.65 | 9.11 | 19.97 | 19.65 | 21.30 | 20.96 | 9.72 | 46.38 | 81.04 | 84.90 | 15.93 | 16.99 | 57.23 |
| UI73 | 87.30 | 48.12 | 9.05 | 18.82 | 19.95 | 20.32 | 21.54 | 9.78 | 45.40 | 82.36 | 78.66 | 16.43 | 17.74 | 55.12 |
| U190 | 81.79 | 47.05 | 8.80 | 18.69 | 19.72 | 19.86 | 20.95 | 9.35 | 44.61 | 77.54 | 83.72 | 15.29 | 16.25 | 57.53 |
| U194 | 83.16 | 44.24 | 8.55 | 19.32 | 18.80 | 20.60 | 20.04 | 9.11 | 45.47 | 85.47 | 82.75 | 16.07 | 17.13 | 53.20 |

## 3.I. 4 Uley tibiotarsus

### 3.1.4.1 Standard metrics - tibiotarsus

| Uley - tibiotarsi |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | GMM | Bd | Dd | Dip | GL | La | SC |
| WH77 B2 | 148 | 5c-d | U009 | 1 |  |  | 11.79 | 12.34 |  |  |  |  |
| WH77 B2 | 148 | 5c-d | U011 | r | $y$ | $y$ | 10.62 | 11.84 | 20.12 | 115.02 | 110.98 | 6.12 |
| WH77 | 47 | ? | U028 | 1 | $y$ |  | 11.95 | 12.33 | 22.13 | 116.51 | 112.24 | 6.73 |
| WH77 | 47 | ? | U029 | I | y | $y$ | 11.41 | 11.47 | 20.5 | 109.78 | 106.45 | 6.16 |
| WH77 | 332 | 4b | UIO2 | $r$ | $y$ |  | 12.36 | 12.81 | 22.65 | 117.86 | 113.98 | 6.64 |
| WH79 | 1191 | 5d-6b | UI89 | r |  |  |  | 12.89 |  |  |  | 5.84 |

### 3.1.4.2 Measurement ratios - tibiotarsus

| Uley tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| U011 | 52.78 | 9.23 | 10.29 | 57.63 | 5.32 | 9.57 | 10.67 | 5.51 | 89.70 | 58.85 | 17.49 | 30.42 | 18.13 | 96.49 | 51.69 |
| U028 | 54.00 | 10.26 | 10.58 | 56.32 | 5.78 | 10.65 | 10.99 | 6.00 | 96.92 | 55.72 | 18.99 | 30.41 | 19.72 | 96.34 | 54.58 |
| U029 | 55.66 | 10.39 | 10.45 | 53.99 | 5.61 | 10.72 | 10.78 | 5.79 | 99.48 | 55.95 | 18.67 | 30.05 | 19.26 | 96.97 | 53.71 |
| UIO2 | 54.57 | 10.49 | 10.87 | 53.72 | 5.63 | 10.84 | 11.24 | 5.83 | 96.49 | 56.56 | 19.22 | 29.32 | 19.87 | 96.71 | 51.83 |

### 3.1.5 Uley tarsometatarsus

### 3.1.5.1 Standard metrics - tarsometatarsus

| Uley - tarsometatarsi |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur <br> Length |
| WH77 B2 | 148 | 5c-d | U012 | $r$ |  |  |  | 14.23 | 80.25 | 6.83 | 19.32 |
| WH77 | 20 | 5 e | U020 | $r$ |  |  |  | 14.19 |  | 6.64 | 21.52 |
| WH77 | 47 | ? | U026 | r |  |  | 13.10 |  | 82.26 | 6.92 | 22.22 |
| WH77 | 126 | 5a-d | U042 | I |  |  | 14.38 |  |  |  | 20.45 |
| WH77 | 164 | 5 e | U067 | 1 |  |  | 13.01 | 12.19 | 52.82 | 7.49 | 18.10 |
| WH77 | 302 | 4a | U079 | I | $y$ | $y$ | 13.39 | 13.62 | 80.78 | 6.68 | 22.51 |
| WH77 | 302 | 4a | U080 | I | $y$ | $y$ | 13.31 | 13.58 | 81.80 | 6.72 |  |


| Uley - tarsometatarsi |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ area | Context | Phase | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur <br> Length |
| WH77 | 341 | 6 to 7 | UIO5 | $r$ | $y$ | $y$ | 12.80 | 14.71 | 82.70 | 6.74 | 20.62 |
| WH77 | 354 | 4b | UII2 | 1 | $y$ | $y$ | 13.99 | 13.45 | 80.00 | 7.33 |  |
| WH78 | 634 | $5 \mathrm{a}-\mathrm{c}$ | UI54 | 1 | $y$ |  | 14.04 | 14.23 | 79.32 | 7.12 | 19.92 |
| WH78 | 868 | ? | UI56 | 1 | y |  | 12.97 | 13.95 | 77.20 | 6.48 | 17.48 |
| WH78 | 813 | 4b | U159 | $r$ |  |  | 13.20 | 13.06 | 76.98 |  |  |
| WH79 | 1100 | 7 to 8 | U17I | $r$ | $y$ | $y$ | 13.15 | 12.89 | 79.58 | 7.19 |  |
| WH79 | 1228 | 5a-b | UI77 | 1 | $y$ |  | 13.71 | 13.66 | 84.47 | 7.15 | 19.92 |
| WH79 | 1191 | 5d-6b | U191 | r |  |  |  |  |  | 8.26 |  |

### 3.1.5.2 Measurement ratios - tarsometatarsus

| Uley tarsometatarsi measurement ratios |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |  |
| U79 | m | 98.3 I | 49.89 | 8.27 | 16.86 | 16.58 | 49.05 |  |
| U80 | m | 98.0 I | 50.49 | 8.22 | 16.60 | 16.27 | 49.48 |  |
| UI05 | m | 87.02 | 52.66 | 8.15 | 17.79 | 15.48 | 45.82 |  |
| UII2 | m | 104.0 I | 52.39 | 9.16 | 16.8 I | 17.49 | 54.50 |  |
| UI54 | m | 98.66 | 50.7 I | 8.98 | 17.94 | 17.70 | 50.04 |  |
| UI56 | m | 92.97 | 49.96 | 8.39 | 18.07 | 16.80 | 46.45 |  |
| UI7I | m | 102.02 | 54.68 | 9.03 | 16.20 | 16.52 | 55.78 |  |


| Uley tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| UI77 | m | 100.37 | 52.15 | 8.46 | 16.17 | 16.23 | 52.34 |

### 3.2 Fishbourne

### 3.2.I Fishbourne coracoid

### 3.2.I.I Standard metrics - coracoid

| Fishbourne coracoids |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/area | Context | ID | Ch. project ID | Meas. ratio | Side | Bb | Bf | GL | Lm |
| FB62 | 82 | FBI | 469 | $y$ | I | 11.92 | 11.26 | 51.84 | 49.06 |
| FB64 | 169 | FB2 | 472 | $y$ | $r$ | 11.84 | 9.03 | 44.83 | 42.65 |
| FB64 | 178 | FB3 | 474 | $y$ | r | 12.77 | 10.65 | 50.66 | 48.81 |
| FB64 | 225 | FB4 | 478 | $y$ | r | 14.5 | 13.26 | 56.82 | 53.78 |
| FB65 | 257 | FB5 | 479 | $y$ | r | 13.53 | 11.1 | 51.12 | 48.32 |
| FB66 | 337 | FB6 | 485 | $y$ | r | 13.41 | 11.91 | 58.26 | 55.91 |
| FB67 | 347 | FB7 | 495 | $y$ | 1 | 11.07 | 9.45 | 46.14 | 44.03 |
| FB67 | 367 | FB8 | 496 | $y$ | 1 | 13.9 | 12.12 | 56.55 | 53.26 |
| FB67 | 367 | FB9 | 497 | $y$ | r | 11.91 | 10.36 | 47.54 | 45.46 |


| Fishbourne coracoids |  |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/area | Context | ID | Ch. project ID | Meas. ratio | Side | Bb | Bf | GL | Lm |  |
| FB68 | 364 | FBIO | 501 | $y$ | 1 | 15.12 | 12.51 | 58.82 | 56.03 |  |
| FBE02 | 1030 | FBII | 517 | $y$ | r | 11.76 | 11.25 | 48.13 | 45.46 |  |
| FBE02 | 1098.3 | FBI2 | 519 | $y$ | I | 13.03 | 10.63 | 57.17 | 53.65 |  |
| FBE02 | 1098.3 | FBI3 | 520 | $y$ | r | 12.62 | 10.29 | 48.33 | 46.24 |  |
| FBE99 | 907 | FBI4 | 525 | $y$ | r | 11.36 | 10.55 | 48.36 | 46.52 |  |

### 3.2.1.2 Measurement ratios - coracoid

| Fishbourne coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| FBI | 94.64 | 94.46 | 22.99 | 24.30 | 21.72 | 22.95 |
| FB2 | 95.14 | 76.27 | 26.41 | 27.76 | 20.14 | 21.17 |
| FB3 | 96.35 | 83.40 | 25.21 | 26.16 | 21.02 | 21.82 |
| FB4 | 94.65 | 91.45 | 25.52 | 26.96 | 23.34 | 24.66 |
| FB5 | 94.52 | 82.04 | 26.47 | 28.00 | 21.71 | 22.97 |
| FB6 | 95.97 | 88.81 | 23.02 | 23.98 | 20.44 | 21.30 |
| FB7 | 95.43 | 85.37 | 23.99 | 25.14 | 20.48 | 21.46 |
| FB8 | 94.18 | 87.19 | 24.58 | 26.10 | 21.43 | 22.76 |
| FB9 | 95.62 | 86.99 | 25.05 | 26.20 | 21.79 | 22.79 |
| FBI0 | 95.26 | 82.74 | 25.71 | 26.99 | 21.27 | 22.33 |
| FBII | 94.45 | 95.66 | 24.43 | 25.87 | 23.37 | 24.75 |

Fishbourne coracoids measurement ratios

| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| FBI2 | 93.84 | 8 I .58 | 22.79 | 24.29 | 18.59 | 19.8 I |
| FBI3 | 95.68 | 81.54 | 26.11 | 27.29 | 21.29 | 22.25 |
| FBI4 | 96.20 | 92.87 | 23.49 | 24.42 | 21.82 | 22.68 |

### 3.3 Lyminge

### 3.3.I Lyminge coracoid

### 3.3.1.1 Standard metrics - coracoid

| Lyminge - coracoid |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code Iseason | Context | ID | GMM ID | Side | Meas. ratio | GMM | Bb | Bf | GL | Lm | GMM | ABG? |
| LYM08 | 10 | L005 |  | $r$ | $y$ | $y$ | 13.33 | 10.89 | 48.02 | 46.33 | $y$ |  |
| LYM08 | 106 | L022 |  | r |  |  | 11.53 | 9.76 | 48.24 | 45.04 | $y$ |  |
| LYM08 | 247 | L054 | 1054ggxxx\|cor | 1 | $y$ | y | 13.74 | 11.62 | 50.18 | 47.59 | $y$ |  |
| LYM08 | 247 | L055 |  | 1 |  |  | 13.78 | 11.68 | 50.92 | 48.69 | $y$ |  |
| LYM08 | 247 | L056 |  | $r$ | $y$ |  | 12.13 | 9.72 | 47.80 | 46.01 | $y$ |  |
| LYM08 | 247 | L057 |  | r | $y$ | $y$ | 12.75 | 10.77 | 48.62 | 46.22 | $y$ |  |
| LYM08 | 273 | LIOI |  | I | $y$ |  | 13.70 | 11.82 | 49.47 | 46.54 | $y$ |  |
| LYM08 | 509 | LII5 |  | I | $y$ |  | 12.05 | 10.50 | 47.92 | 45.53 | $y$ |  |


| Lyminge - coracoid |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code Iseason | Context | ID | GMM ID | Side | Meas. ratio | GMM | Bb | Bf | GL | Lm | GMM | ABG? |
| LYM08 | 525 | LI27 | II27ggxxxlcor | 1 | $y$ | $y$ | 13.79 | 11.64 | 50.11 | 47.61 | $y$ |  |
| LYM08 | 544 | LI34 | II34ggxxxicor | 1 | $y$ | $y$ | 12.13 | 10.25 | 50.08 | 47.26 | $y$ |  |
| LYM08 | 592 | LI47 | II47ggxxxrcor | $r$ | $y$ | $y$ | 14.95 | 13.24 | 55.25 | 52.63 | $y$ |  |
| LYM08 | 616 | LI49 |  | r | $y$ |  | 14.22 | 12.01 | 58.37 | 56.02 | $y$ |  |
| LYM08 | 620 | LI52 | II52ggxxx\|cor | 1 | $y$ | $y$ | 13.21 | 12.04 | 56.55 | 54.15 | $y$ |  |
| LYM08 | 637 | LI62 |  | 1 | $y$ |  | 14.29 | 11.48 | 53.60 | 50.91 | $y$ |  |
| LYM08 | 642 | LI69 | 1169ggxxxicor | I | $y$ | $y$ | 14.09 | 11.33 | 49.03 | 46.11 | $y$ |  |
| LYM08 | 684 | L222 | 1222ggxxxicor | 1 | $y$ | $y$ | 12.54 | 10.91 | 47.74 | 45.37 | $y$ |  |
| LYM08 | 684 | L223 |  | r |  |  | 12.61 | 10.66 | 47.48 | 45.03 | $y$ |  |
| LYM08 | 684 | L224 |  | 1 | y |  | 11.62 | 9.97 | 49.61 | 46.88 | $y$ |  |
| LYM08 | 684 | L225 |  | r |  |  | 12.61 | 10.73 | 49.44 | 46.51 | $y$ |  |
| LYM08 | 684 | L226 | 1226ggxxxlcor | 1 | y | y | 13.17 | 10.75 | 49.50 | 46.88 | $y$ |  |
| LYM08 | 744 | L273 |  | r | $y$ |  | 14.43 | 11.30 | 55.57 | 53.51 | $y$ |  |
| LYM09 | 1095 | L340 | 1340ggxxxlcor | 1 | $y$ | $y$ | 12.39 | 10.96 | 46.17 | 44.60 | $y$ |  |
| LYM09 | 1095 | L34I | 134Iggxxx\|cor | I | $y$ |  | 12.34 | 9.77 | 47.40 | 45.60 | $y$ |  |
| LYM09 | 1099 | L346 | 1346ggxxxlcor | I | $y$ | y | 12.06 | 10.29 | 46.59 | 44.92 | $y$ |  |
| LYM09 | 1228 | L385 |  | $r$ | $y$ |  | 11.56 | 9.99 | 48.75 | 46.51 | $y$ |  |
| LYM09 | 1296 | L408 | 1408ggxxxrcor | r | $y$ | y | 13.83 | 10.97 | 49.35 | 46.87 | $y$ |  |
| LYM09 | 1310 | L42I |  | I |  |  | 13.20 | 11.05 | 50.75 | 48.13 |  |  |
| LYM09 | 1330 | L477 | 1477ggxxx\|cor | I | y | y | 14.77 | 12.01 | 55.95 | 53.35 | y |  |


| Lyminge - coracoid |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code Iseason | Context | ID | GMM ID | Side | Meas. ratio | GMM | Bb | Bf | GL | Lm | GMM | ABG? |
| LYM09 | 1332 | L489 |  | 1 |  |  | 13.73 | 12.78 | 54.10 | 53.37 |  |  |
| LYM09 | 1332 | L507 |  | r | $y$ |  | 13.10 | 10.73 | 49.17 | 47.14 | $y$ |  |
| LYM09 | 1332 | L508 |  | $r$ | $y$ |  | 13.18 | 10.80 | 54.23 | 52.52 | $y$ |  |
| LYM09 | 1332 | L509 | 1509ggxxxicor | 1 | $y$ | $y$ | 12.76 | 9.52 | 48.57 | 46.91 | $y$ |  |
| LYM09 | 1333 | L519 | 1519ggxxx\|cor | 1 | $y$ | $y$ | 13.72 | 11.40 | 50.51 | 47.64 | $y$ |  |
| LYM09 | 1333 | L520 |  | $r$ |  |  | 13.25 | 11.11 | 50.53 | 47.56 | $y$ |  |
| LYM09 | 1399 | L530 | 1530ggxxx\|cor | I | $y$ | y | 15.23 | 12.17 | 56.19 | 53.19 | $y$ |  |
| LYM09 | 1446 | L537 |  | 1 | $y$ |  | 14.60 | 12.58 | 56.10 | 53.73 | $y$ |  |
| LYM09 | 1464 | L560 | 1560ggxxxrcor | r | y | $y$ | 12.83 | 10.24 | 48.34 | 46.26 | $y$ |  |
| LYM09 | 1514 | L601 |  | $r$ |  |  | 12.86 | 11.26 | 47.38 | 44.96 |  |  |
| LYM09 | 1544 | L614 |  | I | $y$ |  | 12.13 | 11.21 | 51.78 | 50.41 | $y$ |  |
| LYM09 | 1564 | L617 | 1617ggxxxrcor | r | $y$ | y | 13.90 | 12.33 | 56.22 | 53.14 | $y$ |  |
| LYM09 | 1672 | L702 | 1702ggxxxicor | I | $y$ | $y$ | 15.88 | 13.07 | 56.76 | 53.81 | $y$ |  |
| LYM09 | 1672 | L703 | 1703ggxxxlcor | 1 |  |  | 11.45 | 9.16 | 47.21 | 47.19 | $y$ |  |
| LYM09 | 1672 | L708 |  | $r$ | $y$ |  | 12.70 | 9.99 | 48.54 | 45.90 | $y$ |  |
| LYM09 | 1672 | L7I0 | 1710ggxxxlcor | I | $y$ | y | 13.21 | 10.67 | 49.85 | 47.63 | $y$ |  |
| LYM09 | 1672 | L7II |  | r | $y$ |  | 11.43 | 8.89 | 45.71 | 43.24 | $y$ |  |
| LYM09 | 1672 | L716 |  | r | $y$ |  | 14.75 | 12.24 | 54.93 | 52.04 | $y$ |  |
| LYM09 | 1705 | L74I | 174IggxxxIcor | I | $y$ | y | 15.15 | 13.97 | 53.86 | 50.82 | $y$ |  |
| LYM09 | 1725 | L759 |  | I | $y$ |  | 15.52 | 13.32 | 60.72 | 58.17 | y |  |


| Lyminge - coracoid |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code /season | Context | ID | GMM ID | Side | Meas. ratio | GMM | Bb | Bf | GL | Lm | GMM | ABG? |
| LYM09 | 1730 | L781 | 1781ggxxxrcor | $r$ | $y$ | y | 15.64 | 11.81 | 56.78 | 53.67 | $y$ |  |
| LYM09 | 1730 | L787 |  | r | $y$ |  | 13.19 | 10.84 | 48.24 | 45.17 | $y$ |  |
| LYM09 | 1730 | L791 | 1791ggxxxlcor | I | $y$ | $y$ | 13.23 | 10.45 | 48.40 | 45.88 | $y$ |  |
| LYM09 | 1730 | L797 | 1797ggxxxlcor | 1 | $y$ | $y$ | 12.68 | 10.56 | 48.82 | 46.28 | $y$ |  |
| LYM09 | 1817 | L816 | 1816ggxxxrcor | $r$ | $y$ | $y$ | 15.92 | 13.53 | 57.07 | 54.54 | $y$ |  |
| LYM09 | 1828 | L823 | 1823ggxxxlcor | 1 | $y$ | $y$ | 14.25 | 12.00 | 48.36 | 45.71 | $y$ |  |
| LYMI2 | 3226 | L871 |  | 1 |  |  | 14.73 | 12.45 | 54.41 | 52.17 |  |  |
| LYMI2 | 3242 | L881 | 1881ggxxxlcor | 1 | $y$ | $y$ | 13.06 | 10.04 | 50.20 | 47.86 | $y$ |  |
| LYMI2 | 3371 | L893 |  | r | $y$ |  | 15.02 | 12.99 | 58.42 | 54.34 | $y$ |  |
| LYMI2 | 3678 | L901 | 1901ggxxxlcor | 1 | $y$ | $y$ | 15.24 | 12.93 | 55.21 | 52.41 | $y$ |  |
| LYMI3 | 6256 | L916 | 1916ggxxxrcor | $r$ | $y$ | $y$ | 13.56 | 11.90 | 56.93 | 54.18 | $y$ |  |
| LYMI3 | 6256 | L917 | 1917ggxxxrcor | r | $y$ | $y$ | 12.71 | 10.05 | 49.54 | 47.01 | $y$ |  |
| Lym08 | 680 | ABGI | 1255ggxxxlcor | 1 | $y$ | $y$ | 13.42 | 10.58 | 49.01 | 46.28 |  | ABGI |
| Lym08 | 680 | ABGI |  | $r$ |  |  | 13.64 | 10.41 | 48.81 | 45.66 |  | ABGI |
| LymI2 | 3695 | ABG2 | 1249ggxxx\|cor | I | $y$ | $y$ | 15.44 | 11.79 | 57.78 | 55.08 |  | ABG2 |
| LymI2 | 3695 | ABG2 |  | r |  |  | 15.63 | 12.33 | 57.56 | 55.22 |  | ABG2 |
| Lym09 | 1409 | ABG3 |  | r |  |  |  |  | 44.45 |  |  | ABG3 |
| Lym08 | 582 | ABG5P |  | I |  |  |  |  |  |  |  | ABG5P |
| Lym09 | 1482 | ABG6 |  | 1 |  |  |  |  |  |  |  | ABG6 |
| Lym09 | 1600 | ABG7 | 1228ggxxx\|cor | 1 | y | $y$ | 13.40 | 10.80 | 49.40 | 46.70 |  | ABG7 |


| Lyminge - coracoid |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code /season | Context | ID | GMM ID | Side | Meas. ratio | GMM | Bb | Bf | GL | Lm | GMM | ABG? |
| Lym09 | 1333 | ABG8 | 1236ggxxxrcor | $r$ | $y$ | $y$ | 14.30 | 10.70 | 50.60 | 49.00 |  | ABG8 |
| Lym09 | 1312 | ABG9 |  | $r$ | $y$ |  | 12.50 | 10.20 | 49.60 | 46.80 |  | ABG9 |
| Lym08 | 150 | ABGIO | 126\|ggxxxrcor | r | $y$ | y | 12.40 | 9.60 | 48.90 | 46.80 |  | ABGIO |
| Lym09 | 1091 | ABGII |  | $r$ |  |  |  |  |  |  |  | ABGII |

### 3.3.1.2 Measurement ratios - coracoid

| Lyminge coracoid measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | $\mathbf{B f / B b}$ | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| L5 | 96.48 | 81.70 | 27.76 | 28.77 | 22.68 | 23.5 I |
| Li | 93.37 | 84.65 | 23.90 | 25.60 | 20.23 | 21.67 |
| L54 | 94.84 | 84.57 | 27.38 | 28.87 | 23.16 | 24.42 |
| Lii | 95.62 | 84.76 | 27.06 | 28.30 | 22.94 | 23.99 |
| L56 | 96.26 | 80.13 | 25.38 | 26.36 | 20.33 | 21.13 |
| L57 | 95.06 | 84.47 | 26.22 | 27.59 | 22.15 | 23.30 |
| LIOI | 94.08 | 86.28 | 27.69 | 29.44 | 23.89 | 25.40 |
| LII5 | 95.0 I | 87.14 | 25.15 | 26.47 | 21.91 | 23.06 |
| LI27 | 95.0 I | 84.4 I | 27.52 | 28.96 | 23.23 | 24.45 |
| LI34 | 94.37 | 84.50 | 24.22 | 25.67 | 20.47 | 21.69 |
| LI47 | 95.26 | 88.56 | 27.06 | 28.4 I | 23.96 | 25.16 |


| Lyminge coracoid measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| LI49 | 95.97 | 84.46 | 24.36 | 25.38 | 20.58 | 21.44 |
| LI52 | 95.76 | 91. I4 | 23.36 | 24.40 | 21.29 | 22.23 |
| LI62 | 94.98 | 80.34 | 26.66 | 28.07 | 21.42 | 22.55 |
| LI69 | 94.04 | 80.4 I | 28.74 | 30.56 | 23. II | 24.57 |
| L222 | 95.04 | 87.00 | 26.27 | 27.64 | 22.85 | 24.05 |
| L224 | 94.50 | 85.80 | 23.42 | 24.79 | 20.10 | 21.27 |
| L226 | 94.7 I | 81.62 | 26.6 I | 28.09 | 21.72 | 22.93 |
| L273 | 96.29 | 78.3 I | 25.97 | 26.97 | 20.33 | 21.12 |
| L340 | 96.60 | 88.46 | 26.84 | 27.78 | 23.74 | 24.57 |
| L34I | 96.20 | 79.17 | 26.03 | 27.06 | 20.6 I | 21.43 |
| L346 | 96.42 | 85.32 | 25.89 | 26.85 | 22.09 | 22.9 I |
| L385 | 95.4 I | 86.42 | 23.7 I | 24.85 | 20.49 | 21.48 |
| L408 | 94.97 | 79.32 | 28.02 | 29.5 I | 22.23 | 23.4 I |
| Liii | 94.84 | 83.7 I | 26.0 I | 27.43 | 21.77 | 22.96 |
| L477 | 95.35 | 81.3 I | 26.40 | 27.69 | $2 I .47$ | 22.5 I |
| L507 | 95.87 | 81.9 I | 26.64 | 27.79 | 21.82 | 22.76 |
| L508 | 96.85 | 81.94 | 24.30 | 25.10 | 19.92 | 20.56 |
| L509 | 96.58 | 74.6 I | 26.27 | 27.20 | 19.60 | 20.29 |
| L5I9 | 94.32 | 83.09 | 27.16 | 28.80 | 22.57 | 23.93 |
| L530 | 94.66 | 79.9 I | 27.10 | 28.63 | 21.66 | 22.88 |
| L537 | 95.78 | 86.16 | 26.02 | 27.17 | 22.42 | 23.41 |


| Lyminge coracoid measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| L560 | 95.70 | 79.8 I | 26.54 | 27.73 | 21.18 | 22.14 |
| L6I4 | 97.35 | 92.42 | 23.43 | 24.06 | 21.65 | 22.24 |
| L6I7 | 94.52 | 88.7 I | 24.72 | 26.16 | 21.93 | 23.20 |
| L702 | 94.80 | 82.30 | 27.98 | 29.5 I | 23.03 | 24.29 |
| L708 | 94.56 | 78.66 | 26.16 | 27.67 | 20.58 | 21.76 |
| L7I0 | 95.55 | 80.77 | 26.50 | 27.73 | 21.40 | 22.40 |
| L7II | 94.60 | 77.78 | 25.0 I | 26.43 | 19.45 | 20.56 |
| L7I6 | 94.74 | 82.98 | 26.85 | 28.34 | 22.28 | 23.52 |
| L74I | 94.36 | 92.2 I | 28.13 | 29.8 I | 25.94 | 27.49 |
| L759 | 95.80 | 85.82 | 25.56 | 26.68 | 21.94 | 22.90 |
| L78I | 94.52 | 75.5 I | 27.54 | 29.14 | 20.80 | 22.00 |
| L787 | 93.64 | 82.18 | 27.34 | 29.20 | 22.47 | 24.00 |
| L79I | 94.79 | 78.99 | 27.33 | 28.84 | 21.59 | 22.78 |
| L797 | 94.80 | 83.28 | 25.97 | 27.40 | 21.63 | 22.82 |
| L8I6 | 95.57 | 84.99 | 27.90 | 29.19 | 23.7 I | 24.8 I |
| L823 | 94.52 | 84.2 I | 29.47 | 31.17 | 24.8 I | 26.25 |
| Lvi | 95.88 | 84.52 | 27.07 | 28.23 | 22.88 | 23.86 |
| L88I | 95.34 | 76.88 | 26.02 | 27.29 | 20.00 | 20.98 |
| L893 | 93.02 | 86.48 | 25.7 I | 27.64 | 22.24 | 23.9 I |
| L90I | 94.93 | 84.84 | 27.60 | 29.08 | 23.42 | 24.67 |
| L9I6 | 95. I7 | 87.76 | 23.82 | 25.03 | 20.90 | 21.96 |


| Lyminge coracoid measurement ratios |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
| ID | $\mathbf{L m} / \mathbf{G L}$ | $\mathbf{B f / B b}$ | $\mathbf{B b} / \mathbf{G L}$ | $\mathbf{B b} / \mathbf{L m}$ | $\mathbf{B f / G L}$ | $\mathbf{B f / L m}$ |  |
| L9I7 | 94.89 | 79.07 | 25.66 | 27.04 | 20.29 | 21.38 |  |
| LABGI | 94.43 | 78.84 | 27.38 | 29.00 | 21.59 | 22.86 |  |
| LABG2 | 95.33 | 76.36 | 26.72 | 28.03 | 20.40 | 21.41 |  |
| LABG7 | 94.53 | 80.60 | 27.13 | 28.69 | 21.86 | 23.13 |  |
| LABG8 | 96.84 | 74.83 | 28.26 | 29.18 | 21.15 | 21.84 |  |
| LABG9 | 94.35 | 81.60 | 25.20 | 26.71 | 20.56 | 21.79 |  |
| LABGI0 | 95.71 | 77.42 | 25.36 | 26.50 | 19.63 | 20.5 I |  |

### 3.3.2 Lyminge humerus

### 3.3.2.1 Standard metrics - humerus

| Lyminge - humerus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | GMM <br> ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| LYM08 | 169 | 31 | I | y | $y$ | 13.46 | 18.13 | 63.85 | 6.57 |
| LYM08 | 215 | 37 | I | $y$ |  | 13.91 | 17.83 | 63.29 | 6.65 |
| LYM08 | 247 | 43 | I | $y$ | $y$ | 15.85 | 19.65 | 74.84 | 7.03 |
| LYM08 | 247 | 44 | 1 | $y$ |  | 12.89 | 16.02 | 59.94 | 5.72 |
| LYM08 | 247 | 45 | I | $y$ | y | 14.40 | 17.82 | 66.75 | 6.74 |
| LYM08 | 247 | 46 | r | y |  | 14.26 | 18.03 | 66.60 | 6.77 |


| Lyminge - humerus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | GMM <br> ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| LYM08 | 247 | 47 | r | y |  | 13.74 | 17.27 | 64.11 | 6.50 |
| LYM08 | 247 | 48 | r | $y$ |  | 15.82 | 19.55 | 74.96 | 7.12 |
| LYM08 | 273 | 99 | r | $y$ |  | 13.60 | 16.46 | 61.50 | 6.03 |
| LYM08 | 273 | 100 | I | $y$ | $y$ | 13.94 | 18.62 | 66.15 | 6.33 |
| LYM08 | 502 | 113 | 1 | $y$ |  | 15.34 | 20.07 | 72.34 | 7.16 |
| LYM08 | 509 | 116 | r | $y$ |  | 16.34 | 20.15 | 74.89 | 7.18 |
| LYM08 | 546 | 135 | $r$ | $y$ |  | 13.81 | 17.07 | 63.78 | 6.00 |
| LYM08 | 642 | 168 | I | $y$ | $y$ | 13.51 | 17.50 | 64.19 | 6.52 |
| LYM08 | 661 | 199 | 1 | y | y | 13.24 | 16.70 | 62.35 | 6.40 |
| LYM08 | 684 | 227 | r |  |  | 13.92 | 18.03 | 64.71 | 6.59 |
| LYM08 | 684 | 228 | I |  |  | 13.92 | 17.90 | 64.88 | 6.79 |
| LYM08 | 684 | 229 | r |  |  | 13.12 | 17.31 | 65.13 | 6.23 |
| LYM08 | 684 | 230 | 1 | $y$ | $y$ | 13.20 | 17.21 | 65.39 | 6.23 |
| LYM08 | 727 | 261 | r | $y$ |  | 13.65 | 17.41 | 65.90 | 6.15 |
| LYM08 | 744 | 276 | I | $y$ | y | 13.78 | 17.71 | 63.14 | 6.50 |
| LYM08 | 744 | 277 | r |  |  | 13.47 | 17.71 | 63.24 | 6.51 |
| LYM09 | 1026 | 306 | r | $y$ |  | 13.27 | 17.67 | 68.31 | 6.33 |
| LYM09 | 1026 | 307 | I | $y$ | y | 14.41 | 17.69 | 64.40 | 6.52 |
| LYM09 | 1101 | 366 | 1 | $y$ | y | 13.43 | 17.86 | 63.63 | 6.29 |
| LYM09 | 1124 | 369 | 1 | y |  | 12.96 | 16.56 | 58.09 | 6.01 |


| Lyminge - humerus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | $\begin{aligned} & \text { GMM } \\ & \text { ID } \end{aligned}$ | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| LYM09 | 1148 | 371 | r | y |  | 13.37 | 17.79 | 63.85 | 6.19 |
| LYM09 | 1284 | 400 | r | $y$ |  | 13.54 | 16.70 | 64.40 | 6.39 |
| LYM09 | 1297 | 412 | $r$ | $y$ |  | 13.31 | 17.18 | 62.51 | 6.45 |
| LYM09 | 1310 | 441 | I | $y$ | $y$ | 13.12 | 17.22 | 61.53 | 6.50 |
| LYM09 | 1312 | 453 | r | $y$ |  | 13.60 | 17.93 | 66.16 | 6.47 |
| LYM09 | 1330 | 478 | r | $y$ |  | 13.69 | 17.41 | 63.22 | 6.08 |
| LYM09 | 1332 | 479 | I | $y$ |  | 13.89 | 17.69 | 61.60 | 6.03 |
| LYM09 | 1332 | 486 | 1 | $y$ |  | 13.13 | 17.83 | 64.36 | 6.14 |
| LYM09 | 1445 | 531 | $r$ | y |  | 13.38 | 16.75 | 62.94 | 6.05 |
| LYM09 | 1592 | 645 | r | $y$ |  | 15.21 | 19.47 | 69.03 | 7.67 |
| LYM09 | 1592 | 646 | I | $y$ | $y$ | 13.39 | 16.57 | 59.36 | 5.91 |
| LYM09 | 1592 | 647 | 1 | $y$ | $y$ | 13.62 | 17.64 | 62.90 | 6.47 |
| LYM09 | 1672 | 700 | I | $y$ | $y$ | 13.55 | 17.23 | 62.34 | 6.42 |
| LYM09 | 1672 | 701 | I | $y$ |  | 15.28 | 19.94 | 72.57 | 6.93 |
| LYM09 | 1672 | 704 | r | $y$ |  | 12.70 | 16.16 | 58.74 | 5.50 |
| LYM09 | 1672 | 712 | I | $y$ | $y$ | 13.97 | 18.27 | 64.96 | 6.64 |
| LYM09 | 1672 | 713 | I | $y$ | $y$ | 13.48 | 17.78 | 64.23 | 6.11 |
| LYM09 | 1672 | 714 | I | $y$ | y | 12.96 | 16.28 | 61.44 | 6.16 |
| LYM09 | 1672 | 715 | r | y |  | 15.20 | 19.65 | 72.32 | 6.92 |
| LYM09 | 1689 | 731 | r | y |  | 14.23 | 18.17 | 66.59 | 6.64 |


| Lyminge - humerus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | $\begin{aligned} & \text { GMM } \\ & \text { ID } \end{aligned}$ | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| LYM09 | 1730 | 780 | r |  |  | 13.41 | 17.27 | 62.96 | 6.35 |
| LYM09 | 1730 | 786 | I | $y$ | $y$ | 13.73 | 17.42 | 63.18 | 6.39 |
| LYM09 | 1737 | 802 | I | $y$ | $y$ | 13.95 | 17.50 | 65.49 | 6.10 |
| LYM09 | 1737 | 803 | r | $y$ |  | 13.44 | 17.38 | 61.42 | 6.36 |
| LYM09 | 1816 | 810 | $r$ | $y$ |  | 13.80 | 17.11 | 62.36 | 6.13 |
| LYM09 | 1816 | 811 | $r$ | $y$ |  | 13.78 | 17.73 | 64.97 | 6.52 |
| LYM09 | 1817 | 813 | r | $y$ |  | 15.89 | 19.98 | 72.22 | 7.41 |
| LYM09 | 1817 | 814 | I | $y$ | y | 13.03 | 16.53 | 59.52 | 6.04 |
| LYMIO | 2541a | 840 | r | $y$ |  | 16.00 | 20.09 | 72.29 | 7.30 |
| LYMIO | 2570c | 849 | r | $y$ |  | 15.49 | 19.81 | 73.01 | 7.32 |
| LYMIO | 2572c | 851 | r | $y$ |  | 12.67 | 16.42 | 61.90 | 6.09 |
| LYMI2 | 3242 | 886 | 1 | $y$ | y | 13.57 | 17.26 | 64.42 | 5.95 |
| LYMI2 | 3242 | 887 | r |  |  | 13.62 | 17.31 | 64.17 | 5.90 |
| LYMI2 | 3242 | 888 | I | $y$ |  | 13.62 | 17.75 | 66.33 | 6.50 |
| LYMI2 | 3678 | 902 | 1 | $y$ | y | 13.55 | 17.37 | 62.76 | 6.18 |
| LYMI3 | 6876 | 919 | r | $y$ |  | 15.76 | 19.10 | 71.39 | 6.96 |
| Lym08 | 680 | ABGI | I | $y$ | y | 13.81 | 18.57 | 65.52 | 6.95 |
| Lym08 | 680 | ABGI | r |  |  | 13.84 | 18.61 | 65.87 | 6.96 |
| Lym09 | 1837 | ABG4 | I | $y$ | $y$ | 13.65 | 17.79 | 63.91 | 5.99 |
| Lym09 | 1837 | ABG4 | r |  |  | 13.77 | 18.19 | 64.44 | 6.14 |


| Lyminge - humerus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | GMM <br> ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |
| Lym08 | 582 | ABG5P | r |  |  | 15.90 | 20.30 | 72.10 | 7.80 |
| Lym08 | 582 | ABG5P | I | $y$ | $y$ | 15.90 | 20.40 | 72.10 | 7.90 |
| Lym08 | 1482 | ABG6 | r |  |  | 13.90 | 18.90 | 66.80 | 6.10 |
| Lym09 | 1600 | ABG7 | r | $y$ | $y$ | 14.20 | 18.00 | 65.60 | 6.20 |
| Lym09 | 1333 | ABG8 | $r$ |  |  | 13.70 | 18.80 | 66.10 | 6.80 |
| Lym09 | 1333 | ABG8 | 1 | $y$ | $y$ | 13.80 | 18.40 | 66.40 | 6.40 |
| Lym08 | 150 | ABGIO | r |  |  | 13.40 | 18.16 | 64.20 | 6.50 |
| Lym08 | 150 | ABGIO | I | $y$ | $y$ | 13.60 | 18.00 | 64.30 | 6.40 |

### 3.3.2.2 Measurement ratios - humerus

| Lyminge humeri measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| L3I | 74.24 | 10.29 | 28.39 | 21.08 | 36.24 | 48.8 I |
| L37 | 78.0 I | 10.5 I | 28.17 | 21.98 | 37.30 | 47.81 |
| L43 | 80.66 | 9.39 | 26.26 | 21.18 | 35.78 | 44.35 |
| L44 | 80.46 | 9.54 | 26.73 | 21.50 | 35.71 | 44.38 |
| L45 | 80.8 I | 10.10 | 26.70 | 21.57 | 37.82 | 46.81 |
| L46 | 79.09 | 10.17 | 27.07 | 21.4 I | 37.55 | 47.48 |
| L47 | 79.56 | 10.14 | 26.94 | 21.43 | 37.64 | 47.31 |


| Lyminge humeri measurement ratios |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| L48 | 80.92 | 9.50 | 26.08 | 21.10 | 36.42 | 45.01 |
| L99 | 82.62 | 9.80 | 26.76 | 22.11 | 36.63 | 44.34 |
| LIOO | 74.87 | 9.57 | 28.15 | 21.07 | 34.00 | 45.4I |
| LII3 | 76.43 | 9.90 | 27.74 | 21.21 | 35.68 | 46.68 |
| LII6 | 81.09 | 9.59 | 26.91 | 21.82 | 35.63 | 43.94 |
| LI35 | 80.90 | 9.41 | 26.76 | 21.65 | 35.15 | 43.45 |
| LI68 | 77.20 | 10.16 | 27.26 | 21.05 | 37.26 | 48.26 |
| LI99 | 79.28 | 10.26 | 26.78 | 21.23 | 38.32 | 48.34 |
| L230 | 76.70 | 9.53 | 26.32 | 20.19 | 36.20 | 47.20 |
| L261 | 78.40 | 9.33 | 26.42 | 20.71 | 35.32 | 45.05 |
| L276 | 77.81 | 10.29 | 28.05 | 21.82 | 36.70 | 47.17 |
| L306 | 75.10 | 9.27 | 25.87 | 19.43 | 35.82 | 47.70 |
| L307 | 81.46 | 10.12 | 27.47 | 22.38 | 36.86 | 45.25 |
| L366 | 75.20 | 9.89 | 28.07 | 21.11 | 35.22 | 46.84 |
| L369 | 78.26 | 10.35 | 28.51 | 22.31 | 36.29 | 46.37 |
| L371 | 75.15 | 9.69 | 27.86 | 20.94 | 34.79 | 46.30 |
| L400 | 81.08 | 9.92 | 25.93 | 21.02 | 38.26 | 47.19 |
| L4I2 | 77.47 | 10.32 | 27.48 | 21.29 | 37.54 | 48.46 |
| L44I | 76.19 | 10.56 | 27.99 | 21.32 | 37.75 | 49.54 |
| L453 | 75.85 | 9.78 | 27.10 | 20.56 | 36.08 | 47.57 |
| L478 | 78.63 | 9.62 | 27.54 | 21.65 | 34.92 | 44.4I |


| Lyminge humeri measurement ratios |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| L479 | 78.52 | 9.79 | 28.72 | 22.55 | 34.09 | 43.41 |
| L486 | 73.64 | 9.54 | 27.70 | 20.40 | 34.44 | 46.76 |
| L531 | 79.88 | 9.61 | 26.61 | 21.26 | 36.12 | 45.22 |
| L645 | 78.12 | 11.11 | 28.21 | 22.03 | 39.39 | 50.43 |
| L646 | 80.81 | 9.96 | 27.91 | 22.56 | 35.67 | 44.14 |
| L647 | 77.21 | 10.29 | 28.04 | 21.65 | 36.68 | 47.50 |
| L700 | 78.64 | 10.30 | 27.64 | 21.74 | 37.26 | 47.38 |
| L701 | 76.63 | 9.55 | 27.48 | 21.06 | 34.75 | 45.35 |
| L704 | 78.59 | 9.36 | 27.51 | 21.62 | 34.03 | 43.31 |
| L712 | 76.46 | 10.22 | 28.13 | 21.51 | 36.34 | 47.53 |
| L713 | 75.82 | 9.51 | 27.68 | 20.99 | 34.36 | 45.33 |
| L714 | 79.61 | 10.03 | 26.50 | 21.09 | 37.84 | 47.53 |
| L715 | 77.35 | 9.57 | 27.17 | 21.02 | 35.22 | 45.53 |
| L731 | 78.32 | 9.97 | 27.29 | 21.37 | 36.54 | 46.66 |
| L786 | 78.82 | 10.11 | 27.57 | 21.73 | 36.68 | 46.54 |
| L802 | 79.71 | 9.31 | 26.72 | 21.30 | 34.86 | 43.73 |
| L803 | 77.33 | 10.35 | 28.30 | 21.88 | 36.59 | 47.32 |
| L810 | 80.65 | 9.83 | 27.44 | 22.13 | 35.83 | 44.42 |
| L8II | 77.72 | 10.04 | 27.29 | 21.21 | 36.77 | 47.31 |
| L813 | 79.53 | 10.26 | 27.67 | 22.00 | 37.09 | 46.63 |
| L814 | 78.83 | 10.15 | 27.77 | 21.89 | 36.54 | 46.35 |

Lyminge humeri measurement ratios

| ID | $\mathbf{B d} / \mathbf{B p}$ | $\mathbf{S C} / \mathbf{G L}$ | $\mathbf{B p} / \mathbf{G L}$ | $\mathbf{B d} / \mathbf{G L}$ | $\mathbf{S C} / \mathbf{B p}$ | $\mathbf{S C} / \mathbf{B d}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| L840 | 79.64 | 10.10 | 27.79 | 22.13 | 36.34 | 45.63 |
| L849 | 78.19 | 10.03 | 27.13 | 21.22 | 36.95 | 47.26 |
| L85I | 77.16 | 9.84 | 26.53 | 20.47 | 37.09 | 48.07 |
| L886 | 78.62 | 9.24 | 26.79 | 21.06 | 34.47 | 43.85 |
| L888 | 76.73 | 9.80 | 26.76 | 20.53 | 36.62 | 47.72 |
| L902 | 78.0 I | 9.85 | 27.68 | 21.59 | 35.58 | 45.61 |
| L9I9 | 82.5 I | 9.75 | 26.75 | 22.08 | 36.44 | 44.16 |
| L257 | 74.37 | 10.61 | 28.34 | 21.08 | 37.43 | 50.33 |
| L243 | 76.73 | 9.37 | 27.84 | 21.36 | 33.67 | 43.88 |
| L264 | 77.94 | 10.96 | 28.29 | 22.05 | 38.73 | 49.69 |
| L999 | 73.54 | 9.13 | 28.29 | 20.81 | 32.28 | 43.88 |
| L229 | 78.89 | 9.45 | 27.44 | 21.65 | 34.44 | 43.66 |
| L237 | 75.00 | 9.64 | 27.7 I | 20.78 | 34.78 | 46.38 |
| L262 | 75.56 | 9.95 | 27.99 | 21.15 | 35.56 | 47.06 |

### 3.3.3 Lyminge femur

### 3.3.3.1 Standard metrics - femur

| Lyminge - femur |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| LYM08 | 8 | 2 | y | 13.04 | 13.78 | 10.62 | 8.90 | 66.78 | 62.90 | 5.82 |
| LYM08 | 12 | 11 | y | 13.05 | 13.35 | 11.56 | 9.08 | 68.11 | 63.83 | 5.83 |
| LYM08 | 156 | 28 | y | 13.39 | 13.42 | 11.35 | 9.22 | 69.66 | 65.66 | 6.23 |
| LYM08 | 231 | 38 | $y$ | 12.21 | 13.01 | 11.28 | 8.40 | 65.97 | 61.76 | 5.87 |
| LYM08 | 247 | 63 | y | 16.46 | 16.81 | 14.24 | 11.25 | 83.19 | 77.61 | 7.25 |
| LYM08 | 247 | 65 | $y$ | 13.95 | 14.61 | 12.12 | 9.49 | 69.51 | 66.14 | 6.33 |
| LYM09 | 1296 | 409 | $y$ | 13.51 | 13.66 | 11.37 | 9.50 | 70.69 | 65.76 | 6.11 |
| LYM09 | 1332 | 510 | $y$ | 13.72 | 13.75 | 11.51 | 9.05 | 71.26 | 66.18 | 5.80 |
| LYM09 | 1449 | 552 | y | 13.60 | 14.00 | 10.97 | 9.54 | 72.43 | 67.15 | 6.21 |
| LYM09 | 1449 | 553 | $y$ | 13.49 | 14.02 | 11.93 | 9.81 | 69.93 | 64.97 | 6.14 |
| LYM09 | 1479 | 565 | $y$ | 13.58 | 13.66 | 11.77 | 8.96 | 70.82 | 65.54 | 5.93 |
| LYM09 | 1500 | 591 | $y$ | 13.12 | 13.60 | 10.75 | 8.72 | 67.00 | 62.16 | 5.98 |
| LYM09 | 1552 | 616 | y | 13.37 | 13.52 | 11.69 | 9.16 | 68.26 | 64.11 | 6.14 |
| LYM09 | 1619 | 657 | $y$ | 13.91 | 14.07 | 11.76 | 9.46 | 70.51 | 65.48 | 6.20 |
| LYM09 | 1664 | 661 |  | 12.84 | 12.93 | 10.88 | 9.16 | 57.63 | 53.06 | 5.06 |
| LYM09 | 1667 | 667 | $y$ | 17.31 | 17.84 | 14.13 | 11.69 | 83.41 | 76.88 | 7.71 |
| LYM09 | 1672 | 698 | $y$ | 12.96 | 12.71 | 10.50 | 8.74 | 68.69 | 64.55 | 5.94 |


| Lyminge - femur |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| LYM09 | 1672 | 699 | $y$ | 13.28 | 13.14 | 10.45 | 9.37 | 68.76 | 64.58 | 5.90 |
| LYM09 | 1672 | 705 | $y$ | 13.49 | 14.23 | 11.15 | 9.13 | 68.75 | 64.60 | 6.50 |
| LYM09 | 1672 | 706 | $y$ | 14.76 | 14.74 | 12.50 | 10.30 | 71.86 | 68.22 | 6.68 |
| LYM09 | 1672 | 709 | $y$ | 12.98 | 13.62 | 10.78 | 9.09 | 66.00 | 61.68 | 5.58 |
| LYM09 | 1672 | 720 | $y$ | 13.41 | 13.29 | 10.83 | 8.44 | 69.57 | 64.54 | 6.73 |
| LYM09 | 1689 | 729 | $y$ | 13.60 | 14.31 | 11.75 | 9.78 | 70.68 | 66.88 | 6.09 |
| LYM09 | 1689 | 730 | $y$ | 13.72 | 14.57 | 12.41 | 9.55 | 75.45 | 70.46 | 6.47 |
| LYM09 | 1707 | 746 | $y$ | 13.22 | 13.84 | 11.01 | 9.00 | 69.50 | 65.29 | 5.86 |
| LYM09 | 1709 | 750 | $y$ | 13.45 | 13.76 | 11.34 | 9.34 | 69.48 | 64.13 | 6.27 |
| LYM09 | 1730 | 782 | $y$ | 15.88 | 16.51 | 12.58 | 10.42 | 80.12 | 75.29 | 6.86 |
| LYM09 | 1730 | 788 | $y$ | 12.88 | 12.81 | 10.49 | 8.75 | 65.85 | 62.04 | 5.60 |
| LYM09 | 1730 | 792 | $y$ | 13.62 | 13.97 | 11.52 | 9.55 | 71.06 | 66.50 | 5.30 |
| LYM09 | 1730 | 798 | $y$ | 13.58 | 13.28 | 11.65 | 8.96 | 69.54 | 64.76 | 5.75 |
| LYM09 | 1737 | 801 | $y$ | 13.88 | 14.89 | 11.65 | 10.08 | 69.97 | 64.95 | 6.39 |
| LYM09 | 1817 | 815 | $y$ | 16.52 | 16.79 | 13.51 | 12.04 | 78.37 | 73.20 | 6.83 |
| LYMI2 | 3083 | 857 | $y$ | 13.68 | 14.00 | 11.32 | 9.84 | 71.32 | 65.90 | 6.26 |
| LYMI2 | 3041 | 863 | $y$ | 13.84 | 13.79 | 11.69 | 9.53 | 70.30 | 65.64 | 5.78 |
| LYMI2 | 3242 | 882 | $y$ | 12.89 | 13.28 | 11.04 | 9.66 | 70.15 | 66.09 | 5.70 |
| LYMI3 | 6256 | 913 | $y$ | 15.53 | 15.95 | 12.96 | 10.94 | 84.94 | 79.26 | 7.08 |
| LYMI3 | 6256 | 914 | $y$ | 13.10 | 14.08 | 11.25 | 9.50 | 72.65 | 67.84 | 6.21 |


| Lyminge - femur |  |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ <br> season | Context | ID | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| LYM09 | 1600 | ABG7 | y | 14.40 | 14.20 | 12.10 | 9.40 | 72.70 | 67.20 | 6.50 |
| LYM09 | 1333 | ABG8 | y | 13.80 | 14.20 | 11.40 | 8.90 | 73.00 | 68.80 | 6.40 |
| LYM09 | 1333 | ABG8 | $y$ | 13.80 | 14.20 | 11.10 | 9.90 | 73.00 | 68.80 | 5.90 |

### 3.3.3.2 Measurement ratios - femur

| Lyminge femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| L2 | 81.44 | 44.63 | 8.72 | 19.53 | 20.63 | 20.73 | 21.91 | 9.25 | 42.24 | 77.07 | 83.80 | 15.90 | 16.88 | 54.80 |
| LII | 88.58 | 44.67 | 8.56 | 19.16 | 19.60 | 20.44 | 20.91 | 9.13 | 43.67 | 86.59 | 78.55 | 16.97 | 18.11 | 50.43 |
| L28 | 84.76 | 46.53 | 8.94 | 19.22 | 19.27 | 20.39 | 20.44 | 9.49 | 46.42 | 84.58 | 81.23 | 16.29 | 17.29 | 54.89 |
| L38 | 92.38 | 48.08 | 8.90 | 18.5 I | 19.72 | 19.77 | 21.07 | 9.50 | 45.12 | 86.70 | 74.47 | 17.10 | 18.26 | 52.04 |
| L63 | 86.51 | 44.05 | 8.71 | 19.79 | 20.21 | 21.21 | 21.66 | 9.34 | 43.13 | 84.71 | 79.00 | 17.12 | 18.35 | 50.91 |
| L65 | 86.88 | 45.38 | 9.11 | 20.07 | 21.02 | 21.09 | 22.09 | 9.57 | 43.33 | 82.96 | 78.30 | 17.44 | 18.32 | 52.23 |
| L409 | 84.16 | 45.23 | 8.64 | 19.11 | 19.32 | 20.54 | 20.77 | 9.29 | 44.73 | 83.24 | 83.55 | 16.08 | 17.29 | 53.74 |
| L5I0 | 83.89 | 42.27 | 8.14 | 19.25 | 19.30 | 20.73 | 20.78 | 8.76 | 42.18 | 83.71 | 78.63 | 16.15 | 17.39 | 50.39 |
| L552 | 80.66 | 45.66 | 8.57 | 18.78 | 19.33 | 20.25 | 20.85 | 9.25 | 44.36 | 78.36 | 86.96 | 15.15 | 16.34 | 56.61 |
| L553 | 88.44 | 45.52 | 8.78 | 19.29 | 20.05 | 20.76 | 21.58 | 9.45 | 43.79 | 85.09 | 82.23 | 17.06 | 18.36 | 51.47 |
| L565 | 86.67 | 43.67 | 8.37 | 19.18 | 19.29 | 20.72 | 20.84 | 9.05 | 43.41 | 86.16 | 76.13 | 16.62 | 17.96 | 50.38 |
| L591 | 81.94 | 45.58 | 8.93 | 19.58 | 20.30 | 21.11 | 21.88 | 9.62 | 43.97 | 79.04 | 81.12 | 16.04 | 17.29 | 55.63 |


| Lyminge femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| L616 | 87.43 | 45.92 | 9.00 | 19.59 | 19.81 | 20.85 | 21.09 | 9.58 | 45.41 | 86.46 | 78.36 | 17.13 | 18.23 | 52.52 |
| L657 | 84.54 | 44.57 | 8.79 | 19.73 | 19.95 | 21.24 | 21.49 | 9.47 | 44.07 | 83.58 | 80.44 | 16.68 | 17.96 | 52.72 |
| L667 | 81.63 | 44.54 | 9.24 | 20.75 | 21.39 | 22.52 | 23.20 | 10.03 | 43.22 | 79.20 | 82.73 | 16.94 | 18.38 | 54.56 |
| L698 | 81.02 | 45.83 | 8.65 | 18.87 | 18.50 | 20.08 | 19.69 | 9.20 | 46.73 | 82.61 | 83.24 | 15.29 | 16.27 | 56.57 |
| L699 | 78.69 | 44.43 | 8.58 | 19.31 | 19.11 | 20.56 | 20.35 | 9.14 | 44.90 | 79.53 | 89.67 | 15.20 | 16.18 | 56.46 |
| L705 | 82.65 | 48.18 | 9.45 | 19.62 | 20.70 | 20.88 | 22.03 | 10.06 | 45.68 | 78.36 | 81.88 | 16.22 | 17.26 | 58.30 |
| L706 | 84.69 | 45.26 | 9.30 | 20.54 | 20.51 | 21.64 | 21.61 | 9.79 | 45.32 | 84.80 | 82.40 | 17.39 | 18.32 | 53.44 |
| L709 | 83.05 | 42.99 | 8.45 | 19.67 | 20.64 | 21.04 | 22.08 | 9.05 | 40.97 | 79.15 | 84.32 | 16.33 | 17.48 | 51.76 |
| L720 | 80.76 | 50.19 | 9.67 | 19.28 | 19.10 | 20.78 | 20.59 | 10.43 | 50.64 | 81.49 | 77.93 | 15.57 | 16.78 | 62.14 |
| L729 | 86.40 | 44.78 | 8.62 | 19.24 | 20.25 | 20.33 | 21.40 | 9.11 | 42.56 | 82.11 | 83.23 | 16.62 | 17.57 | 51.83 |
| L730 | 90.45 | 47.16 | 8.58 | 18.18 | 19.31 | 19.47 | 20.68 | 9.18 | 44.4I | 85.18 | 76.95 | 16.45 | 17.61 | 52.14 |
| L746 | 83.28 | 44.33 | 8.43 | 19.02 | 19.91 | 20.25 | 21.20 | 8.98 | 42.34 | 79.55 | 81.74 | 15.84 | 16.86 | 53.22 |
| L750 | 84.31 | 46.62 | 9.02 | 19.36 | 19.80 | 20.97 | 21.46 | 9.78 | 45.57 | 82.41 | 82.36 | 16.32 | 17.68 | 55.29 |
| L782 | 79.22 | 43.20 | 8.56 | 19.82 | 20.61 | 21.09 | 21.93 | 9.11 | 41.55 | 76.20 | 82.83 | 15.70 | 16.71 | 54.53 |
| L788 | 81.44 | 43.48 | 8.50 | 19.56 | 19.45 | 20.76 | 20.65 | 9.03 | 43.72 | 81.89 | 83.41 | 15.93 | 16.91 | 53.38 |
| L792 | 84.58 | 38.91 | 7.46 | 19.17 | 19.66 | 20.48 | 21.01 | 7.97 | 37.94 | 82.46 | 82.90 | 16.21 | 17.32 | 46.01 |
| L798 | 85.79 | 42.34 | 8.27 | 19.53 | 19.10 | 20.97 | 20.51 | 8.88 | 43.30 | 87.73 | 76.91 | 16.75 | 17.99 | 49.36 |
| L801 | 83.93 | 46.04 | 9.13 | 19.84 | 21.28 | 21.37 | 22.93 | 9.84 | 42.91 | 78.24 | 86.52 | 16.65 | 17.94 | 54.85 |
| L815 | 81.78 | 41.34 | 8.72 | 21.08 | 21.42 | 22.57 | 22.94 | 9.33 | 40.68 | 80.46 | 89.12 | 17.24 | 18.46 | 50.56 |
| L857 | 82.75 | 45.76 | 8.78 | 19.18 | 19.63 | 20.76 | 21.24 | 9.50 | 44.71 | 80.86 | 86.93 | 15.87 | 17.18 | 55.30 |
| L863 | 84.47 | 41.76 | 8.22 | 19.69 | 19.62 | 21.08 | 21.01 | 8.81 | 41.91 | 84.77 | 81.52 | 16.63 | 17.81 | 49.44 |


| Lyminge femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| L882 | 85.65 | 44.22 | 8.13 | 18.37 | 18.93 | 19.50 | 20.09 | 8.62 | 42.92 | 83.13 | 87.50 | 15.74 | 16.70 | 51.63 |
| L913 | 83.45 | 45.59 | 8.34 | 18.28 | 18.78 | 19.59 | 20.12 | 8.93 | 44.39 | 81.25 | 84.41 | 15.26 | 16.35 | 54.63 |
| L914 | 85.88 | 47.40 | 8.55 | 18.03 | 19.38 | 19.31 | 20.75 | 9.15 | 44.11 | 79.90 | 84.44 | 15.49 | 16.58 | 55.20 |
| ABG7 | 84.03 | 45.14 | 8.94 | 19.81 | 19.53 | 21.43 | 21.13 | 9.67 | 45.77 | 85.21 | 77.69 | 16.64 | 18.01 | 53.72 |
| ABG8 | 82.61 | 46.38 | 8.77 | 18.90 | 19.45 | 20.06 | 20.64 | 9.30 | 45.07 | 80.28 | 78.07 | 15.62 | 16.57 | 56.14 |
| ABG9 | 84.40 | 44.68 | 8.50 | 19.03 | 20.65 | 20.49 | 22.24 | 9.16 | 41.18 | 77.78 | 77.31 | 16.06 | 17.30 | 52.94 |

### 3.3.4 Lyminge tibiotarsus

### 3.3.4.1 Standard metrics - tibiotarsus

| Lyminge - tibiotarsus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID | Meas. <br> Ratio | GMM | Dd | Dip | GL | La | SC |
| LYM08 | 247 | L50 | y | y | 10.83 | 18.68 | 101.25 | 96.20 | 5.69 |
| LYM08 | 247 | L5I | y |  | 11.02 | 18.63 | 96.93 | 93.80 | 5.51 |
| LYM08 | 247 | L52 | y | y | 10.24 | 17.27 | 94.13 | 89.71 | 4.99 |
| LYM08 | 331 | LIII | $y$ |  | 10.53 | 17.45 | 94.34 | 91.30 | 5.49 |
| LYM08 | 582 | LI42 | $y$ | y | 12.46 | 18.83 | 115.59 | 110.92 | 6.24 |
| LYM08 | 639 | LI63 | $y$ |  | 10.96 | 19.18 | 100.31 | 96.48 | 5.81 |
| LYM08 | 656 | L193 | y |  | 12.25 | 20.60 | 112.45 | 108.23 | 6.25 |


| Lyminge - tibiotarsus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID | Meas. <br> Ratio | GMM | Dd | Dip | GL | La | SC |
| LYM08 | 658 | LI97 | $y$ |  | 12.86 | 22.57 | 112.81 | 107.39 | 6.51 |
| LYM08 | 684 | L219 | $y$ | $y$ | 11.05 | 18.83 | 97.63 | 94.68 | 5.86 |
| LYM08 | $684$ | L220 |  |  | 10.83 | 18.58 | 97.59 | 93.87 | 5.86 |
| LYM08 | 684 | L221 | $y$ | $y$ | 11.17 | 18.77 | 99.90 | 97.45 | 5.53 |
| LYM08 | 684 | L249 | $y$ |  | 11.20 | 18.78 | 100.88 | 96.74 | 5.63 |
| LYM08 | $744$ | L275 | $y$ |  | 11.00 | 16.76 | 97.61 | 93.82 | 5.72 |
| LYM09 | 1026 | L304 | $y$ |  | 10.96 | 18.34 | 97.17 | 93.32 | 5.72 |
| LYM09 | 1309 | L414 | $y$ |  | 11.07 | 18.42 | 97.83 | 93.58 | 5.64 |
| LYM09 | 1310 | L423 | $y$ |  | 11.24 | 19.09 | 101.64 | 98.03 | 5.74 |
| LYM09 | 1310 | L426 |  |  | 10.50 | 17.68 | 95.00 | 90.63 | 5.38 |
| LYM09 | 1313 | L454 |  | $y$ | 11.14 | 17.74 | 99.34 | 95.44 | 5.21 |
| LYM09 | 1332 | L480 | $y$ |  | 11.53 | 17.90 | 97.56 | 93.79 | 5.50 |
| LYM09 | 1332 | L495 |  |  | 11.21 | 18.13 | 99.57 | 96.47 | 5.51 |
| LYM09 | 1447 | L538 | $y$ |  | 10.52 | 17.95 | 99.41 | 95.12 | 5.32 |
| LYM09 | 1449 | L54I |  |  |  | 18.56 | 105.37 | 101.66 | 5.87 |
| LYM09 | 1506 | L597 | $y$ |  | 11.60 | 18.76 | 103.27 | 99.19 | 5.72 |
| LYM09 | 1506 | L598 | $y$ |  | 10.64 | 17.24 | 94.76 | 91.75 | 5.56 |
| LYM09 | 1665 | L665 | y |  | 12.55 | 21.20 | 111.29 | 106.64 | 5.49 |
| LYM09 | 1672 | L697 | $y$ |  | 10.69 | 16.86 | 98.43 | 94.02 | 5.13 |
| LYM09 | 1730 | L785 | $y$ |  | 10.48 | 17.88 | 96.11 | 92.34 | 5.44 |


| Lyminge - tibiotarsus |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID | Meas. <br> Ratio | GMM | Dd | Dip | GL | La | SC |
| LYM09 | 1730 | L790 | $y$ | $y$ | 11.36 | 18.18 | 97.83 | 93.20 | 5.29 |
| LYM09 | 1730 | L795 | $y$ | $y$ | 12.59 | 21.48 | 112.84 | 106.87 | 6.40 |
| LYM09 | 1730 | L796 |  |  | 12.52 | 21.59 | 113.12 | 106.85 | 6.30 |
| LYM09 | 1817 | L812 | $y$ |  | 12.56 | 22.28 | 113.45 | 107.19 | 6.01 |
| LYMI2 | 3242 | L889 | $y$ | $y$ | 10.65 | 17.67 | 99.02 | 94.46 | 5.07 |
| LYMI2 | 3678 | L898 | $y$ |  | 10.32 | 17.79 | 97.23 | 92.55 | 5.33 |
| Lyml2 | 3695 | ABG2 | $y$ |  | 13.29 | 21.43 | 115.13 | 110.13 | 5.19 |
| Lyml2 | 3695 | ABG2 |  |  | 13.33 | 21.46 | 115.65 | 110.79 | 5.21 |
| Lym09 | 1837 | ABG4 |  |  | 10.87 | 18.00 | 94.24 | 91.04 | 4.58 |
| Lym08 | 582 | ABG5 |  |  | 11.40 | 20.19 | 108.30 | 104.20 | 5.70 |
| Lym08 | 582 | ABG5 |  |  | 11.80 | 22.60 | 109.10 | 104.10 | 5.90 |
| Lym09 | 1482 | ABG6 |  |  | 9.80 | 17.60 | 95.40 | 89.90 | 4.10 |
| Lym09 | 1482 | ABG6 | $y$ | $y$ | 9.80 | 17.10 | 95.00 | 89.60 | 4.50 |
| Lym09 | 1600 | ABG7 | $y$ | $y$ | 10.40 | 19.30 | 100.20 | 95.60 | 4.60 |
| Lym09 | 1600 | ABG7 |  |  | 10.40 | 19.20 | 100.00 | 95.20 | 5.20 |
| Lym09 | 1333 | ABG8 | $y$ | $y$ | 10.00 | 18.80 | 100.40 | 95.60 | 5.30 |
| Lym09 | 1312 | ABG9 | $y$ | $y$ | 10.20 | 18.80 | 102.40 | 97.60 | 5.00 |

### 3.3.4.2 Measurement ratios - tibiotarsus

| Lyminge tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| L50 |  |  | 10.70 |  | 5.62 |  | 11.26 | 5.91 |  | 57.98 | 18.45 | 30.46 | 19.42 | 95.01 | 52.54 |
| L5I |  |  | 11.37 |  | 5.68 |  | 11.75 | 5.87 |  | 59.15 | 19.22 | 29.58 | 19.86 | 96.77 | 50.00 |
| L52 |  |  | 10.88 |  | 5.30 |  | 11.41 | 5.56 |  | 59.29 | 18.35 | 28.89 | 19.25 | 95.30 | 48.73 |
| LIII |  |  | 11.16 |  | 5.82 |  | 11.53 | 6.01 |  | 60.34 | 18.50 | 31.46 | 19.11 | 96.78 | 52.14 |
| LI42 |  |  | 10.78 |  | 5.40 |  | 11.23 | 5.63 |  | 66.17 | 16.29 | 33.14 | 16.98 | 95.96 | 50.08 |
| LI63 |  |  | 10.93 |  | 5.79 |  | 11.36 | 6.02 |  | 57.14 | 19.12 | 30.29 | 19.88 | 96.18 | 53.01 |
| LI93 |  |  | 10.89 |  | 5.56 |  | 11.32 | 5.77 |  | 59.47 | 18.32 | 30.34 | 19.03 | 96.25 | 51.02 |
| L197 |  |  | 11.40 |  | 5.77 |  | 11.98 | 6.06 |  | 56.98 | 20.01 | 28.84 | 21.02 | 95.20 | 50.62 |
| L219 |  |  | 11.32 |  | 6.00 |  | 11.67 | 6.19 |  | 58.68 | 19.29 | 31.12 | 19.89 | 96.98 | 53.03 |
| L22I |  |  | 11.18 |  | 5.54 |  | 11.46 | 5.67 |  | 59.51 | 18.79 | 29.46 | 19.26 | 97.55 | 49.51 |
| L249 |  |  | 11.10 |  | 5.58 |  | 11.58 | 5.82 |  | 59.64 | 18.62 | 29.98 | 19.41 | 95.90 | 50.27 |
| L275 |  |  | 11.27 |  | 5.86 |  | 11.72 | 6.10 |  | 65.63 | 17.17 | 34.13 | 17.86 | 96.12 | 52.00 |
| L304 |  |  | 11.28 |  | 5.89 |  | 11.74 | 6.13 |  | 59.76 | 18.87 | 31.19 | 19.65 | 96.04 | 52.19 |
| L414 |  |  | 11.32 |  | 5.77 |  | 11.83 | 6.03 |  | 60.10 | 18.83 | 30.62 | 19.68 | 95.66 | 50.95 |
| L423 |  |  | 11.06 |  | 5.65 |  | 11.47 | 5.86 |  | 58.88 | 18.78 | 30.07 | 19.47 | 96.45 | 51.07 |
| L480 |  |  | 11.82 |  | 5.64 |  | 12.29 | 5.86 |  | 64.41 | 18.35 | 30.73 | 19.09 | 96.14 | 47.70 |
| L538 |  |  | 10.58 |  | 5.35 |  | 11.06 | 5.59 |  | 58.61 | 18.06 | 29.64 | 18.87 | 95.68 | 50.57 |
| L597 |  |  | 11.23 |  | 5.54 |  | 11.69 | 5.77 |  | 61.83 | 18.17 | 30.49 | 18.91 | 96.05 | 49.31 |
| L598 |  |  | 11.23 |  | 5.87 |  | 11.60 | 6.06 |  | 61.72 | 18.19 | 32.25 | 18.79 | 96.82 | 52.26 |


| Lyminge tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| L665 |  |  | 11.28 |  | 4.93 |  | 11.77 | 5.15 |  | 59.20 | 19.05 | 25.90 | 19.88 | 95.82 | 43.75 |
| L697 |  |  | 10.86 |  | 5.21 |  | 11.37 | 5.46 |  | 63.40 | 17.13 | 30.43 | 17.93 | 95.52 | 47.99 |
| L785 |  |  | 10.90 |  | 5.66 |  | 11.35 | 5.89 |  | 58.61 | 18.60 | 30.43 | 19.36 | 96.08 | 51.91 |
| L790 |  |  | 11.61 |  | 5.41 |  | 12.19 | 5.68 |  | 62.49 | 18.58 | 29.10 | 19.51 | 95.27 | 46.57 |
| L795 |  |  | 11.16 |  | 5.67 |  | 11.78 | 5.99 |  | 58.61 | 19.04 | 29.80 | 20.10 | 94.71 | 50.83 |
| L8I2 |  |  | 11.07 |  | 5.30 |  | 11.72 | 5.61 |  | 56.37 | 19.64 | 26.97 | 20.79 | 94.48 | 47.85 |
| L889 |  |  | 10.76 |  | 5.12 |  | 11.27 | 5.37 |  | 60.27 | 17.84 | 28.69 | 18.71 | 95.39 | 47.61 |
| L898 |  |  | 10.61 |  | 5.48 |  | 11.15 | 5.76 |  | 58.01 | 18.30 | 29.96 | 19.22 | 95.19 | 51.65 |
| ABG2 |  |  | 11.54 |  | 4.51 |  | 12.07 | 4.71 |  | 62.02 | 18.61 | 24.22 | 19.46 | 95.66 | 39.05 |
| ABG6 |  |  | 10.32 |  | 4.74 |  | 10.94 | 5.02 |  | 57.31 | 18.00 | 26.32 | 19.08 | 94.32 | 45.92 |
| ABG7 |  |  | 10.38 |  | 4.59 |  | 10.88 | 4.81 |  | 53.89 | 19.26 | 23.83 | 20.19 | 95.41 | 44.23 |
| ABG8 |  |  | 9.96 |  | 5.28 |  | 10.46 | 5.54 |  | 53.19 | 18.73 | 28.19 | 19.67 | 95.22 | 53.00 |
| ABG9 |  |  | 9.96 |  | 4.88 |  | 10.45 | 5.12 |  | 54.26 | 18.36 | 26.60 | 19.26 | 95.31 | 49.02 |

### 3.3.5 Lyminge tarsometatarsus

### 3.3.5.1 Standard metrics - tarsometatarsus

| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM08 | 231 | 39 | r |  |  | 11.84 | 11.85 | 67.30 | 5.98 |  |
| LYM08 | 231 | 40 | r |  |  | 12.55 | 11.92 | 66.44 | 5.76 |  |
| LYM08 | 247 | 58 | r |  |  | 12.27 | 12.06 | 64.16 | 5.37 |  |
| LYM08 | 247 | 59 | $r$ |  |  | 11.72 | 11.72 | 64.16 | 5.37 |  |
| LYM08 | 271 | 84 | r |  |  | 14.19 | 13.96 | 70.05 | 6.83 |  |
| LYM08 | 271 | 85 | I |  |  | 14.15 | $13.97$ | $70.47$ | 6.60 |  |
| LYM08 | 273 | 86 | r |  |  | 11.04 | 11.52 | 65.61 | 5.01 |  |
| LYM08 | 273 | 87 | I | $y$ | $y$ | 11.39 | 11.35 | 62.87 | 5.33 |  |
| LYM08 | 273 | 88 | I | $y$ | $y$ | 12.14 | 12.25 | 69.56 | 5.58 |  |
| LYM08 | 273 | 89 | r |  |  | 11.96 | 12.02 | 70.59 | 5.84 |  |
| LYM08 | 273 | 90 | r |  |  | 11.97 | 12.16 | 71.63 | 5.82 |  |
| LYM08 | 273 | 91 | 1 |  |  |  | 14.32 | 77.00 | 6.65 | 14.22 |
| LYM08 | 273 | 92 | r |  |  | 13.10 | 14.07 | 77.55 | 6.58 | 13.75 |
| LYM08 | 273 | 93 | $r$ |  |  | 12.48 | 12.16 | 70.24 |  |  |
| LYM08 | 273 | 94 | r |  |  | 11.07 | 11.64 | 65.95 | 5.08 |  |
| LYM08 | 273 | 95 | I |  |  | 12.90 | 12.18 | 69.99 |  |  |
| LYM08 | 273 | 96 | r |  |  | 11.12 | 11.40 | 63.39 | 5.35 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM08 | 331 | 109 | r |  |  | 10.36 | 11.09 | 62.24 |  |  |
| LYM08 | 331 | 112 | I | $y$ | $y$ | 9.78 | 11.11 | 61.19 | 5.12 |  |
| LYM08 | 524 | 124 | $r$ |  |  |  | 12.23 | 65.70 | 5.41 |  |
| LYM08 | 544 | 133 | I | $y$ | $y$ | 11.47 | 12.04 | 64.05 | 5.37 |  |
| LYM08 | 591 | 143 | $r$ |  |  | 10.77 | 11.18 | 61.04 | 5.57 |  |
| LYM08 | 592 | 145 | 1 | y |  | 14.37 | 14.54 | 82.87 | 7.03 | 15.46 |
| LYM08 | 592 | 146 | r |  |  | 14.20 | 14.57 | 83.35 | 6.90 | 14.84 |
| LYM08 | 616 | 148 | I |  |  | 11.18 | 11.75 | 63.03 | 5.36 |  |
| LYM08 | 620 | 151 | 1 |  |  | 14.45 | 14.27 | 76.66 |  |  |
| LYM08 | 624 | 153 | r |  |  | 11.73 | 11.97 | 65.25 |  |  |
| LYM08 | 628 |  | $r$ |  |  | 11.90 | 12.19 | 67.87 |  |  |
| LYM08 | 628 | 157 | 1 | y | $y$ | 11.07 | 11.70 | 64.73 | 5.34 |  |
| LYM08 | 628 | 158 | r |  |  | 11.22 | 11.60 | 65.44 | 5.21 |  |
| LYM08 | 639 | 164 | I | y | $y$ | 12.76 | 12.36 | 67.73 | 5.92 |  |
| LYM08 | 650 | 177 | r |  |  | 12.67 | 11.74 | 63.19 | 5.77 | 16.01 |
| LYM08 | 650 | 178 | 1 |  |  | 13.23 | 11.91 | 63.45 | 5.96 | 17.26 |
| LYM08 | 650 | 179 | I | y | $y$ | 11.54 | 12.25 | 63.19 | 5.49 |  |
| LYM08 | 650 | 180 | 1 | $y$ | $y$ | 11.29 | 11.54 | 66.10 | 5.75 |  |
| LYM08 | 650 | 181 | $r$ |  |  | 11.75 | 11.90 | 66.89 | 5.81 |  |
| LYM08 | 650 | 182 | r |  |  | 11.78 | 12.63 | 67.48 | 5.52 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM08 | 650 | 183 | $r$ |  |  | 11.74 | 12.25 | 64.12 | 5.69 |  |
| LYM08 | 650 | 184 | $r$ |  |  | 12.53 | 12.44 | 65.42 | 5.77 |  |
| LYM08 | 651 | 187 | I | $y$ | $y$ | 11.79 | 12.80 | 66.39 | 5.54 |  |
| LYM08 | 651 | 188 | $r$ |  |  | 11.83 | 12.04 | 67.35 | 5.53 |  |
| LYM08 | 656 | 192 | $r$ |  |  | 11.77 | 12.03 | 70.29 | 5.61 |  |
| LYM08 | 681 | 201 | r |  |  | 13.29 | 13.93* | 79.46 |  |  |
| LYM08 | 684 | 206 | I | $y$ | $y$ | 11.47 | 11.14 | 61.13 | 5.27 |  |
| LYM08 | 684 | 207 | 1 |  |  | 11.25 | 11.30 | 65.58 | 5.38 |  |
| LYM08 | 684 | 208 | I | $y$ | $y$ | 12.19 | 11.99 | 66.26 | 5.88 |  |
| LYM08 | 684 | 209 | I | $y$ | $y$ | 11.62 | 11.48 | 69.55 | 5.73 |  |
| LYM08 | 684 | 210 | 1 | $y$ | $y$ | 12.23 | 11.68 | 69.43 | 5.81 |  |
| LYM08 | 684 | 211 | r |  |  | 12.23 | 11.86 | 69.54 | 5.80 |  |
| LYM08 | 684 | 212 | 1 |  |  | 13.88 | 13.88 | 71.12 | 7.04 |  |
| LYM08 | 684 | 213 | r |  |  | 14.30 | 14.22 | 74.30 |  |  |
| LYM08 | 684 | 214 | $r$ |  |  | 11.51 | 11.63 | 60.58 | 5.25 |  |
| LYM08 | 684 | 215 | $r$ |  |  | 11.14 | 11.20 | 65.88 | 5.34 |  |
| LYM08 | 684 | 216 | $r$ |  |  | 11.91 | 12.06 | 66.23 | 6.01 |  |
| LYM08 | 684 | 217 | r |  |  | 11.89 | 11.67 | 70.08 | 6.14 |  |
| LYM08 | 684 | 218 | r |  |  | 11.50 | 12.43 | 64.12 | 5.91 |  |
| LYM08 | 731 | 265 | r |  |  | 11.52 | 11.68 | 63.73 | 5.56 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM08 | 744 | 279 | $r$ |  |  | 11.88 | 11.87 | 67.11 | 5.62 |  |
| LYM09 | 1026 | 308 | $r$ |  |  | 11.18 | 11.56 | 67.45 | 5.63 |  |
| LYM09 | 1039 | 312 | $r$ |  |  | 11.42 | 11.48 | 62.68 |  |  |
| LYM09 | 1079 | 327 | 1 |  |  | 11.75 | 12.32 | 65.67 |  |  |
| LYM09 | 1079 | 328 | 1 | y | $y$ | 12.10 | 11.89 | 64.77 | 5.70 |  |
| LYM09 | 1079 | 329 | r |  |  | 11.46 | 11.70 | 64.93 | 5.80 |  |
| LYM09 | 1079 | 330 | I | $y$ |  | 12.20 | 12.19 | 68.90 | 5.70 |  |
| LYM09 | 1079 | 331 | r |  |  | 12.20 | 11.80 | 69.09 | 5.71 |  |
| LYM09 | 1079 | 332 | I | y | $y$ | 11.74 | 11.86 | 66.91 | 5.31 |  |
| LYM09 | 1079 | 333 | r |  |  | 12.31 | 11.94 | 68.88 | 5.89 |  |
| LYM09 | 1079 | 334 | 1 | y | $y$ | 12.26 | 11.96 | 69.02 | 5.66 |  |
| LYM09 | 1079 | 335 | $r$ |  |  | 11.97 | 12.42 | 68.19 | 6.02 |  |
| LYM09 | 1079 | 336 | $r$ |  |  | 11.35 | $11.85$ | 65.41 | $5.67$ |  |
| LYM09 | 1079 | 337 | I | $y$ | $y$ | 11.83 | 11.97 | 64.18 | 5.46 |  |
| LYM09 | 1095 | 342 | r |  |  | 11.21 | 11.63 | 65.88 | 5.73 |  |
| LYM09 | 1310 | 425 | 1 |  |  | 12.09 | 11.83 | 69.84 | 5.70 |  |
| LYM09 | 1311 | 445 | 1 |  |  | 11.71 | 11.40* | 63.90 | 4.97 |  |
| LYM09 | 1311 | 446 | r |  |  | 11.45 | 11.35 | 63.88 | 5.05 |  |
| LYM09 | 1312 | 447 | I |  |  | 11.71 | 11.82 | 69.65 |  |  |
| LYM09 | 1326 | 463 | r |  |  | 11.08 | 12.20 | 57.53 |  |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM09 | 1327 | 469 | I |  |  | 11.91 | 11.84 | 67.24 | 5.59 |  |
| LYM09 | 1327 | 470 | r |  |  | 12.33 | 11.66 | 68.57 | 5.33 |  |
| LYM09 | 1327 | 471 | I |  |  | 12.33* | 12.20* | 67.00 | 6.14* |  |
| LYM09 | 1327 | 472 | r |  |  | 12.22* | 12.04* | 67.88 | 6.16* |  |
| LYM09 | 1327 | 473 | 1 | $y$ | $y$ | 12.49 | 11.63 | 68.61 | 5.55 |  |
| LYM09 | 1332 | 511 | I |  | $y$ | 11.11 | 12.14 | 65.15 | 5.96 |  |
| LYM09 | 1332 | 512 | $r$ |  |  | 11.17 | 11.62 | 64.76 | 5.43 |  |
| LYM09 | 1332 | 513 | r |  |  | 12.33 | 12.54 | 67.82 | 5.59 |  |
| LYM09 | 1333 | 521 | 1 | $y$ | $y$ | 12.42 | 12.15 | 70.68 | 5.92 |  |
| LYM09 | 1349 | 526 | 1 | $y$ | $y$ | 11.59 | 11.79 | 66.12 | 5.17 |  |
| LYM09 | 1349 | 527 | r | $y$ |  | 11.85 | 11.89 | 66.21 | 5.20 |  |
| LYM09 | 1464 | 559 | r |  |  | 14.31 | 14.01 | 79.13 | 7.27 | 17.94 |
| LYM09 | 1480 | 566 | r |  |  | 11.80 | 11.90 | 68.27 | 5.71 |  |
| LYM09 | 1480 | 567 | I |  |  | 11.98 | 11.85 | 68.85 | 5.62 |  |
| LYM09 | 1480 | 568 | r |  |  | 12.09 | 11.78 | 69.72 | 5.71 |  |
| LYM09 | 1480 | 569 | I | $y$ | $y$ | 12.17 | 11.81 | 69.56 | 5.69 |  |
| LYM09 | 1480 | 570 | I | $y$ | $y$ | 14.41 | 13.77 | 77.02 | 6.53 |  |
| LYM09 | 1481 | 571 | r |  |  | 11.59 | 11.56 | 66.46 | 5.60 |  |
| LYM09 | 1482 | 574 | I | y | $y$ | 12.12 | 11.89 | 64.66 | 6.07 |  |
| LYM09 | 1482 | 575 | I | $y$ | $y$ | 11.74 | 11.62 | 64.70 | 5.44 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM09 | 1482 | 576 | r |  |  | 11.33 | 12.00 | 65.18 | 5.45 |  |
| LYM09 | 1500 | 590 | I | $y$ | $y$ | 11.24 | 11.58 | 60.86 | 5.35 |  |
| LYM09 | 1506 | 599 | I | $y$ | $y$ | 12.24 | 11.77 | 68.92 | 5.70 |  |
| LYM09 | 1514 | 609 | r |  |  | 10.76 | 10.89 | 61.39 | 5.64 |  |
| LYM09 | 1521 | 611 | 1 | $y$ | $y$ | 10.87 | 11.35 | 63.17 | 5.31 | 10.36 |
| LYM09 | 1523 | 612 | 1 | $y$ | $y$ | 11.24 | 11.60 | 65.34 | 5.35 |  |
| LYM09 | 1523 | 613 | r |  |  | 11.23 | 11.56 | 65.94 | 5.28 |  |
| LYM09 | 1552 | 615 | 1 |  |  | 11.13 | 12.38 | 63.58 | 5.24 |  |
| LYM09 | 1566 | 618 | 1 |  |  | 11.69 | 12.23 | 60.77 | 5.29 |  |
| LYM09 | 1566 | 619 | r |  |  | 12.75 | 11.85 | 61.61 | 5.47 |  |
| LYM09 | 1566 | 620 | 1 | y | $y$ | 11.52 | 11.45 | 67.08 | 5.49 |  |
| LYM09 | 1566 | 621 | $r$ |  |  | 11.51 | 11.68 | 67.63 | 5.49 |  |
| LYM09 | 1566 | 622 | $r$ |  |  | 12.33 | 12.03 | 67.70 | 5.53 |  |
| LYM09 | 1586 | 630 | I |  |  | 11.52 | 12.42 | 60.64 | 5.40 |  |
| LYM09 | 1612 | 650 | 1 |  |  |  | 11.61 | 66.15 | 5.28 |  |
| LYM09 | 1618 | 651 | I | y | $y$ | 12.13 | 11.62 | 66.08 | 5.59 |  |
| LYM09 | 1618 | 652 | r |  |  | 11.50 | 11.54 | 66.28 | 5.27 |  |
| LYM09 | 1618 | 653 | r |  |  | 11.87 | 11.82 | 67.90 | 5.78 |  |
| LYM09 | 1672 | 693 | I |  |  | 11.43 | 10.78 | 63.71 | 5.76 |  |
| LYM09 | 1672 | 694 | r |  |  |  | 12.60 | 69.93 | 5.22 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYM09 | 1672 | 696 | $r$ |  |  | 11.19 | 11.44 | 65.37 | 5.23 |  |
| LYM09 | 1672 | 707 | $r$ |  |  | 11.23 | 11.92 | 60.53 | 5.42 |  |
| LYM09 | 1672 | 717 | $r$ |  |  | 13.15 | 14.29 | 73.24 | 6.64 | 21.82 |
| LYM09 | 1672 | 718 | I | y | $y$ | 13.25 | 13.37 | 76.44 | 6.38 | 22.52 |
| LYM09 | 1672 | 719 | r |  |  | 11.32 | 11.62 | 61.41 | 5.36 |  |
| LYM09 | 1730 | 783 | I | $y$ | $y$ | 13.54 | 13.00 | 73.80 | 6.21 |  |
| LYM09 | 1730 | 784 | $r$ |  |  | 13.13 | 13.21 | 74.60 | 6.23 |  |
| LYM09 | 1730 | 789 | $r$ |  |  | 13.52 | 13.86 | 76.93 | 6.43 |  |
| LYM09 | 1730 | 793 | I | y | $y$ | 11.54 | 12.17 | 66.76 | 5.60 |  |
| LYM09 | 1730 | 799 | r |  |  | 11.56 | 12.05 | 66.70 | 5.73 |  |
| LYM09 | 1825 | 817 | 1 | y | $y$ | 14.09 | 13.65 | 76.05 | 6.72 |  |
| LYM09 | 1835 | 824 | 1 |  |  | 12.41 |  | 67.50 | 6.29 |  |
| LYMIO | 2508b | 835 | I |  |  | 13.90 | 14.03 | 84.30 |  | 18.36 |
| LYMIO | 2518a | 836 | I |  |  | 11.96 | 11.88 | 70.62 | 5.83 |  |
| LYMI2 | 3083 | 858 | 1 | y | $y$ | 11.88 | 12.15 | 68.93 | 5.58 |  |
| LYMI2 | 3172 | 867 | r |  |  | 10.48 | 10.85 | 65.33 | 4.91 |  |
| LYMI2 | 3189 | 868 | 1 | y | $y$ | 10.95 | 11.50 | 65.96 | 5.08 |  |
| LYMI2 | 3189 | 869 | r |  |  | 11.81 | 12.59 | 67.27 | 5.77 |  |
| LYMI2 | 3208 | 870 | r |  |  | 11.22 | 11.76 | 63.44 | 5.59 |  |
| LYMI2 | 3242 | 875 | r |  |  |  | 11.52 | 68.00 | 5.61 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code/ season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| LYMI2 | 3242 | 884 | I | $y$ | $y$ | 11.18 | 11.09 | 65.59 | 4.92 |  |
| LYMI2 | 3242 | 885 | r |  |  | 11.18 | 11.27 | 65.97 | 5.00 |  |
| LYMI2 | 3302 | 891 | I | $y$ | $y$ | 11.73 | 12.10 | 66.85 | 5.90 |  |
| LYMI2 | 3302 | 892 | r |  |  | 11.84 | 11.72 | 66.76 | 6.00 |  |
| LYMI2 | 3555 | 894 | I |  |  | 14.24 | 14.09 | 77.42 | 7.23 | 12.48 |
| LYMI2 | 3555 | 895 | r |  |  | 14.04 | 13.68 | 77.95 | 7.10 | 12.75 |
| LYMI2 | 3678 | 899 | 1 | $y$ | $y$ | 10.90 | 11.25 | 63.47 | 5.20 |  |
| LYMI2 | 3678 | 900 | $r$ |  |  | 10.93 | 11.22 | 63.43 | 5.24 |  |
| LYMI2 | 3810 | 903 | r |  |  | 11.17 | 11.68 | 66.25 | 5.77 |  |
| LYMI2 | 3863 | 904 | I | y | $y$ | 12.09 | 12.37 | 70.86 | 5.45 |  |
| LYMI2 | 3863 | 905 | r |  |  | 12.15 | 12.13 | 71.52 | 5.42 |  |
| LYMI3 | 6256 | 915 | I | $y$ | $y$ | 11.70 | 11.32 | 70.95 | 5.34 |  |
| Lyml2 | 3695 | ABG2 | I | $y$ | $y$ | 13.46 | 14.10 | 77.37 | 6.57 |  |
| Lyml2 | 3695 | ABG2 | r |  |  | 13.41 | 13.94 | 77.92 | 6.10 |  |
| Lym09 | 1409 | ABG3 NO | I |  |  |  |  | 57.57 | 5.84 |  |
| Lym09 | 1837 | ABG4 | r |  |  | 11.54 | 11.30 | 62.96 | 5.53 |  |
| Lym09 | 1837 | ABG4 | I | y | $y$ | 11.42 | 11.72 | 62.80 | 5.53 |  |
| Lym09 | 1600 | ABG7 | r |  |  | 12.20 | 11.90 | 68.80 | 5.50 |  |
| Lym09 | 1600 | ABG7 | I | $y$ | $y$ | 11.90 | 11.60 | 67.90 | 5.80 |  |
| Lym09 | 1312 | ABG9 | r |  |  | 11.80 | 11.80 | 69.50 | 5.80 |  |


| Lyminge - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Site code/ <br> season | Context | ID number | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| Lym09 | I09I | ABGII | r |  |  |  |  | 58.44 | 4.30 |  |

### 3.3.5.2 Measurement ratios - tarsometatarsus

| Lyminge tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| L87 | u | 100.35 | 46.80 | 8.48 | 18.05 | 18.12 | 46.96 |
| L88 | u | 99.10 | 45.96 | 8.02 | 17.61 | 17.45 | 45.55 |
| LII2 | u | 88.03 | 52.35 | 8.37 | 18.16 | 15.98 | 46.08 |
| LI33 | u | 95.27 | 46.82 | 8.38 | 18.80 | 17.91 | 44.60 |
| LI45 | m | 98.83 | 48.92 | 8.48 | 17.55 | 17.34 | 48.35 |
| LI57 | u | 94.62 | 48.24 | 8.25 | 18.08 | 17.10 | 45.64 |
| LI64 | u | 103.24 | 46.39 | 8.74 | 18.25 | 18.84 | 47.90 |
| LI79 | u | 94.20 | 47.57 | 8.69 | 19.39 | 18.26 | 44.82 |
| LI80 | u | 97.83 | 50.93 | 8.70 | 17.46 | 17.08 | 49.83 |
| LI87 | u | 92.11 | 46.99 | 8.34 | 19.28 | 17.76 | 43.28 |
| L206 | u | 102.96 | 45.95 | 8.62 | 18.22 | 18.76 | 47.31 |
| L208 | u | 101.67 | 48.24 | 8.87 | 18.10 | 18.40 | 49.04 |
| L209 | u | 101.22 | 49.31 | 8.24 | 16.51 | 16.71 | 49.91 |
| L2IO | u | 104.71 | 47.51 | 8.37 | 16.82 | 17.61 | 49.74 |


| Lyminge tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| L328 | u | 101.77 | 47.11 | 8.80 | 18.36 | 18.68 | 47.94 |
| L330 | $u$ | 100.08 | 46.72 | 8.27 | 17.69 | 17.71 | 46.76 |
| L332 | u | 98.99 | 45.23 | 7.94 | 17.73 | 17.55 | 44.77 |
| L334 | u | 102.51 | 46.17 | 8.20 | 17.33 | 17.76 | 47.32 |
| L337 | u | 98.83 | 46.15 | 8.51 | 18.65 | 18.43 | 45.61 |
| L473 | u | 107.39 | 44.44 | 8.09 | 16.95 | 18.20 | 47.72 |
| L52I | u | 102.22 | 47.67 | 8.38 | 17.19 | 17.57 | 48.72 |
| L526 | u | 98.30 | 44.61 | 7.82 | 17.83 | 17.53 | 43.85 |
| L567 | u | 101.10 | 46.91 | 8.16 | 17.21 | 17.40 | 47.43 |
| L569 | $u$ | 103.05 | 46.75 | 8.18 | 16.98 | 17.50 | 48.18 |
| L570 | m | 104.65 | 45.32 | 8.48 | 17.88 | 18.71 | 47.42 |
| L574 | u | 101.93 | 50.08 | 9.39 | 18.39 | 18.74 | 51.05 |
| L575 | u | 101.03 | 46.34 | 8.41 | 17.96 | 18.15 | 46.82 |
| L590 | u | 97.06 | 47.60 | 8.79 | 19.03 | 18.47 | 46.20 |
| L599 | u | 103.99 | 46.57 | 8.27 | 17.08 | 17.76 | 48.43 |
| L611 | m | 95.77 | 48.85 | 8.41 | 17.97 | 17.21 | 46.78 |
| L612 | u | 96.90 | 47.60 | 8.19 | 17.75 | 17.20 | 46.12 |
| L620 | u | 100.61 | 47.66 | 8.18 | 17.07 | 17.17 | 47.95 |
| L651 | u | 104.39 | 46.08 | 8.46 | 17.58 | 18.36 | 48.11 |
| L718 | m | 99.10 | 48.15 | 8.35 | 17.49 | 17.33 | 47.72 |
| L783 | u | 104.15 | 45.86 | 8.41 | 17.62 | 18.35 | 47.77 |


| Lyminge tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| L793 | u | 94.82 | 48.53 | 8.39 | 18.23 | 17.29 | 46.01 |
| L8I7 | u | 103.22 | 47.69 | 8.84 | 17.95 | 18.53 | 49.23 |
| L858 | u | 97.78 | 46.97 | 8.10 | 17.63 | 17.23 | 45.93 |
| L868 | u | 95.22 | 46.39 | 7.70 | 17.43 | 16.60 | 44.17 |
| L884 | u | 100.81 | 44.01 | 7.50 | 16.91 | 17.05 | 44.36 |
| L891 | u | 96.94 | 50.30 | 8.83 | 18.10 | 17.55 | 48.76 |
| L894 | m | 101.06 | 50.77 | 9.34 | 18.20 | 18.39 | 51.31 |
| L899 | u | 96.89 | 47.71 | 8.19 | 17.72 | 17.17 | 46.22 |
| L904 | u | 97.74 | 45.08 | 7.69 | 17.46 | 17.06 | 44.06 |
| L915 | u | 103.36 | 45.64 | 7.53 | 15.95 | 16.49 | 47.17 |
| L253 | u | 95.46 | 48.81 | 8.49 | 18.22 | 17.40 | 46.60 |
| L246 | u | 97.44 | 48.42 | 8.81 | 18.66 | 18.18 | 47.18 |
| L234 | m | 102.59 | 48.74 | 8.54 | 17.08 | 17.53 | 50.00 |

### 3.4 Flixborough

### 3.4.I Flixborough coracoid

### 3.4.1.1 Standard metrics - coracoid

| Flixborough coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bb | Bf | GL | Lm | Meas. Ratio | GMM |
| FX338 | 14.80 | 12.50 | 56.60 | 53.90 | y | $y$ |
| FX339 | 14.20 | 11.90 | 53.80 | 52.20 | $y$ | $y$ |
| FX344 | 15.10 | 11.50 | 55.60 | 53.40 | $y$ | Y |
| FX345 | 12.70 | 10.30 | 46.50 | 44.20 | $y$ | $y$ |
| FX346 | 12.80 | 10.30 | 50.10 | 48.00 | y | y |
| FX351 | 13.40 | 11.50 | 50.70 | 48.30 | $y$ | $y$ |
| FX357 | 11.70 | 9.70 | 48.90 | 47.00 | $y$ | $y$ |
| FX358 | 14.00 | 12.30 | 50.70 | 48.30 | $y$ | $y$ |
| FX361 | 14.70 | 13.40 | 53.40 | 50.80 | $y$ | $y$ |
| FX362 | 13.70 | 11.80 | 51.60 | 49.00 | $y$ | $y$ |
| FX363 | 16.10 | 13.80 | 56.50 | 54.10 | $y$ | $y$ |
| FX370 | 12.10 | 10.10 | 47.30 | 45.20 | $y$ | $y$ |
| FX371 | 12.60 | 11.10 | 47.30 | 44.30 | $y$ | $y$ |
| FX377 | 14.90 | 13.50 | 55.30 | 52.40 | $y$ | $y$ |
| FX383 | 15.00 | 12.60 | 56.40 | 53.90 | $y$ | $y$ |
| FX385 | 14.12 | 11.35 | 53.76 | 50.18 | y | $y$ |


| Flixborough coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bb | Bf | GL | Lm | Meas. Ratio | GMM |
| FX390 | 15.20 | 12.70 | 56.30 | 53.30 | $y$ | $y$ |
| FX391 | 14.10 | 12.00 | 50.50 | 47.70 | $y$ | $y$ |
| FX392 | 12.70 | 11.90 | 47.50 | 46.10 | $y$ | $y$ |
| FX393 | 11.70 | 9.90 | 49.00 | 46.60 | $y$ | $y$ |
| FX396 | 14.00 | 10.90 | 49.60 | 47.20 | $y$ | $y$ |
| FX397 | 12.00 | 10.60 | 47.80 | 45.70 | $y$ | $y$ |
| FX398 | 14.20 | 13.10 | 56.90 | 54.20 | $y$ | $y$ |
| FX40I | 14.60 | 12.30 | 55.30 | 52.90 | $y$ | $y$ |
| FX402 | 12.96 | 10.89 | 48.34 | 46.24 | $y$ | $y$ |
| FX403 | 15.18 | 12.77 | 57.72 | 55.43 | $y$ | $y$ |
| FX404 | 12.48 | 10.49 | 49.33 | 46.96 | $y$ | $y$ |
| FX406 | 12.20 | 11.80 | 46.90 | 44.00 | $y$ | $y$ |

### 3.4.1.2 Measurement ratios - coracoid

| Flixborough coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| FX338 | 95.23 | 84.46 | 26.15 | 27.46 | 22.08 | 23.19 |
| FX339 | 97.03 | 83.80 | 26.39 | 27.20 | 22.12 | 22.80 |
| FX344 | 96.04 | 76.16 | 27.16 | 28.28 | 20.68 | 21.54 |
| FX345 | 95.05 | 81.10 | 27.31 | 28.73 | 22.15 | 23.30 |


| Flixborough coracoids measurement ratios |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| FX346 | 95.81 | 80.47 | 25.55 | 26.67 | 20.56 | 21.46 |
| FX351 | 95.27 | 85.82 | 26.43 | 27.74 | 22.68 | 23.81 |
| FX357 | 96.11 | 82.91 | 23.93 | 24.89 | 19.84 | 20.64 |
| FX358 | 95.27 | 87.86 | 27.61 | 28.99 | 24.26 | 25.47 |
| FX361 | 95.13 | 91.16 | 27.53 | 28.94 | 25.09 | 26.38 |
| FX362 | 94.96 | 86.13 | 26.55 | 27.96 | 22.87 | 24.08 |
| FX363 | 95.75 | 85.71 | 28.50 | 29.76 | 24.42 | 25.51 |
| FX370 | 95.56 | 83.47 | 25.58 | 26.77 | 21.35 | 22.35 |
| FX371 | 93.66 | 88.10 | 26.64 | 28.44 | 23.47 | 25.06 |
| FX377 | 94.76 | 90.60 | 26.94 | 28.44 | 24.41 | 25.76 |
| FX383 | 95.57 | 84.00 | 26.60 | 27.83 | 22.34 | 23.38 |
| FX385 | 93.34 | 80.38 | 26.26 | 28.14 | 21.11 | 22.62 |
| FX390 | 94.67 | 83.55 | 27.00 | 28.52 | 22.56 | 23.83 |
| FX391 | 94.46 | 85.11 | 27.92 | 29.56 | 23.76 | 25.16 |
| FX392 | 97.05 | 93.70 | 26.74 | 27.55 | 25.05 | 25.81 |
| FX393 | 95.10 | 84.62 | 23.88 | 25.11 | 20.20 | 21.24 |
| FX396 | 95.16 | 77.86 | 28.23 | 29.66 | 21.98 | 23.09 |
| FX397 | 95.61 | 88.33 | 25.10 | 26.26 | 22.18 | 23.19 |
| FX398 | 95.25 | 92.25 | 24.96 | 26.20 | 23.02 | 24.17 |
| FX401 | 95.66 | 84.25 | 26.40 | 27.60 | 22.24 | 23.25 |
| FX402 | 95.66 | 84.03 | 26.81 | 28.03 | 22.53 | 23.55 |


| Flixborough coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| FX403 | 96.03 | 84.12 | 26.30 | 27.39 | 22.12 | 23.04 |
| FX404 | 95.20 | 84.05 | 25.30 | 26.58 | 21.26 | 22.34 |
| FX405 | 93.82 | 96.72 | 26.01 | 27.73 | 25.16 | 26.82 |

### 3.5 Coppergate

### 3.5.I Coracoids

3.5.1.1 Standard metrics - coracoids

| Coppergate coracoids |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Area | Context | Date From | Date To | ID | Bb | Bf | GL | Lm | Side | Meas. ratio | GMM |
| 1979.7 | 17528 | mid IIth | late IIth | y002 | 13.23 | 11.11 | 48.51 | 46.51 | 1 | $y$ | $y$ |
| 1979.7 | 17697 | mid IIth | late IIth | y003 | 15.31 | 12.44 | 58.09 | 55.72 | 1 | $y$ | $y$ |
| 1979.7 | 16895 | mid I Ith | late IIth | y004 | 15.90 | 13.52 | 54.90 | 52.53 | 1 | $y$ | $y$ |
| 1979.7 | 16603 | mid IIth | late IIth | y007 | 12.70 | 11.00 | 47.74 | 45.14 | 1 | $y$ | $y$ |
| 1979.7 | 19283 | mid IIth | late IIth | y011 | 15.88 | 13.86 | 58.57 | 55.94 | 1 | $y$ | $y$ |
| 1979.7 | 15013 | AD 955/6 | early/mid IIth | y015 | 13.13 | 10.78 | 48.03 | 46.29 | 1 | $y$ | $y$ |
| 1979.7 | 15432 | AD 955/6 | early/mid IIth | y016 | 12.46 | 10.30 | 51.76 | 49.56 | 1 | $y$ | $y$ |
| 1979.7 | 15131 | AD 955/6 | early/mid IIth | y017 | 12.18 | 10.34 | 50.58 | 48.55 | 1 | $y$ | $y$ |


| Coppergate coracoids |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Area | Context | Date From | Date To | ID | Bb | Bf | GL | Lm | Side | Meas. ratio | GMM |
| 1979.7 | 15628 | AD 955/6 | early/mid IIth | y019 | 15.14 | 12.55 | 57.01 | 54.42 | 1 | $y$ | $y$ |
| 1979.7 | 15483 | AD 955/6 | early/mid IIth | y022 | 15.37 | 13.67 | 57.44 | 53.90 | 1 | $y$ | $y$ |
| 1979.7 | 6433 | AD 955/6 | early/mid IIth | y025 | 12.99 | 10.57 | 49.22 | 46.72 | 1 | $y$ | $y$ |
| 1979.7 | 6433 | AD 955/6 | early/mid I Ith | y026 | 15.22 | 13.07 | 57.52 | 54.88 | 1 | $y$ | $y$ |
| 1979.7 | 5247 | AD 955/6 | early/mid IIth | y027 | 16.42 | 13.43 | 55.88 | 53.42 | 1 | $y$ | $y$ |
| 1979.7 | 5416 | AD 955/6 | early/mid I Ith | y028 | 17.35 | 14.53 | 58.19 | 55.70 | 1 | $y$ | $y$ |
| 1979.7 | 15338 | AD 955/6 | early/mid I Ith | y029 | 15.00 | 13.10 | 54.88 | 52.07 | I | $y$ | $y$ |
| 1979.7 | 15931 | AD 955/6 | early/mid IIth | y031 | 13.01 | 10.41 | 51.13 | 48.75 | 1 | $y$ | $y$ |
| 1979.7 | 15371 | AD 955/6 | early/mid IIth | y032 | 15.38 | 13.40 | 59.72 | 56.65 | 1 | $y$ | $y$ |
| 1979.7 | 15207 | AD 955/6 | early/mid IIth | y033 | 14.62 | 11.84 | 53.05 | 50.16 | 1 | $y$ | $y$ |
| 1979.7 | 15705 | AD 955/6 | early/mid I Ith | y034 | 12.37 | 10.40 | 46.24 | 44.14 | 1 | $y$ | $y$ |
| 1979.7 | 14843 | AD 955/6 | early/mid IIth | y035 | 13.65 | 11.58 | 49.34 | 46.97 | 1 | $y$ | $y$ |
| 1979.7 | 6578 | AD 955/6 | early/mid IIth | y037 | 15.25 | 12.50 | 54.89 | 52.51 | 1 | $y$ | $y$ |
| 1979.7 | 19320 | AD 955/6 | early/mid IIth | y038 | 11.88 | 10.31 | 47.14 | 45.37 | 1 | $y$ | $y$ |
| 1979.7 | 14592 | AD 955/6 | early/mid I Ith | y039 | 16.14 | 14.14 | 56.44 | 53.29 | 1 | $y$ | $y$ |
| 1979.7 | 15659 | AD 955/6 | early/mid IIth | y041 | 15.10 | 12.37 | 53.69 | 51.26 | 1 | $y$ | $y$ |
| 1979.7 | 15659 | AD 955/6 | early/mid I Ith | y042 | 14.86 | 12.15 | 54.85 | 51.93 | 1 | $y$ | $y$ |
| 1979.7 | 7589 | AD 955/6 | early/mid IIth | y044 | 16.24 | 13.63 | 58.51 | 55.54 | 1 | $y$ | $y$ |
| 1979.7 | 22166 | AD 955/6 | AD 955/6 | y045 | 13.27 | 11.15 | 47.44 | 44.77 | 1 | $y$ | $y$ |
| 1979.7 | 22104 | AD 955/6 | AD 955/6 | y047 | 13.10 | 11.14 | 48.80 | 46.73 | 1 | $y$ | $y$ |
| 1979.7 | 26949 | AD 930/5 | AD 955/6 | y051 | 13.71 | 11.22 | 49.01 | 46.15 | 1 | $y$ | $y$ |
| 1979.7 | 22868 | AD 930/5 | AD 955/6 | y052 | 14.84 | 12.02 | 56.25 | 53.27 | I | $y$ | $y$ |
| 1979.7 | 22797 | AD 930/5 | AD 955/6 | y054 | 15.25 | 13.07 | 53.76 | 51.75 | 1 | $y$ | $y$ |
| 1979.7 | 23612 | AD 930/5 | AD 955/6 | y055 | 12.54 | 9.87 | 46.34 | 44.45 | I | $y$ | $y$ |


| Coppergate coracoids |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Area | Context | Date From | Date To | ID | Bb | Bf | GL | Lm | Side | Meas. ratio | GMM |
| 1979.7 | 23137 | AD 930/5 | AD 955/6 | y056 | 11.97 | 9.72 | 47.73 | 45.37 | I | $y$ | y |
| 1978.7 | 7782 | AD 930/5 | AD 955/6 | y057 | 13.73 | 11.68 | 49.39 | 47.77 | 1 | $y$ | $y$ |
| 1978.7 | 7782 | AD 930/5 | AD 955/6 | y058 | 14.70 | 12.56 | 55.36 | 52.16 | 1 | $y$ | $y$ |
| ? | 22574 | AD 930/5 | AD 955/6 | y059 | 12.84 | 11.17 | 52.49 | 50.32 | 1 | $y$ | $y$ |
| ? | 22820 | AD 930/5 | AD 955/6 | y060 | 13.31 | 11.37 | 47.00 | 44.38 | 1 | $y$ | $y$ |
| ? | 22423 | AD 930/5 | AD 955/6 | y061 | 12.54 | 10.99 | 47.32 | 44.96 | I | $y$ | $y$ |
| ? | 23316 | AD 930/5 | AD 955/6 | y063 | 15.47 | 12.51 | 52.42 | 49.80 | 1 | $y$ | $y$ |
| ? | 22914 | AD 930/5 | AD 955/6 | y067 | 14.47 | 12.94 | 55.64 | 52.92 | 1 | $y$ | $y$ |
| ? | 22560 | AD 930/5 | AD 955/6 | y068 | 12.61 | 10.59 | 50.30 | 47.47 | 1 | $y$ | $y$ |
| ? | 18602 | AD 930/5 | AD 955/6 | y069 | 15.41 | 13.22 | 56.80 | 54.40 | 1 | $y$ | $y$ |
| ? | 22808 | AD 930/5 | AD 955/6 | y070 | 12.07 | 10.57 | 44.98 | 42.76 | 1 | $y$ | $y$ |
| 1977.7 | 5484 | late 12th | early 13th | y074 | 13.66 | 11.24 | 50.48 | 48.32 | 1 | $y$ | $y$ |
| 1977.7 | 5484 | late 12th | early 13th | y076 | 14.88 | 12.24 | 55.09 | 53.14 | 1 | $y$ | $y$ |
| 1977.7 | 5484 | late 12th | early 13th | y077 | 15.09 | 12.54 | 56.81 | 53.94 | I | $y$ | $y$ |
| 1977.7 | 5484 | late 12th | early 13th | y078 | 13.73 | 12.07 | 50.05 | 47.80 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y081 | 16.91 | 15.11 | 57.45 | 55.54 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y082 | 16.28 | 13.70 | 57.92 | 54.43 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y085 | 13.47 | 11.40 | 48.24 | 45.72 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y086 | 15.81 | 13.10 | 57.05 | 54.77 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y087 | 13.86 | 11.51 | 49.00 | 45.99 | 1 | $y$ | $y$ |
| 1977.7 | 4620 | late 12th | early 13th | y089 | 13.51 | 10.86 | 47.07 | 44.46 | 1 | $y$ | $y$ |

3.5.1.2 Measurement ratios - coracoids

| Coppergate coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Y528 | 95.88 | 83.98 | 27.27 | 28.45 | 22.90 | 23.89 |
| Y529 | 95.92 | 81.25 | 26.36 | 27.48 | 21.42 | 22.33 |
| Y530 | 95.68 | 85.03 | 28.96 | 30.27 | 24.63 | 25.74 |
| Y533 | 94.55 | 86.61 | 26.60 | 28.13 | 23.04 | 24.37 |
| Y537 | 95.5 I | 87.28 | 27.11 | 28.39 | 23.66 | 24.78 |
| Y54I | 96.38 | 82.10 | 27.34 | 28.36 | 22.44 | 23.29 |
| Y542 | 95.75 | 82.66 | 24.07 | 25.14 | 19.90 | 20.78 |
| Y543 | 95.99 | 84.89 | 24.08 | 25.09 | 20.44 | 21.30 |
| Y545 | 95.46 | 82.89 | 26.56 | 27.82 | 22.01 | 23.06 |
| Y548 | 93.84 | 88.94 | 26.76 | 28.52 | 23.80 | 25.36 |
| Y55I | 94.92 | 81.37 | 26.39 | 27.80 | 21.48 | 22.62 |
| Y552 | 95.4 I | 85.87 | 26.46 | 27.73 | 22.72 | 23.82 |
| Y553 | 95.60 | 81.79 | 29.38 | 30.74 | 24.03 | 25.14 |
| Y554 | 95.72 | 83.75 | 29.82 | 31.15 | 24.97 | 26.09 |
| Y555 | 94.88 | 87.33 | 27.33 | 28.81 | 23.87 | 25.16 |
| Y557 | 95.35 | 80.02 | 25.44 | 26.69 | 20.36 | 21.35 |
| Y558 | 94.86 | 87.13 | 25.75 | 27.15 | 22.44 | 23.65 |
| Y559 | 94.55 | 80.98 | 27.56 | 29.15 | 22.32 | 23.60 |
| Y560 | 95.46 | 84.07 | 26.75 | 28.02 | 22.49 | 23.56 |


| Coppergate coracoids measurement ratios |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Y561 | 95.20 | 84.84 | 27.67 | 29.06 | 23.47 | 24.65 |
| Y563 | 95.66 | 81.97 | 27.78 | 29.04 | 22.77 | 23.80 |
| Y564 | 96.25 | 86.78 | $25.20$ | $26.18$ | $21.87$ | $22.72$ |
| Y565 | 94.42 | 87.61 | 28.60 | 30.29 | 25.05 | 26.53 |
| Y567 | 95.47 | 81.92 | 28.12 | 29.46 | 23.04 | 24.13 |
| Y568 | 94.68 | 81.76 | 27.09 | $28.62$ | 22.15 | 23.40 |
| Y570 | 94.92 | 83.93 | 27.76 | 29.24 | 23.30 | 24.54 |
| Y571 | 94.37 | 84.02 | 27.97 | 29.64 | 23.50 | $24.91$ |
| Y573 | 95.76 | 85.04 | 26.84 | 28.03 | 22.83 | 23.84 |
| Y577 | 94.16 | 81.84 | 27.97 | 29.71 | 22.89 | 24.31 |
| Y578 | 94.70 | 81.00 | 26.38 | 27.86 | 21.37 | 22.56 |
| Y580 | 96.26 | 85.70 | 28.37 | 29.47 | 24.31 | 25.26 |
| Y58I | 95.92 | 78.71 | 27.06 | 28.21 | 21.30 | 22.20 |
| Y582 | 95.06 | 81.20 | 25.08 | 26.38 | 20.36 | 21.42 |
| Y583 | 96.72 | 85.07 | 27.80 | 28.74 | 23.65 | 24.45 |
| Y584 | 94.22 | 85.44 | 26.55 | 28.18 | 22.69 | 24.08 |
| Y585 | 95.87 | 86.99 | 24.46 | 25.52 | 21.28 | 22.20 |
| Y586 | 94.43 | 85.42 | 28.32 | 29.99 | 24.19 | 25.62 |
| Y587 | 95.01 | 87.64 | 26.50 | 27.89 | 23.22 | 24.44 |
| Y589 | 95.00 | 80.87 | 29.51 | 31.06 | 23.86 | 25.12 |
| Y593 | 95.11 | 89.43 | 26.01 | 27.34 | 23.26 | 24.45 |


| Coppergate coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Y594 | 94.37 | 83.98 | 25.07 | 26.56 | 21.05 | 22.31 |
| Y595 | 95.77 | 85.79 | 27.13 | 28.33 | 23.27 | 24.30 |
| Y596 | 95.06 | 87.57 | 26.83 | 28.23 | 23.50 | 24.72 |
| Y600 | 95.72 | 82.28 | 27.06 | 28.27 | 22.27 | 23.26 |
| Y602 | 96.46 | 82.26 | 27.01 | 28.00 | 22.22 | 23.03 |
| Y603 | 94.95 | 83.10 | 26.56 | 27.98 | 22.07 | 23.25 |
| Y604 | 95.50 | 87.91 | 27.43 | 28.72 | 24.12 | 25.25 |
| Y607 | 96.68 | 89.36 | 29.43 | 30.45 | 26.30 | 27.21 |
| Y608 | 93.97 | 84.15 | 28.11 | 29.91 | 23.65 | 25.17 |
| Y6II | 94.78 | 84.63 | 27.92 | 29.46 | 23.63 | 24.93 |
| Y6I2 | 96.00 | 82.86 | 27.71 | 28.87 | 22.96 | 23.92 |
| Y6I3 | 93.86 | 83.04 | 28.29 | 30.14 | 23.49 | 25.03 |
| Y6I5 | 94.46 | 80.38 | 28.70 | 30.39 | 23.07 | 24.43 |

### 3.6 Chester

### 3.6.1 Chester coracoid

### 3.6.1.1 Standard metrics - coracoid

| Chester - coracoids |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. Ratio | GMM | Bb | Bf | GL | Lm |
| CHE/AMP04 | 3084 | 4550 | C33 | I | $y$ | $y$ | 16.47 | 13.89 | 58.61 | 55.92 |
| CHE/AMP04 | 3084 | 4550 | C34 | I | $y$ | $y$ | 16.87 | 13.71 | 61.42 | 58.92 |
| CHE/AMP04 | 3084 | 4550 | C35 | I | $y$ | $y$ | 14.21 | 12.37 | 54.13 | 51.22 |
| CHE/AMP04 | 3084 | 4550 | C36 | I | $y$ | $y$ | 15.01 | 12.72 | 52.28 | 48.81 |
| CHE/AMP04 | 3084 | 4550 | C37 | I | $y$ | $y$ | 16.68 | 13.02 | 57.18 | 55.09 |
| CHE/AMP04 | 3084 | 4550 | C38 | 1 | $y$ | $y$ | 13.32 | 11.18 | 50.37 | 47.65 |
| CHE/AMP04 | 3084 | 4550 | C39 | r |  |  | 13.16 | 12.58 | 49.79 | 47.32 |
| CHE/AMP04 | 3084 | 4550 | C40 | r |  |  | 14.96 | 12.86 | 52.13 | 48.92 |
| CHE/AMP04 | 3084 | 4550 | C4I | r |  |  | 12.88 | 10.30 | 51.95 | 49.45 |
| CHE/AMP04 | 3084 | 4541 | C78 | r |  |  | 13.74 | 11.37 | 54.31 | 51.36 |
| CHE/AMP04 | 3084 | 4541 | C87 | I | $y$ | $y$ | 16.33 | 13.68 | 55.33 | 51.32 |
| CHE/AMP04 | 3084 | 4541 | C88 | 1 | $y$ | $y$ | 12.96 | 11.30 | 47.33 | 44.99 |
| CHE/AMP04 | 3084 | 4541 | C89 | r |  |  | 13.68 | 11.67 | 55.03 | 51.54 |
| CHE/AMP04 | 3084 | 4531 | CIOI | 1 | y | y | 13.21 | 10.95 | 50.63 | 47.91 |
| CHE/AMP04 | 3084 | 4531 | Cl02 | $r$ |  |  | 14.04 | 11.33 | 57.54 | 55.62 |
| CHE/AMP04 | 3084 | 4528 | CI38 | $r$ |  |  | 12.28 | 14.58 | 59.85 | 56.60 |


| Chester - coracoids |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. Ratio | GMM | Bb | Bf | GL | Lm |
| CHE/AMP04 | 3084 | 4545 | CI58 | I | y | $y$ | 14.12 | 11.31 | 55.47 | 52.39 |
| CHE/AMP04 | 3084 | 4545 | CI59 | $r$ |  |  | 14.33 | 11.24 | 55.17 | 52.04 |
| CHE/AMP04 | 3084 | 4549 | Cl66 | 1 | y | y | 13.85 | 12.14 | 52.70 | 51.21 |
| CHE/AMP04 | 3084 | 4549 | C167 | r |  |  | 13.70 | 11.51 | 53.97 | 51.61 |
| CHE/AMP04 | 3084 | 4530 | C182 | 1 | y | y | 14.23 | 11.11 | 57.95 | 56.01 |
| CHE/AMP04 | 3084 | 4536 | C208 | $r$ |  |  | 13.92 | 11.12 | 46.63 | 44.68 |
| CHE/AMP04 | 3084 | 4547 | C219 | 1 | $y$ | y | 17.22 | 14.72 | 61.32 | 58.12 |
| CHE/AMP04 | 3084 | 4547 | C223 | r |  |  | 15.81 | 13.65 | 55.44 | 52.20 |

### 3.6.1.2 Measurement ratios - coracoid

| Chester coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| C33 | 95.4 I | 84.34 | 28.10 | 29.45 | 23.70 | 24.84 |
| C34 | 95.93 | 81.27 | 27.47 | 28.63 | 22.32 | 23.27 |
| C35 | 94.62 | 87.05 | 26.25 | 27.74 | 22.85 | 24.15 |
| C36 | 93.36 | 84.74 | 28.71 | 30.75 | 24.33 | 26.06 |
| C37 | 96.34 | 78.06 | 29.17 | 30.28 | 22.77 | 23.63 |
| C38 | 94.60 | 83.93 | 26.44 | 27.95 | 22.20 | 23.46 |
| C87 | 92.75 | 83.77 | 29.5 I | 31.82 | 24.72 | 26.66 |
| C88 | 95.06 | 87.19 | 27.38 | 28.81 | 23.87 | 25.12 |


| Chester coracoids measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| CI0I | 94.63 | 82.89 | 26.09 | 27.57 | 21.63 | 22.86 |
| CI58 | 94.45 | 80.10 | 25.46 | 26.95 | 20.39 | 21.59 |
| CI66 | 97.17 | 87.65 | 26.28 | 27.05 | 23.04 | 23.71 |
| CI82 | 96.65 | 78.07 | 24.56 | 25.41 | 19.17 | 19.84 |
| C219 | 94.78 | 85.48 | 28.08 | 29.63 | 24.01 | 25.33 |

### 3.6.2 Chester humerus

### 3.6.2.1 Standard metrics - humerus

| Chester - humerus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. Ratio | GMM | Bd | Bp | GL | SC |
| CHE/AMP04 | 3084 | none | C4 | $r$ |  |  | 14.48 | 17.11 | 66.01 | 6.22 |
| CHE/AMP04 | 3084 | none | CII | I | $y$ | $y$ | 14.84 | 18.95 | 69.80 | 7.02 |
| CHE/AMP04 | 3084 | 4550 | C42 | I | $y$ | $y$ | 14.30 | 18.39 | 67.67 | 6.77 |
| CHE/AMP04 | 3084 | 4550 | C43 | 1 | $y$ | $y$ | 14.44 | 17.23 | 65.72 | 6.23 |
| CHE/AMP04 | 3084 | 4550 | C44 | I | $y$ | $y$ | 15.12 | 19.42 | 72.53 | 6.76 |
| CHE/AMP04 | 3084 | 4550 | C45 | I | $y$ | $y$ | 15.26 | 18.82 | 69.20 | 6.36 |
| CHE/AMP04 | 3084 | 4550 | C46 | I | $y$ | y | 13.79 | 17.53 | 61.79 | 6.47 |
| CHE/AMP04 | 3084 | 4550 | C47 | $r$ |  |  | 17.06 | 21.50 | 82.03 | 7.27 |
| CHE/AMP04 | 3084 | 4550 | C48 | r |  |  | 15.81 | 19.60 | 72.93 | 6.81 |


| Chester - humerus |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. Ratio | GMM | Bd | Bp | GL | SC |
| CHE/AMP04 | 625 | 4689 | C94 | r |  |  | 15.24 | 19.06 | 71.72 | 7.36 |
| CHE/AMP04 | 3084 | 4525 | C95 | 1 | $y$ | $y$ | I7.81 | 23.36 | 81.60 | 7.79 |
| CHE/AMP04 | 3084 | 4527 | Cl09 | 1 | $y$ | $y$ | 18.47 | 22.85 | 82.60 | 8.00 |
| CHE/AMP04 | 3084 | 4527 | CIIO | $r$ |  |  | 13.83 | 17.51 | 62.00 | 6.47 |
| CHE/AMP04 | 3084 | 4537 | Cl 23 | $r$ |  |  | 15.81 | 19.47 | 70.12 | 6.59 |
| CHE/AMP04 | 3084 | 4535 | Cl33 | 1 | $y$ | y | 14.58 | 18.18 | 68.58 | 6.48 |
| CHE/AMP04 | 3084 | 4528 | CI40 | $r$ |  |  | 14.14 | 17.65 | 66.04 | 6.60 |
| CHE/AMP04 | 3084 | 4546 | Cl49 | $r$ |  |  | 18.30 | 22.79 | 82.29 | 7.98 |
| CHE/AMP04 | 3084 | 4545 | CI57 | $r$ |  |  | 16.10 | 20.59 | 75.78 | 7.35 |
| CHE/AMP04 | 3084 | 4545 | Cl60 | $r$ |  |  | 14.17 | 17.80 | 67.53 | 6.51 |
| CHE/AMP04 | 3084 | 4530 | CI79 | $r$ |  |  | 15.76 | 20.88 | 72.32 | 7.26 |
| CHE/AMP04 | 3084 | 4548 | C196 | $r$ |  |  | 15.30 | 18.68 | 69.32 | 6.37 |
| CHE/AMP04 | 3084 | 4529 | C198 | $r$ |  |  | 14.73 | 19.19 | 69.88 | 6.68 |
| CHE/AMP04 | 3084 | 4529 | C199 | r |  |  | 16.62 | 20.89 | 79.36 | 7.59 |
| CHE/AMP04 | 3084 | 4547 | C 212 | I | y | y | 15.62 | 20.98 | 72.54 | 7.26 |
| CHE/AMP04 | 3084 | 4547 | C 213 | I | $y$ | y | 14.42 | 17.94 | 66.48 | 6.68 |
| CHE/AMP04 | 3084 | 4547 | C 214 | 1 | $y$ | $y$ | 16.53 | 21.15 | 81.44 | 7.12 |
| CHE/AMP04 | 3084 | 4547 | C2I5 | r |  |  | 14.45 | 18.14 | 65.51 | 6.51 |

### 3.6.2.2 Measurement ratios - humerus

| Chester humeri measurement ratios |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| CII | 78.3 I | 10.06 | 27.15 | 21.26 | 37.04 | 47.30 |
| C42 | 77.76 | 10.00 | 27.18 | 21.13 | 36.81 | 47.34 |
| C43 | 83.81 | 9.48 | 26.22 | 21.97 | 36.16 | 43.14 |
| C44 | 77.86 | 9.32 | 26.78 | 20.85 | 34.81 | 44.71 |
| C45 | 81.08 | 9.19 | 27.20 | 22.05 | 33.79 | 41.68 |
| C46 | 78.67 | 10.47 | 28.37 | 22.32 | 36.91 | 46.92 |
| C95 | 76.24 | 9.55 | 28.63 | 21.83 | 33.35 | 43.74 |
| CI09 | 80.83 | 9.69 | 27.66 | 22.36 | 35.01 | 43.31 |
| CI33 | 80.20 | 9.45 | 26.51 | 21.26 | 35.64 | 44.44 |
| C2I2 | 74.45 | 10.01 | 28.92 | 21.53 | 34.60 | 46.48 |
| C2I3 | 80.38 | 10.05 | 26.99 | 21.69 | 37.24 | 46.32 |
| C214 | 78.16 | 8.74 | 25.97 | 20.30 | 33.66 | 43.07 |

### 3.6.3 Chester femur

3.6.3.1 Standard metrics - femur

| Chester - femur |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample | ID | Side | Meas. <br> Ratio | Bd | Bp | Dd | Dp | GL | Lm | SC |
| CHE/AMP04 | 3064 | - | Cl | 1 | $y$ | 18.84 | 17.94 | 15.61 | 11.90 | 92.96 | 86.53 | 8.02 |
| CHE/AMP04 | 3084 | - | C9 | 1 | $y$ | 17.92 | 17.63 | 14.76 | 13.01 | 88.54 | 84.22 | 8.32 |
| CHE/AMP04 | 3084 | 4550 | C30 | 1 | y | 17.04 | 17.85 | 14.23 | 12.74 | 87.10 | 80.43 | 7.69 |
| CHE/AMP04 | 3084 | 4550 | C32 | 1 | y | 13.81 | 13.68 | 11.41 | 9.16 | 68.99 | 64.68 | 6.08 |
| CHE/AMP04 | 3084 | 4541 | C81 | 1 | y | 15.39 | 16.89 | 12.49 | 10.81 | 78.73 | 73.03 | 6.84 |
| CHE/AMP04 | 3084 | 4546 | CI5I | 1 | y | 17.19 | 17.48 | 14.59 | 11.87 | 90.02 | 84.73 | 7.40 |
| CHE/AMP04 | 3084 | 4546 | CI52 | I | y | 14.40 | 14.44 | 11.57 | 10.23 | 74.07 | 69.06 | 6.51 |
| CHE/AMP04 | 3084 | 4549 | Cl65 | 1 | $y$ | 14.09 | 15.38 | 11.86 | 10.03 | 73.76 | 68.95 | 6.45 |
| CHE/AMP04 | 3084 | 4548 | C195 | 1 | $y$ | 15.93 | 16.19 | 12.72 | 10.67 | 81.85 | 76.07 | 6.92 |
| CHE/AMP04 | 3084 | 4536 | C209 | 1 | y | 17.29 | 17.00 | 13.84 | 11.19 | 86.46 | 79.77 | 7.73 |
| CHE/AMP04 | 3084 | 4547 | C22I | 1 | y | 13.84 | 14.67 | 12.04 | 9.64 | 73.56 | 68.85 | 5.90 |

### 3.6.3.2 Measurement ratios- femur

| Chester femora measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| C001 | 82.86 | 42.57 | 8.63 | 20.27 | 19.30 | 21.77 | 20.73 | 9.27 | 44.70 | 87.01 | 76.23 | 16.79 | 18.04 | $51.38$ |
| C009 | 82.37 | 46.43 | 9.40 | 20.24 | 19.91 | 21.28 | 20.93 | 9.88 | 47.19 | 83.72 | 88.14 | 16.67 | 17.53 | 56.37 |
| C030 | 83.51 | 45.13 | 8.83 | 19.56 | 20.49 | 21.19 | 22.19 | 9.56 | 43.08 | 79.72 | 89.53 | 16.34 | 17.69 | 54.04 |
| C032 | 82.62 | 44.03 | 8.81 | 20.02 | 19.83 | 21.35 | 21.15 | 9.40 | 44.44 | 83.41 | 80.28 | 16.54 | 17.64 | 53.29 |
| C08I | 81.16 | 44.44 | 8.69 | 19.55 | 21.45 | 21.07 | 23.13 | 9.37 | 40.50 | 73.95 | 86.55 | 15.86 | 17.10 | 54.76 |
| CI5I | 84.87 | 43.05 | 8.22 | 19.10 | 19.42 | 20.29 | 20.63 | 8.73 | 42.33 | 83.47 | 81.36 | 16.21 | 17.22 | 50.72 |
| CI52 | 80.35 | 45.21 | 8.79 | 19.44 | 19.50 | 20.85 | $20.91$ | 9.43 | 45.08 | 80.12 | 88.42 | 15.62 | 16.75 | $56.27$ |
| Cl65 | 84.17 | 45.78 | 8.74 | 19.10 | 20.85 | 20.44 | 22.31 | 9.35 | 41.94 | 77.11 | 84.57 | 16.08 | 17.20 | 54.38 |
| C195 | 79.85 | 43.44 | 8.45 | 19.46 | 19.78 | 20.94 | 21.28 | 9.10 | 42.74 | 78.57 | 83.88 | 15.54 | 16.72 | 54.40 |
| C209 | 80.05 | 44.71 | 8.94 | 20.00 | 19.66 | 21.67 | 21.31 | 9.69 | 45.47 | 81.41 | 80.85 | 16.01 | 17.35 | 55.85 |
| C22I | 86.99 | 42.63 | 8.02 | 18.81 | 19.94 | 20.10 | 21.31 | 8.57 | 40.22 | 82.07 | 80.07 | 16.37 | 17.49 | 49.00 |

### 3.6.4 Chester tibiotarsus

### 3.6.4.1 Standard metrics - tibiotarsus

| Chester - tibiotarsus |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. <br> Ratio | GMM | Bd | Dd | Dip | GL | La | SC |
| CHE/AMP04 | 3084 |  | C7 | r |  |  | 11.40 | 11.07 | 19.97 | 107.83 | 103.86 | 5.64 |
| CHE/AMP04 | 3084 |  | C8 | $r$ |  |  | 10.81 | 11.71 | 19.64 | 108.05 | 104.47 | 5.71 |
| CHE/AMP04 | 3084 | 4550 | Cl8 | $r$ |  |  | 14.35 | 14.58 | 26.20 | 102.31 | 96.85 | 9.44 |
| CHE/AMP04 | 3084 | 4550 | C24 | I | $y$ | $y$ | 10.60 | 11.17 | 18.17 | 98.82 | 95.43 | 5.83 |
| CHE/AMP04 | 3084 | 4550 | C25 | $r$ |  |  | 11.58 | 12.34 | 20.30 | 108.86 | 104.02 | 6.06 |
| CHE/AMP04 | 3084 | 4550 | C26 | 1 |  | $y$ | 11.43 | 12.20 | 20.16 | 107.72 | 104.23 | 6.03 |
| CHE/AMP04 | 3084 | 4550 | C27 | r |  |  | 10.59 | 11.58 | 19.32 | 102.92 | 99.59 | 5.56 |
| CHE/AMP04 | 3084 | 4550 | C28 | 1 | $y$ | $y$ | 10.57 | 11.56 | 19.38 | 102.50 | 98.96 | 5.49 |
| CHE/AMP04 | 3084 | $4550$ | C29 | r |  |  | 11.22 | $11.90$ | $20.20$ | 110.92 | 106.74 | 5.91 |
| CHE/AMP04 | 3084 | 4531 | C99 | r |  |  | 13.33 | 14.12 | 23.48 | 124.57 | 118.45 | 7.08 |
| CHE/AMP04 | 3084 | 4531 | Cl00 | 1 | $y$ | $y$ | 11.34 | 11.41 | 19.29 | 103.86 | 100.17 | 5.74 |
| CHE/AMP04 | 3084 | 4527 | Cl08 | I | $y$ | $y$ | 12.19 | 11.73 | 19.97 | 109.67 | 105.66 | 6.41 |
| CHE/AMP04 | 3084 | 4535 | CI32 | I | $y$ | $y$ | 10.17 | 10.60 | 18.48 | 103.73 | 99.03 | 5.86 |
| CHE/AMP04 | 3084 | 4540 | CI46 | 1 | $y$ | $y$ | 11.34 | 12.85 | 21.79 | 114.08 | 110.19 | 6.42 |
| CHE/AMP04 | 3084 | 4546 | CI48 | $r$ |  |  | 11.55 | 11.45 | 18.78 | 103.53 | 99.63 | 5.70 |
| CHE/AMP04 | 3084 | 4546 | CI50 | 1 | $y$ | $y$ | 10.85 | 11.39 | 19.70 | 102.54 | 98.24 | 6.01 |
| CHE/AMP04 | 3084 | 4549 | CI70 | 1 | $y$ | $y$ | 13.18 | 13.54 | 23.93 | 126.81 | 122.24 | 7.49 |


| Chester - tibiotarsus |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. <br> Ratio | GMM | Bd | Dd | Dip | GL | La | SC |
| CHE/AMP04 | 3084 | 4530 | CI74 | $r$ |  |  | 12.92 | 13.39 | 23.58 | 127.14 | 123.28 | 6.50 |
| CHE/AMP04 | 3084 | 4530 | CI75 | 1 | $y$ | $y$ | 12.82 | 13.43 | 23.33 | 126.48 | 122.26 | 7.10 |
| CHE/AMP04 | 3084 | 4530 | CI76 | I | $y$ | $y$ | 11.61 | 11.93 | 19.76 | 106.46 | 103.60 | 5.66 |
| CHE/AMP04 | 3084 | 4530 | CI77 | 1 | y | $y$ | 11.02 | 11.45 | 19.01 | 103.52 | 99.89 | 5.80 |
| CHE/AMP04 | 3084 | 4530 | CI78 | $r$ |  |  | 11.97 | 12.49 | 20.93 | 116.01 | 111.58 | 6.09 |
| CHE/AMP04 | 3084 | 4548 | C194 | r |  |  | 11.50 | 11.33 | 19.40 | 102.95 | 98.19 | 5.68 |
| CHE/AMP04 | 3084 | 4547 | C216 | r |  |  | 13.06 | 13.45 | 23.19 | 126.41 | 122.04 | 7.25 |

### 3.6.4.2 Measurement ratios - tibiotarsus

| Chester tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| C024 | 58.34 | 10.73 | 11.30 | 55.00 | 5.90 | 11.11 | 11.70 | 6.11 | 94.90 | 61.47 | 18.39 | 32.09 | 19.04 | 96.57 | 52.19 |
| C026 | 56.70 | 10.61 | 11.33 | 52.76 | 5.60 | 10.97 | 11.70 | 5.79 | 93.69 | 60.52 | 18.72 | 29.91 | 19.34 | 96.76 | 49.43 |
| C028 | 54.54 | 10.31 | 11.28 | 51.94 | 5.36 | 10.68 | 11.68 | 5.55 | 91.44 | 59.65 | 18.91 | 28.33 | 19.58 | 96.55 | 47.49 |
| Cl00 | 58.79 | 10.92 | 10.99 | 50.62 | 5.53 | 11.32 | 11.39 | 5.73 | 99.39 | 59.15 | 18.57 | 29.76 | 19.26 | 96.45 | 50.31 |
| Cl08 | 61.04 | 11.12 | 10.70 | 52.58 | 5.84 | 11.54 | 11.10 | 6.07 | 103.92 | 58.74 | 18.21 | 32.10 | 18.90 | 96.34 | 54.65 |
| CI32 | 55.03 | 9.80 | 10.22 | 57.62 | 5.65 | 10.27 | 10.70 | 5.92 | 95.94 | 57.36 | 17.82 | 31.71 | 18.66 | 95.47 | 55.28 |
| CI46 | 52.04 | 9.94 | 11.26 | 56.61 | 5.63 | 10.29 | 11.66 | 5.83 | 88.25 | 58.97 | 19.10 | 29.46 | 19.77 | 96.59 | 49.96 |
| CI50 | 55.08 | 10.58 | 11.11 | 55.39 | 5.86 | 11.04 | 11.59 | 6.12 | 95.26 | 57.82 | 19.21 | 30.51 | 20.05 | 95.81 | 52.77 |


| Chester tibiotarsi measurement ratios |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| CI70 | 55.08 | 10.39 | 10.68 | 56.83 | 5.91 | 10.78 | 11.08 | 6.13 | 97.34 | 56.58 | 18.87 | 31.30 | 19.58 | 96.40 | 55.32 |
| CI75 | 54.95 | 10.14 | 10.62 | 55.38 | 5.61 | 10.49 | 10.98 | 5.81 | 95.46 | 57.57 | 18.45 | 30.43 | 19.08 | 96.66 | 52.87 |
| CI76 | 58.76 | 10.91 | 11.21 | 48.75 | 5.32 | 11.21 | 11.52 | 5.46 | 97.32 | 60.37 | 18.56 | 28.64 | 19.07 | 97.31 | 47.44 |
| CI77 | 57.97 | 10.65 | 11.06 | 52.63 | 5.60 | 11.03 | 11.46 | 5.81 | 96.24 | 60.23 | 18.36 | 30.51 | 19.03 | 96.49 | 50.66 |

### 3.6.5 Chester tarsometatarsus

### 3.6.5.1 Standard metrics - tarsometatarsus

| Chester - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC | Spur Length |
| CHE/AMP04 | 3021 | - | C002 | 1 | y | $y$ | 13.71 | 14.23 | 82.27 | 7.01 |  |
| CHE/AMP04 | 3084 | 4550 | C017 | r |  |  | 17.41 | 17.64 | 73.23 | 8.87 |  |
| CHE/AMP04 | 3084 | 4550 | C019 | r |  |  | 12.37 | 12.22 | 68.52 | 5.85 |  |
| CHE/AMP04 | 3084 | 4550 | C020 | r |  |  | 15.49 | 13.26 | 82.62 | 7.14 | 12.91 |
| CHE/AMP04 | 3084 | 4550 | C02I | r |  |  | 13.06 | 12.76 | 75.96 | 5.83 |  |
| CHE/AMP04 | 3084 | 4550 | C022 | 1 | $y$ | $y$ | 13.29 | 12.77 | 70.57 | 6.08 |  |
| CHE/AMP04 | 3084 | 4550 | C023 | 1 | $y$ | $y$ | 13.32 | 13.15 | 74.06 | 6.06 |  |
| CHE/AMP04 | 3084 | 4537 | CI24 | 1 | $y$ | $y$ | 15.01 | 15.58 | 87.78 | 6.86 |  |
| CHE/AMP04 | 3084 | 4534 | CI26 | 1 | $y$ | $y$ | 13.44 | 12.74 | 75.58 | 6.18 |  |


| Chester - tarsometatarsus |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Site code | Context | Sample no | ID | Side | Meas. <br> Ratio | GMM | Bd | Bp | GL | SC |  |
| CHE/AMP04 | 3084 | 4534 | Cl27 | $r$ |  |  | 14.34 | 14.44 | 87.81 | 7.72 | 13.69 |
| CHE/AMP04 | 3084 | 4528 | CI39 | $r$ |  |  | 12.34 | 11.46 | 69.11 | 5.85 |  |
| CHE/AMP04 | 3084 | 4540 | CI45 | r |  |  | 13.42 | 12.67 | 73.6 | 6.12 |  |
| CHE/AMP04 | 3084 | 4549 | CI7I | r |  |  | 14.41 | 14.63 | 85.4 | 7.23 |  |
| CHE/AMP04 | 3084 | 4530 | Cl80 | 1 | $y$ | $y$ | 14.81 | 14.35 | 84.71 | 7.16 | 9.59 |
| CHE/AMP04 | 3084 | 4530 | CI8I | r |  |  | 15.05 | 14.7 | 87.87 | 7.68 | 10.74 |
| CHE/AMP04 | 3084 | 4544 | C193 | 1 | $y$ | $y$ | 12.27 | 11.49 | 68.53 | 6.07 |  |
| CHE/AMP04 | 3084 | 4547 | C217 | 1 | $y$ | $y$ | 14.53 | 13.84 | 84.66 | 7.3 | 9.82 |
| CHE/AMP04 | 3084 | 4547 | C218 | 1 | $y$ | $y$ | 12.51 | 12.18 | 68.4I | 5.95 |  |

### 3.6.5.2 Measurement ratios - tarsometatarsus

| Chester tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Sex | $\mathbf{B d} / \mathbf{B p}$ | $\mathbf{S C} / \mathbf{B d}$ | $\mathbf{S C} / \mathbf{G L}$ | $\mathbf{B p / G L}$ | $\mathbf{B d / G L}$ | $\mathbf{S C} / \mathbf{B p}$ |
| C 002 | u | 96.35 | 5 I .13 | 8.52 | 17.30 | 16.66 | 49.26 |
| C 022 | u | 104.07 | 45.75 | 8.62 | 18.10 | I 8.83 | 47.6 I |
| C 023 | u | 10 I .29 | 45.50 | 8.18 | 17.76 | 17.99 | 46.08 |
| Cl 24 | m | 96.34 | 45.70 | 7.8 I | 17.75 | 17.10 | 44.03 |
| Cl 26 | u | 105.49 | 45.98 | 8.18 | 16.86 | 17.78 | 48.5 I |
| Cl 80 | m | 103.2 I | 48.35 | 8.45 | 16.94 | 17.48 | 49.90 |


| Chester tarsometatarsi measurement ratios |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| ID | Sex | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| Cl 193 | u | 106.79 | 49.47 | 8.86 | 16.77 | 17.90 | 52.83 |
| C 217 | m | 104.99 | 50.24 | 8.62 | 16.35 | 17.16 | 52.75 |
| C 218 | u | 102.7 I | 47.56 | 8.70 | 17.80 | 18.29 | 48.85 |

### 3.7 Archaeological GLs for Kernel Density Estimates

### 3.7.I Lyminge

| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ |
| 48.02 | -0.0767 | 63.85 | -0.0641 | 66.78 | -0.1058 | 101.25 | -0.0606 | 64.16 | -0.0787 | 64.64 | -0.0646 |
| 48.24 | -0.0747 | 63.29 | -0.0679 | 68.11 | -0.0972 | 96.93 | -0.0795 | 70.47 | -0.0379 | 70.36 | -0.0277 |
| 48.64 | -0.0712 | 74.84 | 0.0049 | 69.66 | -0.0875 | 94.13 | -0.0922 | 65.61 | -0.0690 | 62.29 | -0.0806 |
| 50.18 | -0.0576 | 59.94 | -0.0915 | 65.20 | -0.1162 | 94.34 | -0.0913 | 62.87 | -0.0875 | 58.93 | -0.1047 |
| 50.92 | -0.0513 | 66.75 | -0.0448 | 65.97 | -0.1111 | 115.59 | -0.0030 | 69.56 | -0.0436 | 75.45 | 0.0026 |
| 47.80 | -0.0787 | 66.60 | -0.0458 | 83.19 | -0.0104 | 100.31 | -0.0646 | 71.63 | -0.0308 | 60.39 | -0.0941 |
| 48.62 | -0.0713 | 64.11 | -0.0623 | 69.51 | -0.0884 | 112.45 | -0.0150 | 77.00 | 0.0006 | 61.19 | -0.0884 |
| 49.47 | -0.0638 | 74.96 | 0.0056 | 67.78 | -0.0993 | 112.81 | -0.0136 | 62.24 | -0.0919 | 61.73 | -0.0846 |
| 47.92 | -0.0776 | 61.50 | -0.0804 | 70.55 | -0.0819 | 97.63 | -0.0764 | 61.19 | -0.0992 | 69.05 | -0.0359 |
| 50.11 | -0.0582 | 66.15 | -0.0487 | 71.23 | -0.0778 | 99.90 | -0.0664 | 64.05 | -0.0794 | 64.70 | -0.0642 |
| 50.08 | -0.0585 | 72.34 | -0.0099 | 72.76 | -0.0685 | 100.88 | -0.062I | 61.04 | -0.1003 | 60.87 | -0.0907 |


| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ |
| 55.25 | -0.0158 | 74.89 | 0.0052 | 70.77 | -0.0806 | 97.61 | -0.0765 | 82.87 | 0.0325 | 59.70 | -0.0991 |
| 58.37 | 0.0080 | 66.78 | -0.0446 | 70.29 | -0.0835 | 97.17 | -0.0784 | 64.73 | -0.0748 | 63.99 | -0.0689 |
| 56.55 | -0.0057 | 63.78 | -0.0645 | 68.75 | -0.0932 | 97.83 | -0.0755 | 67.73 | -0.0551 | 63.40 | -0.0730 |
| 53.60 | -0.0290 | 64.19 | -0.0618 | 70.16 | -0.0844 | 101.64 | -0.0589 | 63.19 | -0.0853 | 61.30 | -0.0876 |
| 49.03 | -0.0677 | 62.35 | -0.0744 | 71.04 | -0.0789 | 95.00 | -0.0882 | 66.10 | -0.0657 | 59.56 | -0.1001 |
| 46.73 | -0.0886 | 65.39 | -0.0537 | 80.87 | -0.0227 | 91.15 | -0.1062 | 66.89 | -0.0606 | 63.45 | -0.0726 |
| 47.74 | -0.0793 | 66.11 | -0.0490 | 80.59 | -0.0242 | 99.34 | -0.0688 | 67.48 | -0.0568 | 61.60 | -0.0855 |
| 49.61 | -0.0626 | 65.90 | -0.0503 | 70.38 | -0.0830 | 97.56 | -0.0767 | 64.12 | -0.0789 | 77.70 | 0.0154 |
| 49.50 | -0.0635 | 63.14 | -0.0689 | 71.96 | -0.0733 | 99.57 | -0.0678 | 65.42 | -0.0702 | 70.79 | -0.025 |
| 55.57 | -0.0133 | 68.31 | -0.0347 | 70.20 | -0.0841 | 99.41 | -0.0685 | 66.39 | -0.0638 | 62.63 | -0.0783 |
| 46.17 | -0.0938 | 64.40 | -0.0603 | 71.12 | -0.0784 | 105.37 | -0.0432 | 70.29 | -0.0390 | 62.59 | -0.0786 |
| 47.40 | -0.0824 | 74.16 | 0.0009 | 70.69 | -0.0811 | 114.69 | -0.0064 | 61.13 | -0.0997 | 60.92 | -0.0903 |
| 46.59 | -0.0899 | 63.63 | -0.0656 | 67.34 | -0.1022 | 103.27 | -0.0520 | 65.58 | -0.0692 | 61.70 | -0.0848 |
| 48.75 | -0.0702 | 58.09 | -0.1051 | 73.52 | -0.0640 | 94.76 | -0.0893 | 66.26 | -0.0647 | 62.51 | -0.0791 |
| 49.35 | -0.0649 | 63.85 | -0.064I | 74.28 | -0.0596 | 111.29 | -0.0195 | 69.55 | -0.0436 | 62.54 | -0.0789 |
| 50.75 | -0.0527 | 64.40 | -0.0603 | 78.56 | -0.0352 | 99.88 | -0.0665 | 69.43 | -0.0444 | 64.58 | -0.0650 |
| 55.95 | -0.0104 | 62.51 | -0.0733 | 71.00 | -0.0792 | 98.43 | -0.0728 | 60.58 | -0.1036 | 74.58 | -0.0024 |
| 54.10 | -0.0250 | 61.53 | -0.0801 | 72.12 | -0.0724 | 117.09 | 0.0026 | 65.88 | -0.0672 | 73.03 | -0.0116 |
| 49.17 | -0.0665 | 66.54 | -0.0461 | 71.26 | -0.0776 | 96.11 | -0.0832 | 66.23 | -0.0649 | 65.77 | -0.0570 |
| 54.23 | -0.0239 | 66.16 | -0.0486 | 81.77 | -0.0178 | 97.83 | -0.0755 | 70.08 | -0.0403 | 64.12 | -0.0681 |
| 48.57 | -0.0718 | 64.12 | -0.0622 | 72.43 | -0.0705 | 98.52 | -0.0724 | 64.12 | -0.0789 | 75.17 | 0.0010 |
| 50.51 | -0.0548 | 63.22 | -0.0684 | 69.93 | -0.0858 | 112.84 | -0.0135 | 63.73 | -0.0816 | 58.33 | -0.1092 |
| 56.19 | -0.0085 | 61.60 | -0.0797 | 70.82 | -0.0803 | 113.45 | -0.0111 | 67.11 | -0.0591 | 62.58 | -0.0786 |


| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ |
| 56.10 | -0.0092 | 64.36 | -0.0606 | 67.00 | -0.1044 | 99.02 | -0.0702 | 67.45 | -0.0569 | 64.40 | -0.0662 |
| 48.34 | -0.0738 | 65.11 | -0.0556 | 74.81 | -0.0565 | 97.23 | -0.0782 | 64.77 | -0.0746 | 64.40 | -0.0662 |
| 51.78 | -0.0440 | 62.94 | -0.0703 | 68.26 | -0.0963 | 100.38 | -0.0643 | 64.93 | -0.0735 | 63.10 | -0.0750 |
| 56.22 | -0.0083 | 67.88 | -0.0375 | 72.33 | -0.0711 | 115.13 | -0.0048 | 68.90 | -0.0477 |  |  |
| 57.40 | 0.0008 | 69.03 | -0.0302 | 70.51 | -0.0822 | 94.24 | -0.0917 | 69.09 | -0.0465 |  |  |
| 56.76 | -0.0041 | 59.36 | -0.0957 | 57.63 | -0.1698 | 109.10 | -0.0281 | 66.91 | -0.0604 |  |  |
| 47.21 | -0.0841 | 62.90 | -0.0706 | 83.41 | -0.0092 | 95.40 | -0.0864 | 68.88 | -0.0478 |  |  |
| 48.54 | -0.0721 | 64.99 | -0.0564 | 68.69 | -0.0935 | 100.20 | -0.0651 | 69.02 | -0.0470 |  |  |
| 49.85 | -0.0605 | 62.34 | -0.0745 | 68.76 | -0.0931 | 100.40 | -0.0642 | 68.19 | -0.0522 |  |  |
| 45.71 | -0.0981 | 72.57 | -0.0085 | 68.75 | -0.0932 | 102.40 | -0.0557 | 65.41 | -0.0703 |  |  |
| 54.93 | -0.0183 | 58.74 | -0.1003 | 71.86 | -0.0740 |  |  | 64.18 | -0.0785 |  |  |
| 53.86 | -0.0269 | 64.96 | -0.0566 | 66.00 | -0.1109 |  |  | 65.88 | -0.0672 |  |  |
| 60.72 | 0.0252 | 64.23 | -0.0615 | 69.57 | -0.0880 |  |  | 63.90 | -0.0804 |  |  |
| 56.78 | -0.0040 | 61.44 | -0.0808 | 70.68 | -0.0811 |  |  | 67.00 | -0.0599 |  |  |
| 48.24 | -0.0747 | 72.32 | -0.0100 | 75.45 | -0.0528 |  |  | 68.61 | -0.0495 |  |  |
| 48.40 | -0.0733 | 66.59 | -0.0458 | 69.50 | -0.0885 |  |  | 65.15 | -0.0720 |  |  |
| 48.82 | -0.0696 | 63.18 | -0.0687 | 69.48 | -0.0886 |  |  | 64.76 | -0.0746 |  |  |
| 57.07 | -0.0017 | 65.49 | -0.0531 | 80.12 | -0.0267 |  |  | 67.82 | -0.0546 |  |  |
| 48.36 | -0.0737 | 61.42 | -0.0809 | 65.85 | -0.1119 |  |  | 70.68 | -0.0366 |  |  |
| 54.41 | -0.0225 | 62.36 | -0.0743 | 71.06 | -0.0788 |  |  | 66.12 | -0.0656 |  |  |
| 50.20 | -0.0575 | 64.97 | -0.0565 | 69.54 | -0.0882 |  |  | 79.13 | 0.0124 |  |  |
| 58.42 | 0.0084 | 72.22 | -0.0106 | 69.97 | -0.0855 |  |  | 68.85 | -0.0480 |  |  |
| 55.21 | -0.0161 | 59.52 | -0.0946 | 78.37 | -0.0363 |  |  | 69.56 | -0.0436 |  |  |


| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ |
| 56.93 | -0.0028 | 72.29 | -0.0102 | 67.37 | -0.1020 |  |  | 77.02 | 0.0007 |  |  |
| 49.54 | -0.0632 | 73.01 | -0.0058 | 71.32 | -0.0772 |  |  | 66.46 | -0.0634 |  |  |
| 49.01 | -0.0679 | 61.90 | -0.0775 | 70.30 | -0.0835 |  |  | 64.66 | -0.0753 |  |  |
| 57.78 | 0.0036 | 64.42 | -0.0602 | 70.15 | -0.0844 |  |  | 64.70 | -0.0750 |  |  |
| 44.45 | -0.1103 | 66.33 | -0.0475 | 84.94 | -0.0013 |  |  | 60.86 | -0.1016 |  |  |
| 49.40 | -0.0644 | 62.76 | -0.0715 | 72.65 | -0.0692 |  |  | 68.92 | -0.0476 |  |  |
| 50.60 | -0.0540 | 71.39 | -0.0156 | 72.15 | -0.0722 |  |  | 61.39 | -0.0978 |  |  |
| 49.60 | -0.0627 | 65.52 | -0.0529 | 78.40 | -0.0361 |  |  | 63.17 | -0.0854 |  |  |
| 48.90 | -0.0688 | 75.79 | 0.0104 | 69.50 | -0.0885 |  |  | 65.34 | -0.0707 |  |  |
|  |  | 60.89 | -0.0847 | 72.70 | -0.0689 |  |  | 63.58 | -0.0826 |  |  |
|  |  | 63.91 | -0.0637 | 73.00 | -0.0671 |  |  | 67.08 | -0.0593 |  |  |
|  |  | 72.10 | -0.0113 | 74.10 | -0.0606 |  |  | 67.70 | -0.0553 |  |  |
|  |  | 66.80 | -0.0445 |  |  |  |  | 60.64 | -0.1032 |  |  |
|  |  | 65.60 | -0.0523 |  |  |  |  | 66.15 | -0.0654 |  |  |
|  |  | 66.40 | -0.0471 |  |  |  |  | 66.08 | -0.0659 |  |  |
|  |  | 64.30 | -0.0610 |  |  |  |  | 66.28 | -0.0645 |  |  |
|  |  |  |  |  |  |  |  | 67.90 | -0.054 I |  |  |
|  |  |  |  |  |  |  |  | 63.71 | -0.0817 |  |  |
|  |  |  |  |  |  |  |  | 69.93 | -0.0413 |  |  |
|  |  |  |  |  |  |  |  | 65.37 | -0.0705 |  |  |
|  |  |  |  |  |  |  |  | 60.53 | -0.1040 |  |  |
|  |  |  |  |  |  |  |  | 73.24 | -0.0212 |  |  |
|  |  |  |  |  |  |  |  | 76.44 | -0.0026 |  |  |


| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ |
|  |  |  |  |  |  |  |  | 61.41 | -0.0977 |  |  |
|  |  |  |  |  |  |  |  | 73.80 | -0.0179 |  |  |
|  |  |  |  |  |  |  |  | 76.93 | 0.0002 |  |  |
|  |  |  |  |  |  |  |  | 66.76 | -0.0614 |  |  |
|  |  |  |  |  |  |  |  | 66.70 | -0.0618 |  |  |
|  |  |  |  |  |  |  |  | 76.05 | -0.0048 |  |  |
|  |  |  |  |  |  |  |  | 68.93 | -0.0475 |  |  |
|  |  |  |  |  |  |  |  | 65.33 | -0.0708 |  |  |
|  |  |  |  |  |  |  |  | 65.96 | -0.0666 |  |  |
|  |  |  |  |  |  |  |  | 67.27 | -0.0581 |  |  |
|  |  |  |  |  |  |  |  | 63.44 | -0.0836 |  |  |
|  |  |  |  |  |  |  |  | 68.00 | -0.0534 |  |  |
|  |  |  |  |  |  |  |  | 65.59 | -0.0691 |  |  |
|  |  |  |  |  |  |  |  | 66.85 | -0.0608 |  |  |
|  |  |  |  |  |  |  |  | 77.42 | 0.0029 |  |  |
|  |  |  |  |  |  |  |  | 63.47 | -0.0834 |  |  |
|  |  |  |  |  |  |  |  | 66.25 | -0.0647 |  |  |
|  |  |  |  |  |  |  |  | 70.86 | -0.0355 |  |  |
|  |  |  |  |  |  |  |  | 70.95 | -0.0350 |  |  |
|  |  |  |  |  |  |  |  | 77.37 | 0.0026 |  |  |
|  |  |  |  |  |  |  |  | 57.57 | -0.1257 |  |  |
|  |  |  |  |  |  |  |  | 62.80 | -0.0880 |  |  |
|  |  |  |  |  |  |  |  | 67.90 | -0.0541 |  |  |


| Lyminge |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ | GL | $\begin{gathered} \hline \text { Log } \\ \text { scaled } \end{gathered}$ |
|  |  |  |  |  |  |  |  | 69.50 | -0.0439 |  |  |
|  |  |  |  |  |  |  |  | 58.44 | -0.1192 |  |  |

### 3.7.2 Chester

| Chester |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled |
| 58.61 | 0.0098 | 69.80 | -0.0254 | 1.97 | 0.0379 | 98.82 | -0.0711 | 82.27 | 0.0293 | 79.72 | 0.0265 |
| 61.42 | 0.0302 | 67.67 | -0.0388 | 1.95 | 0.0167 | 107.72 | -0.0337 | 70.57 | -0.0373 | 80.14 | 0.0288 |
| 54.13 | -0.0247 | 65.72 | -0.0515 | 1.94 | 0.0096 | 102.50 | -0.0552 | 74.06 | -0.0163 | 68.29 | -0.0407 |
| 52.28 | -0.0398 | 72.53 | -0.0087 | 1.84 | -0.0917 | 103.86 | -0.0495 | 87.78 | 0.0575 | 63.59 | -0.0717 |
| 57.18 | -0.0009 | 69.20 | -0.0291 | 1.90 | -0.0343 | 109.67 | -0.0259 | 75.58 | -0.0075 | 69.62 | -0.0323 |
| 50.37 | -0.0560 | 61.79 | -0.0783 | 1.95 | 0.0239 | 103.73 | -0.0500 | 84.71 | 0.0420 | 64.91 | -0.0627 |
| 55.33 | -0.0152 | 81.60 | 0.0425 | 1.87 | -0.0608 | 114.08 | -0.0087 | 68.53 | -0.0500 | 64.84 | -0.0632 |
| 47.33 | -0.0830 | 82.60 | 0.0477 | 1.87 | -0.0626 | 102.54 | -0.0551 | 84.66 | 0.0418 | 75.45 | 0.0026 |
| 50.63 | -0.0537 | 68.58 | -0.0330 | 1.91 | -0.0174 | 126.81 | 0.0372 | 68.41 | -0.0508 | 64.41 | -0.0661 |
| 55.47 | -0.0141 | 72.54 | -0.0087 | 1.94 | 0.0064 | 126.48 | 0.0361 |  |  | 70.23 | -0.0285 |
| 52.70 | -0.0363 | 66.48 | -0.0465 | 1.87 | -0.0638 | 106.46 | -0.0388 |  |  | 71.33 | -0.0218 |
| 57.95 | 0.0049 | 81.44 | 0.0416 |  |  | 103.52 | -0.0509 |  |  | 78.50 | 0.0198 |
| 61.32 | 0.0294 |  |  |  |  |  |  |  |  | 80.88 | 0.0328 |

### 3.7.3 Uley

| Uley |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled |
| 52.73 | -0.0361 | 69.99 | -0.0242 | 69.99 | -0.0242 | 115.02 | -0.0052 | 80.25 | 0.0185 | 75.28 | 0.0016 |
| 55.28 | -0.0156 | 73.51 | -0.0029 | 76.47 | 0.0143 | 116.51 | 0.0004 | 82.26 | 0.0293 | 67.80 | -0.0438 |
| 52.68 | -0.0365 | 76.47 | 0.0143 | 68.03 | -0.0365 | 109.78 | -0.0254 | 80.78 | 0.0214 | 75.01 | 0.0001 |
| 56.90 | -0.0030 | 71.77 | -0.0133 | 72.43 | -0.0093 | 117.86 | 0.0054 | 81.80 | 0.0268 | 75.14 | 0.0008 |
| 57.80 | 0.0038 | 68.03 | -0.0365 | 73.42 | -0.0034 |  |  | 82.70 | 0.0316 | 71.92 | -0.0182 |
| 56.43 | -0.0066 | 72.43 | -0.0093 | 78.48 | 0.0255 |  |  | 80.00 | 0.0172 | 65.17 | -0.0610 |
| 59.38 | 0.0155 | 73.42 | -0.0034 | 74.84 | 0.0049 |  |  | 79.32 | 0.0135 | 74.91 | -0.0005 |
| 58.86 | 0.0117 | 69.77 | -0.0256 | 75.83 | 0.0106 |  |  | 77.20 | 0.0017 | 71.14 | -0.0229 |
| 56.38 | -0.0070 | 78.48 | 0.0255 | 73.60 | -0.0024 |  |  | 76.98 | 0.0005 | 70.21 | -0.0287 |
| 57.85 | 0.0041 | 74.84 | 0.0049 | 73.32 | -0.0040 |  |  | 79.58 | 0.0149 | 70.54 | -0.0266 |
| 56.54 | -0.0058 | 75.83 | 0.0106 | 69.58 | -0.0267 |  |  | 84.47 | 0.0408 | 70.72 | -0.0255 |
| 56.38 | -0.0070 | 73.60 | -0.0024 | 70.30 | -0.0223 |  |  |  |  | 71.50 | -0.0208 |
| 53.22 | -0.0321 | 73.32 | -0.0040 | 66.73 | -0.0449 |  |  |  |  | 77.31 | 0.0132 |
| 54.25 | -0.0238 | 69.58 | -0.0267 | 76.45 | 0.0141 |  |  |  |  | 69.83 | -0.0310 |
| 56.24 | -0.0081 | 70.30 | -0.0223 | 72.54 | -0.0087 |  |  |  |  | 71.97 | -0.0179 |
| 58.71 | 0.0106 | 66.73 | -0.0449 | 63.29 | -0.0679 |  |  |  |  | 72.67 | -0.0137 |
| 53.47 | -0.0300 | 76.45 | 0.0141 | 63.20 | -0.0685 |  |  |  |  |  |  |
| 57.00 | -0.0023 | 72.54 | -0.0087 | 71.82 | -0.0130 |  |  |  |  |  |  |
| 54.65 | -0.0206 | 63.29 | -0.0679 |  |  |  |  |  |  |  |  |
| 57.08 | -0.0017 | 63.20 | -0.0685 |  |  |  |  |  |  |  |  |
| 53.20 | -0.0322 | 71.82 | -0.0130 |  |  |  |  |  |  |  |  |


| Uley |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coracoid |  | Humerus |  | Femur |  | Tibiotarsus |  | Tarsometatarsus |  | Ulna |  |
| GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled |
| 53.40 | -0.0306 | 72.35 | -0.0098 |  |  |  |  |  |  |  |  |
| 54.13 | -0.0247 | 75.49 | 0.0087 |  |  |  |  |  |  |  |  |
| 46.86 | -0.0874 | 72.75 | -0.0074 |  |  |  |  |  |  |  |  |
| 52.19 | -0.0406 |  |  |  |  |  |  |  |  |  |  |
| 54.79 | -0.0195 |  |  |  |  |  |  |  |  |  |  |
| 56.50 | -0.0061 |  |  |  |  |  |  |  |  |  |  |
| 50.90 | -0.0514 |  |  |  |  |  |  |  |  |  |  |
| 55.26 | -0.0157 |  |  |  |  |  |  |  |  |  |  |
| 48.93 | -0.0686 |  |  |  |  |  |  |  |  |  |  |
| 57.47 | 0.0013 |  |  |  |  |  |  |  |  |  |  |
| 50.71 | -0.0531 |  |  |  |  |  |  |  |  |  |  |
| 58.32 | 0.0077 |  |  |  |  |  |  |  |  |  |  |
| 58.79 | 0.0111 |  |  |  |  |  |  |  |  |  |  |
| 48.32 | -0.0740 |  |  |  |  |  |  |  |  |  |  |
| 56.18 | -0.0086 |  |  |  |  |  |  |  |  |  |  |

### 3.7.4 Fishbourne, Coppergate and Flixborough coracoids

| Fishbourne |  | Coppergate |  |  |  |  | Flixborough |  |
| :---: | ---: | ---: | ---: | :---: | ---: | ---: | ---: | :---: |
| GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled |  |
| 51.84 | -0.0435 | 48.60 | -0.0715 | 48.80 | -0.0697 | 56.60 | -0.0053 |  |
| 44.83 | -0.1066 | 48.51 | -0.0723 | 54.24 | -0.0238 | 53.80 | -0.0274 |  |
| 50.66 | -0.0535 | 58.09 | 0.0059 | 49.57 | -0.0629 | 55.60 | -0.0131 |  |
| 56.82 | -0.0037 | 54.90 | -0.0186 | 47.77 | -0.0790 | 46.50 | -0.0907 |  |
| 51.12 | -0.0496 | 54.04 | -0.0254 | 49.01 | -0.0679 | 50.10 | -0.0583 |  |
| 58.26 | 0.0072 | 58.63 | 0.0100 | 56.25 | -0.0080 | 50.70 | -0.0531 |  |
| 46.14 | -0.0941 | 47.74 | -0.0793 | 54.17 | -0.0244 | 48.90 | -0.0688 |  |
| 56.55 | -0.0057 | 50.59 | -0.0541 | 53.76 | -0.0277 | 50.70 | -0.0531 |  |
| 47.54 | -0.0811 | 47.82 | -0.0785 | 46.34 | -0.0922 | 53.40 | -0.0306 |  |
| 58.82 | 0.0114 | 46.16 | -0.0939 | 47.73 | -0.0794 | 51.60 | -0.0455 |  |
| 48.13 | -0.0757 | 58.57 | 0.0095 | 49.39 | -0.0645 | 56.50 | -0.0061 |  |
| 57.17 | -0.0010 | 56.95 | -0.0027 | 55.36 | -0.0150 | 51.54 | -0.0460 |  |
| 48.33 | -0.0739 | 56.25 | -0.0080 | 52.49 | -0.0381 | 47.30 | -0.0833 |  |
| 48.36 | -0.0737 | 48.03 | -0.0766 | 47.00 | -0.0861 | 47.30 | -0.0833 |  |
|  |  | 51.76 | -0.0442 | 47.32 | -0.0831 | 55.30 | -0.0154 |  |
|  |  | 50.58 | -0.0542 | 56.64 | -0.0050 | 49.70 | -0.0618 |  |
|  |  | 49.84 | -0.0606 | 52.42 | -0.0387 | 56.40 | -0.0069 |  |
|  |  | 57.01 | -0.0022 | 53.33 | -0.0312 | 53.76 | -0.0277 |  |
|  |  | 53.95 | -0.0262 | 46.09 | -0.0945 | 56.30 | -0.0076 |  |
|  |  | 53.59 | -0.0291 | 54.39 | -0.0226 | 50.50 | -0.0549 |  |


| Fishbourne |  | Coppergate |  |  |  |  | Flixborough |  |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: | ---: | :---: |
| GL | Log scaled | GL | Log scaled | GL | Log scaled | GL | Log scaled |  |
|  |  | 57.44 | 0.0011 | 55.64 | -0.0128 | 47.50 | -0.0815 |  |
|  |  | 44.40 | -0.1108 | 50.30 | -0.0566 | 49.00 | -0.0680 |  |
|  |  | 53.61 | -0.0289 | 56.80 | -0.0038 | 52.40 | -0.0388 |  |
|  |  | 49.22 | -0.0660 | 44.98 | -0.1051 | 49.60 | -0.0627 |  |
|  |  | 57.52 | 0.0017 | 57.72 | 0.0032 | 47.80 | -0.0787 |  |
|  |  | 55.88 | -0.0109 | 50.45 | -0.0553 | 56.90 | -0.0030 |  |
|  |  | 58.19 | 0.0067 | 54.58 | -0.0211 | 55.30 | -0.0154 |  |
|  |  | 54.88 | -0.0187 | 50.48 | -0.0550 | 48.34 | -0.0738 |  |
|  |  | 52.13 | -0.0411 | 48.99 | -0.0680 | 57.72 | 0.0032 |  |
|  |  | 59.13 | -0.0495 | 55.09 | -0.0171 | 49.33 | -0.0650 |  |
|  |  | 53.05 | -0.0335 | 50.05 | -0.0588 |  |  |  |
|  |  | 46.24 | -0.0931 | 54.75 | -0.0198 |  |  |  |
|  |  | 49.34 | -0.0650 | 51.50 | -0.0463 |  |  |  |
|  |  | 56.69 | -0.0046 | 57.45 | 0.0011 |  |  |  |
|  |  | 54.89 | -0.0187 | 57.92 | 0.0047 |  |  |  |
|  |  | 47.14 | -0.0848 | 51.20 | -0.0489 |  |  |  |
|  |  | 56.44 | -0.0066 | 48.05 | -0.0765 |  |  |  |
|  |  | 53.69 | -0.0283 | 48.24 | -0.0747 |  |  |  |
|  |  | 54.85 | -0.0190 | 57.05 | -0.0019 |  |  |  |
|  |  | 54.97 | -0.0180 | 49.00 | -0.0680 |  |  |  |
|  |  | 58.51 | 0.0091 | 49.06 | -0.0674 |  |  |  |
|  |  |  | 51.44 | -0.0469 |  |  |  |  |

### 3.7.5 R code for producing kernel density plots - example

densityplot( $\sim$ Cor + Hum + Uln + Fem + Tbt + Tmt, data $=$ CHEEL.csv, auto.key $=$ TRUE, main=expression("Chester elements"), xlab = "Logscaled value")

### 3.8 Limb bone indices

| Specimens included in the limb bone indices study |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Breed | Sex | Femur \% | TBT\% | TMT\% | Brachial Index |
| a003 | Dorking | $f$ | 30.3772596 | 41.8096673 | 27.8130731 | 0.982626824 |
| e001 | Dorking | f | 30.948683 | 41.693873 | 27.357444 | 0.997097411 |
| e010 | RJF | f | 30.0487937 | 43.1643625 | 26.7868438 | 1.036490156 |
| e013 | OE Game | m | 28.3842527 | 41.6273802 | 29.9883671 | 1.003535723 |
| e014 | Dorking | m | 29.110541 | 41.594505 | 29.294954 | 0.994675507 |
| h003 | Silkie | f | 30.698668 | 42.267739 | 27.033593 | 1.020688614 |
| h01l | Dorking | f | 30.4740694 | 41.7944639 | 27.7314668 | 1.022086031 |
| n001 | OE Game | f | 29.382181 | 41.5954532 | 29.0223658 | 1.047641963 |
| r660 | Silkie | f | 30.8659767 | 41.3511507 | 27.7828726 | 1.019049118 |
| r661 | Silkie | f | 30.5302084 | 42.2533858 | 27.2164057 | 1.028621598 |
| r663 | OE Game | f | 30.0115075 | 41.5650173 | 28.4234753 | 1.032695957 |
| r666 | Silkie | m | 29.3934805 | 42.1614729 | 28.4450466 | 1.034472511 |
| r667 | OE Game | f | 29.826284 | 41.944864I | 28.228852 | 1.033352419 |
| r723 | Dorking | f | 30.5721118 | 41.6324637 | 27.7954245 | 1.0309238 |
| r724 | Dorking | f | 30.2058463 | 41.966187 | 27.8279667 | 1.024436312 |
| r732 | OE Game | m | 29.5282894 | 41.6125613 | 28.8591493 | 1.032905603 |
| r735 | OE Game | m | 29.8152324 | 4I.4I28496 | 28.771918 | 1.047354839 |


| Specimens included in the limb bone indices study |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ID | Breed | Sex | Femur \% | TBT\% | TMT\% | Brachial Index |
| r736 | Hamburgh | m | 28.4128386 | 42.0877503 | 29.4994111 | 1.011221945 |
| r740 | Hamburgh | m | 28.4405881 | 42.2270427 | 29.3323693 | 1.007216015 |
| r741 | Hamburgh | m | 28.6891978 | 41.9979923 | 29.3128099 | 1.013114754 |
| r742 | Hamburgh | f | 29.407787 | 42.0385793 | 28.5536337 | 1.016519096 |
| r651 | Hamburgh | m | 29.7414852 | 42.1130169 | 28.1454979 | 1.003886514 |
| t007 | Silkie | m | 29.8664612 | 41.7345367 | 28.3990021 | 1.029347529 |
| t022 | Hamburgh | m | 29.010829 | 42.0208087 | 28.9683623 | 1.007854338 |
| t032 | Silkie | f | 30.4125737 | 41.611002 | 27.9764244 | 1.024465327 |
| t034 | Silkie | m | 29.5477102 | 42.3684957 | 28.083794I | 0.991328341 |
| t04I | OE Game | m | 29.7820215 | 41.7928262 | 28.4251523 | 1.017287558 |
| t059 | RJF | m | 29.3779244 | 41.3975608 | 29.2245148 | 1.063445004 |
| t065 | Dorking | m | 30.0403377 | 41.5152958 | 28.4443665 | 1.022070313 |
| t143 | RJF | $f$ | 29.5629942 | 41.9345675 | 28.5024383 | 1.00875236 |
| t144 | RJF | m | 28.7159348 | 42.2071482 | 29.076917 | 1.023887728 |
| t145 | RJF | f | 29.9293741 | 42.3266557 | 27.7439702 | 1.041125541 |
| t146 | RJF | m | 29.1518259 | 42.4517594 | 28.3964147 | 1.011157803 |
| e004 | Hamburgh | f | 29.2194884 | 41.9846831 | 28.7958286 | 1.02735717 |
| w518 | OE Game | $f$ | 30.2322046 | 41.5194011 | 28.2483943 | 1.024020041 |
| w519 | RJF | f | 29.8431893 | 42.4470334 | 27.7097773 | 1.02843877 |
| w528 | Dorking | m | 30.5045613 | 41.5840748 | 27.9113639 | 1.007849618 |
| w537 | Dorking | f | 29.8227745 | 42.1470768 | 28.0301487 | 1.038276908 |
| w611 | OE Game | m | 28.5618622 | 41.8909439 | 29.5471939 | 1.012224024 |
| w612 | OE Game | m | 28.5718669 | 41.3710568 | 30.0570762 | 1.005993151 |
| z001 | RJF | m | 30.3167083 | 42.2613497 | 27.421942 | 1.026573427 |


| Specimens included in the limb bone indices study |  |  |  |  |  |  |
| :---: | :--- | :---: | :---: | :---: | :---: | :---: |
| ID | Breed | Sex | Femur \% | TBT\% | TMT\% | Brachial Index |
| ABG2 | Driff Terr | m | 28.9424799 | 42.1150401 | 28.9424799 | I .002291242 |
| ABG7 | Lyminge | f | 30.1910299 | 41.6112957 | 28.1976744 | I .01863354 |
| ABG9 | Lyminge | f | 30.1219512 | 41.6260163 | 28.2520325 | $\mathrm{n} / \mathrm{a}$ |
| SRD7I9 | W Deeping | f | 29.8706717 | 41.5936588 | 28.5356696 | I .019047619 |

## Appendix D: Statistical Analysis Linear Biometrics

## 4.I Measurement ratios

4.I.I Skewness

Bold $=$ highly skewed $<-I$ and $>1$

| Coracoid - skewness |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Dorking | 1.134 | 0.711 | 0.094 | -0.232 | 0.836 | 0.703 |
| Hamburgh | 2.007 | 0.309 | -0.773 | -0.533 | -0.172 | -0.112 |
| RJF | 0.216 | 0.727 | -0.281 | 0.019 | -0.710 | -0.623 |
| O E Game | -0.597 | 0.525 | 0.720 | 0.637 | 1.050 | 1.077 |
| Silkie | -0.92I | 0.984 | -1.686 | -1.248 | 1.593 | 1.570 |
| Asian Game | -1.22I | -0.840 | -1.849 | -1.408 | -0.392 | 0.625 |


| Humerus - skewness |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |  |
| Dorking | 0.086 | -0.029 | $-\mathbf{- I . 3 8 3}$ | 0.629 | 0.086 | 0.25 I |  |
| Hamburgh | 0.129 | 0.119 | $\mathbf{- I . 1 6 I}$ | 0.815 | 0.177 | 0.527 |  |
| RJF | 0.471 | -0.585 | -0.152 | -0.589 | $\mathbf{- 2 . 1 1 8}$ | -0.654 |  |
| O E Game | -0.039 | 0.078 | 0.526 | -0.833 | 0.116 | $\mathbf{- I . 3 3 0}$ |  |
| Silkie | 0.555 | 0.527 | -0.112 | -0.288 | 0.673 | 0.604 |  |
| Asian Game | 0.508 | 0.202 | -0.344 | -0.970 | 0.011 | 0.805 |  |


| Femur - skewness |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Dorking | 0.031 | 0.910 | 0.026 | 1.040 | 1.183 | 0.017 | 1.206 | 0.360 | 1.034 | -0.199 | -0.202 | 1.072 | -0.516 | -0.960 | 0.131 |
| Ham-burgh | 0.605 | 0.444 | -0.484 | 0.908 | 2.201 | -0.175 | 2.711 | 0.540 | 1.104 | 0.184 | -1.289 | -0.712 | -0.125 | 0.301 | -0.222 |
| RJF | 0.991 | 0.243 | -1.742 | 0.181 | -0.950 | 0.527 | -1.287 | -0.741 | -0.189 | 0.174 | 0.360 | 0.605 | -0.116 | -0.188 | 0.084 |
| O E Game | -0.802 | -0.520 | 0.941 | 1.193 | 1.747 | -0.049 | 1.047 | 0.184 | 1.223 | 0.643 | 1.194 | -0.057 | 0.587 | 0.646 | 0.893 |
| Silkie | 1.518 | 0.897 | -1.448 | 0.425 | -0.348 | 0.221 | -0.223 | 0.350 | 0.443 | 0.500 | 0.375 | 0.694 | 0.905 | 0.842 | 0.331 |
| Asian Game | -0.748 | 1.567 | 0.894 | -1.34I | -1.419 | 0.617 | -1.487 | 0.159 | -0.840 | -0.397 | -0.085 | 0.269 | -0.576 | -0.838 | -0.772 |

Tibiotarsus - skewness

|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Dorking | -0.072 | 0.047 | 1.152 | -0.079 | 1.038 | -0.011 | 1.148 | 1.422 | -0.023 | -0.084 | 0.938 | 1.834 | 1.238 | -0.274 | 1.464 |
| Hamburgh | 1.719 | 0.642 | 2.391 | -0.565 | 1.663 | 0.753 | 2.236 | 1.552 | 0.323 | 0.401 | 0.482 | 0.052 | 0.497 | 0.079 | 0.905 |
| RJF | -0.541 | -0.829 | 0.633 | -0.715 | 0.180 | -1.14 | 0.231 | 0.148 | 0.635 | 1.961 | -1.473 | 0.900 | -1.104 | 0.103 | -1.753 |
| O E Game | 0.926 | 0.386 | 0.839 | -0.922 | 0.320 | 0.467 | 1.104 | 0.352 | -0.006 | 0.545 | -0.152 | -0.408 | -0.057 | 0.428 | 0.335 |
| Silkie | 0.872 | 1.088 | -0.308 | 0.031 | -0.120 | 0.699 | 0.176 | 0.239 | 0.286 | -0.615 | 0.237 | -0.802 | -0.263 | -0.485 | 0.328 |
| Asian Game | -1.554 | -0.040 | 1.024 | 0.024 | 1.560 | -0.126 | 0.945 | 1.508 | -0.057 | -1.605 | 0.149 | -0.739 | 0.384 | -0.484 | 0.257 |


| Tarsometatarsus - skewness |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| Dorking | -1.393 | 1.637 | -1.965 | -1.64I | -1.473 | 0.369 |
| Hamburgh | 0.079 | 0.228 | 0.190 | -0.438 | 1.042 | -0.029 |
| RJF | -0.514 | -0.475 | -0.468 | -0.068 | -1.145 | -1.385 |
| O E Game | -1.448 | -0.117 | -0.561 | -0.356 | -0.350 | -0.138 |
| Silkie | 0.146 | 0.158 | -0.812 | 0.862 | -0.192 | -0.262 |
| Asian Game | -0.804 | 1.613 | 1.648 | 1.022 | 0.218 | 0.144 |

## 4.I. 2 Normality tests

Null hypothesis is that distribution is normal. Non-normal distributions are in bold.
4.1.2.1 Coracoids - measurement ratios

| Dorking coracoids |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| Shapiro-Wilk W | 0.88 I | 0.94 I 2 | 0.9167 | 0.9186 | 0.93 I | 0.9425 |
| p (normal) | 0.1609 | 0.5942 | 0.3658 | 0.3807 | 0.4905 | 0.6085 |
| Anderson-Darling A | 0.50 II | 0.249 I | 0.350 I | 0.289 I | 0.3 I 38 | 0.26 |
| p (normal) | 0.1507 | 0.6552 | 0.3845 | 0.5302 | 0.476 | 0.6 I 58 |
| p (Monte Carlo) | 0.158 | 0.709 | 0.398 I | 0.5737 | 0.5092 | 0.6765 |
| Jarque-Bera JB | 1.362 | 0.6274 | 0.8969 | 0.7768 | 0.7 I 83 | 0.5255 |
| p(normal) | 0.5062 | 0.7307 | 0.6386 | 0.678 I | 0.6983 | 0.7689 |
| p (Monte Carlo) | $0.1 \mathrm{I7}$ | 0.55 I | 0.3007 | 0.3993 | 0.4477 | 0.6553 |


| Hamburgh coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Shapiro-Wilk W | 0.7839 | 0.93 | 0.9149 | 0.9664 | 0.9258 | 0.9614 |
| P(normal) | 0.01921 | 0.516 | 0.3895 | 0.8686 | 0.4791 | 0.8235 |
| Anderson-Darling A | 0.7773 | 0.3071 | 0.3081 | 0.1892 | 0.3047 | 0.2233 |
| P(normal) | 0.02468 | 0.4812 | 0.4782 | 0.8521 | 0.488 | 0.7377 |
| P(Monte Carlo) | 0.0246 | 0.5149 | 0.5093 | 0.8926 | 0.5177 | 0.7796 |
| Jarque-Bera JB | 4.194 | 0.4028 | 0.7782 | 0.4602 | 0.5094 | 0.1803 |
| P(normal) | 0.1228 | 0.8176 | 0.6777 | 0.7945 | 0.7751 | 0.9138 |
| p(Monte Carlo) | 0.0121 | 0.7482 | 0.361 | 0.7043 | 0.6459 | 0.9313 |


| Red Junglefowl coracoids |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Lm/GL | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| Shapiro-Wilk W | 0.973 I | 0.9608 | 0.9552 | 0.9779 | 0.9405 | 0.9457 |
| p(normal) | 0.92 | 0.8252 | 0.7767 | 0.9485 | 0.6433 | 0.6908 |
| Anderson-Darling A | 0.194 | 0.2204 | 0.183 I | 0.135 I | 0.296 I | 0.2709 |
| p(normal) | 0.8253 | 0.7309 | 0.8583 | 0.9553 | 0.4944 | 0.55 |
| p(Monte Carlo) | 0.8709 | 0.7873 | 0.8995 | 0.9877 | 0.5349 | 0.6189 |
| Jarque-Bera JB | 0.2135 | 0.4874 | 0.4927 | 0.4285 | 0.3795 | 0.352 I |
| p(normal) | 0.8988 | 0.7837 | 0.7816 | 0.8072 | 0.8272 | 0.8386 |
| p(Monte Carlo) | 0.9108 | 0.646 I | 0.648 I | 0.7163 | 0.778 | 0.7922 |


| Old English Game coracoids |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Lm/GL | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| Shapiro-Wilk W | 0.9605 | 0.9389 | 0.952 | 0.9472 | 0.8525 | 0.8603 |
| p(normal) | 0.804 | 0.5706 | 0.7 I 25 | 0.6594 | 0.07938 | 0.09657 |
| Anderson-Darling A | 0.2027 | 0.307 | 0.2472 | 0.2644 | 0.7009 | 0.6754 |
| p(normal) | 0.8208 | 0.4955 | 0.662 | 0.6007 | $\mathbf{0 . 0 4 3 2 2}$ | 0.05079 |
| p(Monte Carlo) | 0.8452 | 0.5199 | 0.7158 | 0.6525 | $\mathbf{0 . 0 4 1 8}$ | 0.0503 |
| Jarque-Bera JB | 0.4825 | 0.6029 | 0.5558 | 0.429 | I .232 | I .254 |
| p(normal) | 0.7856 | 0.7397 | 0.7574 | 0.807 | 0.540 I | 0.5342 |
| p(Monte Carlo) | 0.6914 | 0.5603 | 0.6204 | 0.734 I | 0.140 I | 0.1409 |


| Silkie coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Shapiro-Wilk W | 0.902 | 0.8079 | 0.8334 | 0.8686 | 0.8202 | 0.8354 |
| p(normal) | 0.3433 | 0.04898 | 0.08614 | 0.1804 | 0.06451 | 0.09008 |
| Anderson-Darling A | 0.4483 | 0.6766 | 0.5434 | 0.4553 | 0.5753 | 0.515 |
| p(normal) | 0.1896 | 0.04289 | 0.1027 | 0.1811 | 0.08331 | 0.1212 |
| p(Monte Carlo) | 0.202 | 0.0401 | 0.1071 | 0.1901 | 0.0879 | 0.1261 |
| Jarque-Bera JB | 0.6096 | 1.063 | 2.112 | 1.088 | 1.776 | 1.732 |
| p(normal) | 0.7373 | 0.5877 | 0.3478 | 0.5805 | 0.4114 | 0.4207 |
| p(Monte Carlo) | 0.498 | 0.1394 | 0.0392 | 0.1273 | 0.053 | 0.0569 |


| Asian Game coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| Shapiro-Wilk W | 0.9108 | 0.8616 | 0.792 | 0.8519 | 0.9736 | 0.9126 |
| P(normal) | 0.442 | 0.1948 | 0.04973 | 0.1631 | 0.9157 | 0.4539 |
| Anderson-Darling A | 0.3444 | 0.4259 | 0.6182 | 0.4387 | 0.2129 | 0.3197 |
| p(normal) | 0.3455 | 0.202 | 0.05574 | 0.1852 | 0.7353 | 0.4043 |
| p(Monte Carlo) | 0.3814 | 0.2194 | 0.0586 | 0.198 | 0.8109 | 0.4435 |
| Jarque-Bera JB | 0.7977 | 0.6812 | 1.859 | 1.077 | 0.145 | 0.331 |
| p(normal) | 0.6711 | 0.7113 | 0.3947 | 0.5837 | 0.9301 | 0.8475 |
| p(Monte Carlo) | 0.2244 | 0.3466 | 0.0345 | 0.0999 | 0.9542 | 0.8102 |


| Lyminge coracoids |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| N | 6 I | 60 | 6 I | 61 | 6 I | 61 |
| Shapiro-Wilk W | 0.9618 | 0.98 I 3 | 0.9742 | 0.9826 | 0.9735 | 0.9746 |
| p (normal) | 0.05407 | 0.4879 | 0.2242 | 0.5354 | 0.2062 | 0.2337 |
| Anderson-Darling A | 0.7156 | 0.2836 | 0.507 | 0.389 | 0.3559 | 0.3014 |
| p (normal) | 0.05874 | 0.6208 | 0.1933 | 0.3744 | 0.4476 | 0.5678 |
| p (Monte Carlo) | 0.0587 | 0.6469 | 0.1831 | 0.3765 | 0.4516 | 0.5997 |
| Jarque-Bera JB | 10.04 | 0.7537 | 1.43 | 0.9683 | 2.668 | 3.094 |
| p (normal) | $6.62 \mathrm{E}-03$ | 0.686 | 0.4892 | 0.6162 | 0.2635 | 0.2129 |
| p (Monte Carlo) | 0.0142 | 0.6366 | 0.3722 | 0.5395 | 0.1486 | 0.1085 |


| Uley coracoids |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| N | 22 | 22 | 22 | 22 | 22 | 22 |
| Shapiro-Wilk W | 0.9526 | 0.9633 | 0.9509 | 0.9526 | 0.9566 | 0.9659 |
| p (normal) | 0.3559 | 0.5582 | 0.3293 | 0.3556 | 0.4229 | 0.6 I 68 |
| Anderson-Darling A | 0.34 I 2 | 0.334 | 0.4 | 0.3556 | 0.3205 | 0.2483 |
| p (normal) | 0.462 | 0.4806 | 0.3334 | 0.427 | 0.5 IOI | 0.7184 |
| p (Monte Carlo) | 0.47 I 8 | 0.4899 | 0.343 I | 0.4394 | 0.5292 | 0.7425 |
| Jarque-Bera JB | 2.169 | 0.332 I | I .179 | I .156 | 0.7359 | 0.5843 |
| p (normal) | 0.338 I | 0.847 | 0.5547 | 0.5609 | 0.6922 | 0.7466 |
| p (Monte Carlo) | 0.1208 | 0.825 I | 0.343 | 0.3684 | 0.5857 | 0.674 |


| Flixborough coracoids |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Lm/GL | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| N | 28 | 28 | 28 | 28 | 28 | 28 |
| Shapiro-Wilk W | 0.949 | 0.9565 | 0.968 I | 0.9675 | 0.9589 | 0.9703 |
| p (normal) | 0.187 I | 0.2875 | 0.5303 | 0.5 I 63 | 0.3276 | 0.589 I |
| Anderson-Darling A | 0.62 I 8 | 0.656 I | 0.3306 | 0.2677 | 0.422 I | 0.372 I |
| p (normal) | 0.09502 | 0.07772 | 0.497 I | 0.659 | 0.3004 | 0.3969 |
| p (Monte Carlo) | 0.0974 | 0.0763 | 0.5062 | 0.674 I | 0.3044 | 0.402 |
| Jarque-Bera JB | 0.643 | 1.13 | 0.9575 | I .063 | 0.7264 | 0.6557 |
| p (normal) | 0.725 I | 0.5682 | 0.6196 | 0.5877 | 0.6954 | 0.7205 |


| P (Monte Carlo) | 0.6601 | 0.4111 | 0.4805 | 0.4386 | 0.6022 | 0.6499 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |


| Fishbourne coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| N | 14 | 14 | 14 | 14 | 14 | 14 |
| Shapiro-Wilk W | 0.9639 | 0.9606 | 0.9324 | 0.9303 | 0.935 | 0.9479 |
| p(normal) | 0.7858 | 0.7323 | 0.3301 | 0.3077 | 0.3578 | 0.5286 |
| Anderson-Darling A | 0.2222 | 0.2653 | 0.2993 | 0.3712 | 0.4487 | 0.3739 |
| P(normal) | 0.7872 | 0.6363 | 0.5353 | 0.3717 | 0.2363 | 0.366 |
| P(Monte Carlo) | 0.8094 | 0.6787 | 0.5719 | 0.389 | 0.2353 | 0.3862 |
| Jarque-Bera JB | 0.7522 | 0.4853 | 1.047 | 0.9733 | 0.2521 | 0.02527 |
| P(normal) | 0.6865 | 0.7846 | 0.5924 | 0.6147 | 0.8816 | 0.9874 |
| P(Monte Carlo) | 0.5139 | 0.7176 | 0.3252 | 0.3659 | 0.8721 | 0.9906 |


| Chester coracoids |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |
| N | 13 | 13 | 13 | 13 | 13 | 13 |
| Shapiro-Wilk W | 0.965 | 0.9274 | 0.9678 | 0.9893 | 0.9304 | 0.9623 |
| p (normal) | 0.8288 | 0.3148 | 0.867 I | 0.9995 | 0.3446 | 0.7893 |
| Anderson-Darling A | 0.2782 | 0.335 | $0.2 \mathrm{I77}$ | 0.1279 | 0.358 | 0.240 I |
| p (normal) | 0.5883 | 0.4515 | 0.7977 | 0.9771 | 0.3961 | 0.72 II |
| p (Monte Carlo) | 0.625 | 0.4682 | 0.8164 | 0.9902 | 0.4108 | 0.7456 |


| Jarque-Bera JB | 0.168 | 0.8714 | 0.5253 | 0.1988 | 1.584 | 0.7727 |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
| P (normal) | 0.9194 | 0.6468 | 0.769 | 0.9054 | 0.4529 | 0.6795 |
| P (Monte Carlo) | 0.9266 | 0.4202 | 0.6814 | 0.9035 | 0.1317 | 0.4864 |


| Coppergate coracoids |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
|  | $\mathrm{Lm} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Bb}$ | $\mathrm{Bb} / \mathrm{GL}$ | $\mathrm{Bb} / \mathrm{Lm}$ | $\mathrm{Bf} / \mathrm{GL}$ | $\mathrm{Bf} / \mathrm{Lm}$ |  |
| N | 53 | 53 | 53 | 53 | 53 | 53 |  |
| Shapiro-Wilk W | 0.9806 | 0.9757 | 0.9777 | 0.9726 | 0.983 | 0.9846 |  |
| p (normal) | 0.5377 | 0.3496 | 0.4199 | 0.2598 | 0.6497 | 0.7213 |  |
| Anderson-Darling A | 0.296 I | 0.4263 | 0.3606 | 0.4235 | 0.3617 | 0.3366 |  |
| p(normal) | 0.58 II | 0.3036 | 0.4346 | 0.3084 | 0.4322 | 0.4939 |  |
| p(Monte Carlo) | 0.6048 | 0.3063 | 0.4453 | 0.314 | 0.4334 | 0.4996 |  |
| Jarque-Bera JB | I .258 | I .701 | 0.7605 | 1.267 | 0.2315 | 0.5867 |  |
| p(normal) | 0.5332 | 0.4272 | 0.6837 | 0.5308 | 0.8907 | 0.7458 |  |
| p (Monte Carlo) | 0.4266 | 0.2954 | 0.6261 | 0.4269 | 0.883 | 0.702 |  |

### 4.1.2.2 Humeri - measurement ratios

| Dorking humeri |  |  |  |  |  |  |  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0.9391 | 0.9488 | 0.8737 | 0.9346 | 0.9593 | 0.9077 |  |  |  |  |  |  |  |
| Shapiro-Wilk W | 0.5726 | 0.6767 | 0.1347 | 0.5264 | 0.7906 | 0.2998 |  |  |  |  |  |  |  |
| p(normal) | 0.2924 | 0.307 | 0.5322 | 0.2743 | 0.1895 | 0.3542 |  |  |  |  |  |  |  |
| Anderson-Darling A |  | 0.523 I | 0.4955 | 0.123 I | 0.5694 | 0.8596 |  |  |  |  |  |  |  |
| p(normal) | 0.563 I | 0.518 | 0.127 I | 0.6288 | 0.8878 | 0.4026 |  |  |  |  |  |  |  |
| p(Monte Carlo) | 0.7382 | 0.4908 | 2.02 | 0.5274 | 0.4763 | 0.9318 |  |  |  |  |  |  |  |
| Jarque-Bera JB | 0.6914 | 0.7824 | 0.3643 | 0.7682 | 0.788 I | 0.6276 |  |  |  |  |  |  |  |
| p(normal) | 0.4329 | 0.6692 | 0.063 I | 0.6463 | 0.6975 | 0.269 |  |  |  |  |  |  |  |
| p(Monte Carlo) |  |  |  |  |  |  |  |  |  |  |  |  |  |


| Hamburgh humeri |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| Shapiro-Wilk W | 0.9466 | 0.9649 | 0.8274 | 0.9137 | 0.924 | 0.9297 |
| p(normal) | 0.6529 | 0.8481 | 0.04171 | 0.3424 | 0.4264 | 0.4784 |
| Anderson-Darling A | 0.2412 | 0.1666 | 0.6793 | 0.4054 | 0.355 | 0.3308 |
| p(normal) | 0.6844 | 0.9075 | 0.04954 | 0.2753 | 0.3735 | 0.4311 |
| p(Monte Carlo) | 0.732 | 0.9404 | 0.047 | 0.293 | 0.4002 | 0.457 |
| Jarque-Bera JB | 0.6119 | 0.41 | 1.505 | 0.6813 | 0.6191 | 0.8113 |
| P(normal) | 0.7364 | 0.8147 | 0.4711 | 0.7113 | 0.7338 | 0.6665 |
| P(Monte Carlo) | 0.5694 | 0.7595 | 0.0985 | 0.4851 | 0.5495 | 0.3629 |


| Red Junglefowl humeri |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |
| Shapiro-Wilk W | 0.9554 | 0.9597 | 0.9604 | 0.9629 | 0.7582 | 0.9477 |
| p(normal) | 0.7656 | 0.8069 | 0.8143 | 0.8368 | $\mathbf{0 . 0 1 0 0 7}$ | 0.6878 |
| Anderson-Darling A | 0.2925 | 0.2633 | 0.2546 | 0.2 I 27 | 0.8365 | 0.2982 |
| p(normal) | 0.5142 | 0.5905 | 0.6206 | 0.7764 | $\mathbf{0 . 0 1 6 9}$ | 0.5053 |
| p(Monte Carlo) | 0.5573 | 0.6517 | 0.6863 | 0.81 | $\mathbf{0 . 0 1 6 8}$ | 0.5427 |
| Jarque-Bera JB | 0.1917 | 0.2953 | 0.1586 | 0.4786 | 4.857 | 0.4573 |
| p(normal) | 0.9086 | 0.8627 | 0.9238 | 0.7872 | 0.08816 | 0.7956 |
| p(Monte Carlo) | 0.9187 | 0.8456 | 0.9375 | 0.6706 | $\mathbf{0 . 0 0 7 1}$ | 0.6967 |


| Old English Game |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| Shapiro-Wilk W | 0.8326 | 0.8863 | 0.8615 | 0.967 | 0.9671 | 0.9011 |
| P(normal) | 0.03596 | 0.1539 | 0.07943 | 0.8617 | 0.8631 | 0.2253 |
| Anderson-Darling A | 0.7121 | 0.5252 | 0.6181 | 0.2171 | 0.243 | 0.432 |
| P(normal) | 0.04256 | 0.1344 | 0.07647 | 0.7821 | 0.6888 | 0.2414 |
| p(Monte Carlo) | 0.0406 | 0.1344 | 0.0785 | 0.8112 | 0.729 | 0.253 |
| Jarque-Bera JB | 1.32 | 1.071 | 1.268 | 0.3653 | 0.09394 | 1.428 |
| p (normal) | 0.5169 | 0.5852 | 0.5303 | 0.833 | 0.9541 | 0.4898 |
| p (Monte Carlo) | 0.1457 | 0.2291 | 0.1586 | 0.8012 | 0.9624 | 0.1242 |


| Silkie humeri |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |
| Shapiro-Wilk W | 0.9127 | 0.92 I 2 | 0.97 I 2 | 0.9365 | 0.9094 | 0.9479 |
| p(normal) | 0.4 I 5 I | 0.4792 | 0.907 | 0.6078 | 0.392 | 0.7102 |
| Anderson-Darling A | 0.322 I | 0.2926 | 0.2 I 67 | 0.2622 | 0.383 | 0.2588 |
| p(normal) | 0.4224 | 0.5043 | 0.745 | 0.5759 | 0.289 | 0.587 I |
| p(Monte Carlo) | 0.4548 | 0.5403 | 0.8005 | 0.6437 | 0.3082 | 0.6538 |
| Jarque-Bera JB | 0.6739 | 0.705 I | 0.1367 | 0.542 | 0.6253 | 0.3403 |
| p(normal) | 0.7139 | 0.7029 | 0.9339 | 0.7626 | 0.73 I 5 | 0.8435 |
| p(Monte Carlo) | 0.4239 | 0.3874 | 0.957 | 0.5837 | 0.4865 | 0.8162 |


| Asian Game humeri |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ |
| N | 6 | 6 | 6 | 6 | 6 | 6 |
| Shapiro-Wilk W | 0.9732 | 0.9197 | 0.8728 | 0.94 I 2 | 0.7955 | 0.885 |
| p (normal) | 0.913 I | 0.503 | 0.2374 | 0.6685 | 0.05348 | 0.2928 |
| Anderson-Darling A | 0.1733 | 0.258 | 0.5519 | 0.2475 | 0.62 | 0.352 I |
| p (normal) | 0.87 II | 0.565 I | 0.08719 | 0.6004 | 0.05505 | 0.3286 |
| p (Monte Carlo) | 0.9304 | 0.6427 | 0.0902 | 0.6867 | 0.0553 | 0.3649 |
| Jarque-Bera JB | 0.3927 | 0.5908 | 0.06303 | 0.5632 | 0.9318 | 0.676 |
| p (normal) | 0.8217 | 0.7442 | 0.969 | 0.7546 | 0.6276 | 0.7132 |


| P (Monte Carlo) | 0.7393 | 0.4683 | 0.9872 | 0.5132 | 0.1418 | 0.3457 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |


| Chester humeri |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| N | 12 | 12 | 12 | 12 | 12 | 12 |
| Shapiro-Wilk W | 0.9739 | 0.9681 | 0.9415 | 0.9617 | 0.9151 | 0.9149 |
| p(normal) | 0.9469 | 0.8902 | 0.5183 | 0.8074 | 0.2476 | 0.2466 |
| Anderson-Darling A | 0.2451 | 0.2583 | 0.3315 | 0.1893 | 0.3767 | 0.4388 |
| P(normal) | 0.6972 | 0.6496 | 0.4549 | 0.8751 | 0.3507 | 0.2429 |
| P(Monte Carlo) | 0.7263 | 0.6891 | 0.4755 | 0.8908 | 0.3739 | 0.2527 |
| Jarque-Bera JB | 0.02673 | 0.2133 | 0.7527 | 0.5786 | 1.058 | 0.9376 |
| p(normal) | 0.9867 | 0.8988 | 0.6864 | 0.7488 | 0.5893 | 0.6258 |
| P(Monte Carlo) | 0.9902 | 0.895 | 0.4896 | 0.64 | 0.2758 | 0.3528 |


| Lyminge humeri |  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{SC} / \mathrm{Bd}$ |  |  |  |  |  |
| N | 63 | 63 | 63 | 63 | 63 | 63 |
| Shapiro-Wilk W | 0.9855 | 0.9724 | 0.9723 | 0.9753 | 0.9926 | 0.961 I |
| p (normal) | 0.6643 | 0.1688 | 0.1655 | 0.235 | 0.9696 | 0.05401 |
| Anderson-Darling A | 0.2237 | 0.4056 | 0.5883 | 0.3845 | 0.1942 | 0.7895 |
| p (normal) | 0.8 I 72 | 0.3423 | 0.12 | 0.384 | 0.8891 | 0.03846 |
| p (Monte Carlo) | 0.8 I 73 | 0.338 | 0.1293 | 0.3876 | 0.8946 | 0.0386 |


| Jarque-Bera JB | 0.9385 | 2.32 | 2.45 I | 3.582 | 0.4 I 42 | I .3 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| p (normal) | 0.6255 | 0.3135 | 0.2936 | 0.1668 | 0.813 | 0.522 I |
| p (Monte Carlo) | 0.5579 | 0.187 I | 0.1794 | 0.0892 | 0.7917 | $0.42 \mathrm{I7}$ |


| Uley humeri |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| N | 24 | 24 | 24 | 24 | 24 | 24 |
| Shapiro-Wilk W | 0.974 | 0.9095 | 0.9719 | 0.9532 | 0.9429 | 0.9552 |
| P(normal) | 0.7655 | 0.05437 | 0.7147 | 0.3169 | 0.1893 | 0.3494 |
| Anderson-Darling A | 0.2467 | 0.7959 | 0.2096 | 0.4968 | 0.5937 | 0.315 |
| P(normal) | 0.7271 | 0.04347 | 0.8433 | 0.1925 | 0.1099 | 0.5211 |
| P(Monte Carlo) | 0.7438 | 0.0329 | 0.8489 | 0.1968 | 0.1082 | 0.5382 |
| Jarque-Bera JB | 0.4291 | 4.414 | 0.8616 | 0.5447 | 1.415 | 1.395 |
| p (normal) | 0.8069 | 0.11 | 0.65 | 0.7616 | 0.493 | 0.4979 |
| p(Monte Carlo) | 0.7791 | 0.0468 | 0.5172 | 0.7031 | 0.2744 | 0.2681 |

### 4.1.2.3 Femora - measurement ratios

| Dorking femora |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.9157 | 0.9068 | 0.9148 | 0.8951 | 0.9151 |
| P(normal) | 0.358 | 0.294 | 0.3513 | 0.2248 | 0.3533 |
| Anderson-Darling A | 0.3753 | 0.3934 | 0.3816 | 0.4197 | 0.3795 |
| p(normal) | 0.3307 | 0.2963 | 0.3184 | 0.2521 | 0.3225 |
| p (Monte Carlo) | 0.3452 | 0.3084 | 0.343 | 0.2684 | 0.3423 |
| Jarque-Bera JB | 0.8466 | 0.8679 | 0.8618 | 1.158 | 1.562 |
| P(normal) | 0.6549 | 0.6479 | 0.6499 | 0.5605 | 0.458 |
| p(Monte Carlo) | 0.3376 | 0.3239 | 0.3215 | 0.168 | 0.0998 |
| Dorking |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.948 | 0.8971 | 0.9319 | 0.9121 | 0.9087 |
| p(normal) | 0.6682 | 0.2356 | 0.4993 | 0.3306 | 0.3069 |
| Anderson-Darling A | 0.2473 | 0.4825 | 0.2891 | 0.3708 | 0.3411 |
| P(normal) | 0.6618 | 0.1698 | 0.5302 | 0.3398 | 0.4057 |
| P(Monte Carlo) | 0.711 | 0.1795 | 0.5703 | 0.3565 | 0.4247 |
| Jarque-Bera JB | 0.6968 | 1.798 | 0.7437 | 1.104 | 0.7733 |
| p(normal) | 0.7058 | 0.407 | 0.6895 | 0.5759 | 0.6793 |
| P(Monte Carlo) | 0.4661 | 0.0799 | 0.4258 | 0.1857 | 0.4016 |
| Dorking |  |  |  |  |  |


|  | $\mathrm{Dd} / \mathrm{Bp}$ | $\mathrm{Dp} / \mathrm{Dd}$ | $\mathrm{Dd} / \mathrm{GL}$ | $\mathrm{Dd} / \mathrm{Lm}$ | $\mathrm{SC} / \mathrm{Dd}$ |
| :---: | :--- | :--- | :--- | :--- | :--- |
| Shapiro-Wilk W | 0.9378 | 0.9089 | 0.9456 | 0.8955 | 0.9728 |
| p (normal) | 0.5586 | 0.3084 | 0.642 | 0.2268 | 0.9175 |
| Anderson-Darling A | 0.277 | 0.3679 | 0.2558 | 0.4325 | 0.1922 |
| p (normal) | 0.5613 | 0.3457 | 0.6308 | 0.2328 | 0.852 I |
| p (Monte Carlo) | 0.6149 | 0.3565 | 0.6901 | 0.2491 | 0.875 |
| Jarque-Bera JB | 0.6652 | 1.186 | 0.6821 | 1.095 | 0.1806 |
| p (normal) | 0.7171 | 0.5528 | 0.71 I | 0.5784 | 0.9137 |
| p(Monte Carlo) | 0.4979 | 0.1551 | 0.489 | 0.1779 | 0.9267 |


| Hamburgh femora |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | $\mathrm{Bd} / \mathrm{GL}$ |  |
| Shapiro-Wilk W | 0.942 | 0.9125 | 0.9477 | 0.9136 | 0.7375 |  |
| p(normal) | 0.603 | 0.3335 | 0.665 I | 0.342 I | $\mathbf{0 . 0 0 3 8 8 6}$ |  |
| Anderson-Darling A | 0.2362 | 0.3327 | 0.2204 | 0.3484 | 0.9926 |  |
| p(normal) | 0.703 | 0.4263 | 0.7614 | 0.3885 | $\mathbf{0 . 0 0 6 8 7 2}$ |  |
| p(Monte Carlo) | 0.7426 | 0.4535 | 0.8033 | 0.4059 | $\mathbf{0 . 0 0 7}$ |  |
| Jarque-Bera JB | 0.5828 | 0.7805 | 0.5294 | 0.9892 | 6.899 |  |
| p(normal) | 0.7472 | 0.6769 | 0.7674 | 0.6098 | $\mathbf{0 . 0 3 1 7 5}$ |  |
| p(Monte Carlo) | 0.58 I | 0.395 | 0.6353 | 0.2299 | $\mathbf{0 . 0 0 3 4}$ |  |
| Hamburgh femora |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Shapiro-Wilk W | 0.99 | 0.6049 | 0.9746 | 0.8782 | 0.9849 |  |


| P(normal) | 0.996 | 0.000109 | 0.9306 | 0.1501 | 0.9847 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Anderson-Darling A | 0.1235 | 1.546 | 0.1846 | 0.4567 | 0.1223 |
| P(normal) | 0.9769 | 0.000212 | 0.8727 | 0.2001 | 0.9781 |
| p(Monte Carlo) | 0.9943 | 0.0003 | 0.8987 | 0.207 | 0.9958 |
| Jarque-Bera JB | 0.2413 | 11.99 | 0.3151 | 1.26 | 0.3887 |
| p (normal) | 0.8864 | 0.002494 | 0.8543 | 0.5327 | 0.8233 |
| P(Monte Carlo) | 0.9009 | 0.0001 | 0.8425 | 0.147 | 0.7735 |
| Hamburgh femora |  |  |  |  |  |
|  | Dd/Bp $\times 100$ | Dp/Dd $\times 100$ | Dd/GL $\times 100$ | Dd/Lm $\times 100$ | SC/Dd $\times 100$ |
| Shapiro-Wilk W | 0.8729 | 0.9621 | 0.9598 | 0.9458 | 0.9397 |
| p(normal) | 0.1321 | 0.8197 | 0.7967 | 0.6436 | 0.5783 |
| Anderson-Darling A | 0.5401 | 0.2146 | 0.1853 | 0.2741 | 0.2375 |
| P(normal) | 0.1194 | 0.7814 | 0.871 | 0.5698 | 0.6982 |
| P(Monte Carlo) | 0.1292 | 0.8138 | 0.8943 | 0.6248 | 0.7401 |
| Jarque-Bera JB | 1.698 | 0.607 | 0.4712 | 0.3743 | 0.6997 |
| P(normal) | 0.4279 | 0.7382 | 0.7901 | 0.8293 | 0.7048 |
| p(Monte Carlo) | 0.0821 | 0.5654 | 0.7071 | 0.7859 | 0.4723 |


| Red Junglefowl femora |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.7952 | 0.9194 | 0.8431 | 0.9508 | 0.892 |
| p(normal) | 0.02545 | 0.4253 | 0.08102 | 0.7196 | 0.244 |
| Anderson-Darling A | 0.7279 | 0.296 | 0.572 | 0.1935 | 0.4605 |
| p(normal) | 0.03388 | 0.5085 | 0.09206 | 0.8396 | 0.1865 |
| P(Monte Carlo) | 0.0353 | 0.5496 | 0.1001 | 0.8841 | 0.1981 |
| Jarque-Bera JB | 4.201 | 0.7053 | 3.045 | 0.5288 | 0.9347 |
| p(normal) | 0.1224 | 0.7028 | 0.2181 | 0.7677 | 0.6267 |
| P(Monte Carlo) | 0.0109 | 0.4323 | 0.0238 | 0.6331 | 0.2412 |
| Red Junglefowl |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.9352 | 0.8465 | 0.8919 | 0.9395 | 0.9712 |
| p(normal) | 0.5644 | 0.0878 | 0.2439 | 0.606 | 0.9072 |
| Anderson-Darling A | 0.3795 | 0.6864 | 0.4731 | 0.2189 | 0.2332 |
| p(normal) | 0.3107 | 0.04419 | 0.1718 | 0.754 | 0.7005 |
| p(Monte Carlo) | 0.3319 | 0.0446 | 0.1845 | 0.8037 | 0.7497 |
| Jarque-Bera JB | 0.2942 | 1.421 | 0.4702 | 0.6551 | 0.03477 |
| P(normal) | 0.8632 | 0.4915 | 0.7905 | 0.7207 | 0.9828 |
| P(Monte Carlo) | 0.8488 | 0.099 | 0.6892 | 0.4752 | 0.988 |
| Red Junglefowl |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.9386 | 0.9484 | 0.9386 | 0.8697 | 0.9435 |


| p (normal) | 0.5978 | 0.6954 | 0.597 | 0.1496 | 0.6457 |
| :---: | :--- | :--- | :--- | :--- | :--- |
| Anderson-Darling A | 0.2886 | 0.2468 | 0.3186 | 0.4739 | 0.3549 |
| p (normal) | 0.5216 | 0.6491 | 0.4494 | 0.1709 | 0.3612 |
| p (Monte Carlo) | 0.5664 | 0.7072 | 0.4793 | 0.1839 | 0.3898 |
| Jarque-Bera JB | 0.3257 | 0.5909 | 0.5592 | 0.9294 | 0.02872 |
| p(normal) | 0.8497 | 0.7442 | 0.7561 | 0.6283 | 0.9857 |
| p (Monte Carlo) | 0.8256 | 0.5562 | 0.5926 | 0.2486 | 0.9911 |


| Old English Game femora |  |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | $\mathrm{Bd} / \mathrm{GL}$ |  |  |
| Shapiro-Wilk W | 0.9307 | 0.9003 | 0.919 I | 0.7722 | 0.937 |  |  |
| p(normal) | 0.4544 | 0.2207 | 0.3498 | $\mathbf{0 . 0 0 6 6 5 5}$ | 0.5202 |  |  |
| Anderson-Darling A | 0.296 I | 0.4542 | 0.33 | I .105 | 0.3438 |  |  |
| p(normal) | 0.523 I | 0.2105 | 0.4435 | $\mathbf{0 . 0 0 3 6 7 8}$ | 0.4092 |  |  |
| p(Monte Carlo) | 0.5647 | 0.2186 | 0.4682 | $\mathbf{0 . 0 0 3 7}$ | 0.4322 |  |  |
| Jarque-Bera JB | 0.8225 | 0.8046 | 1.059 | 1.829 | 0.757 |  |  |
| p(normal) | 0.6628 | 0.6688 | 0.5888 | 0.4007 | 0.6849 |  |  |
| p(Monte Carlo) | 0.3927 | 0.4069 | 0.2319 | 0.0794 | 0.4368 |  |  |
| Old English Game |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
| Shapiro-Wilk W | 0.9659 | 0.894 I | $0.95 \mathrm{I7}$ | 0.7845 | 0.9643 |  |  |
| p(normal) | 0.8505 | 0.1886 | 0.6888 | $\mathbf{0 . 0 0 9 4 0 4}$ | 0.8336 |  |  |
| Anderson-Darling A | 0.2432 | 0.5053 | 0.2928 | I .028 | 0.2469 |  |  |


| P(normal) | 0.6882 | 0.1527 | 0.5299 | 0.005945 | 0.6746 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| P(Monte Carlo) | 0.7259 | 0.1679 | 0.5702 | 0.0047 | 0.7136 |
| Jarque-Bera JB | 0.1277 | 1.339 | 0.1672 | 1.875 | 0.5168 |
| P(normal) | 0.9381 | 0.5121 | 0.9198 | 0.3916 | 0.7723 |
| P(Monte Carlo) | 0.949 | 0.1393 | 0.9288 | 0.0832 | 0.6667 |
| Old English Game |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.92I | 0.9307 | 0.9726 | 0.9605 | 0.945 |
| P(normal) | 0.3653 | 0.4549 | 0.9139 | 0.7918 | 0.6099 |
| Anderson-Darling A | 0.3362 | 0.2768 | 0.1895 | 0.2548 | 0.3087 |
| p(normal) | 0.4277 | 0.5721 | 0.8661 | 0.6458 | 0.5028 |
| P(Monte Carlo) | 0.4465 | 0.6269 | 0.8925 | 0.6857 | 0.5144 |
| Jarque-Bera JB | 1.779 | 0.6412 | 0.4545 | 0.517 | 1.094 |
| P(normal) | 0.411 | 0.7257 | 0.7967 | 0.7722 | 0.5786 |
| p(Monte Carlo) | 0.093 | 0.5474 | 0.7176 | 0.6612 | 0.2187 |


| Silkie femora |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.8332 | 0.8495 | 0.8442 | 0.8994 | 0.8821 |
| p(normal) | 0.08588 | 0.1217 | 0.1086 | 0.3275 | 0.236 |
| Anderson-Darling A | 0.5502 | 0.5328 | 0.5205 | 0.3503 | 0.3683 |
| p(normal) | 0.09822 | 0.1101 | 0.1193 | 0.355 | 0.3172 |
| p (Monte Carlo) | 0.1029 | 0.1105 | 0.1213 | 0.3812 | 0.3469 |


| Jarque-Bera JB | 1.606 | 0.9596 | 1.456 | 0.7456 | 0.7132 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| p (normal) | 0.448 | 0.6189 | 0.4829 | 0.6888 | 0.7 |
| P(Monte Carlo) | 0.0641 | 0.1767 | 0.0779 | 0.3325 | 0.3767 |
| Silkie |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.9389 | 0.8924 | 0.9531 | 0.877 | 0.8359 |
| P(normal) | 0.6292 | 0.2876 | 0.7578 | 0.2134 | 0.09097 |
| Anderson-Darling A | 0.2497 | 0.3229 | 0.2132 | 0.4115 | 0.5731 |
| p(normal) | 0.6188 | 0.4204 | 0.758 | 0.2409 | 0.08451 |
| p(Monte Carlo) | 0.6838 | 0.4566 | 0.8132 | 0.2601 | 0.0901 |
| Jarque-Bera JB | 0.4454 | 0.6726 | 0.4388 | 0.7772 | 0.9313 |
| P(normal) | 0.8004 | 0.7144 | 0.803 | 0.678 | 0.6277 |
| p(Monte Carlo) | 0.7083 | 0.4256 | 0.7051 | 0.3007 | 0.1877 |
| Silkie |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.964 | 0.9573 | 0.8212 | 0.847 | 0.9257 |
| p(normal) | 0.8525 | 0.7952 | 0.06594 | 0.1153 | 0.5147 |
| Anderson-Darling A | 0.188 | 0.1896 | 0.6637 | 0.5439 | 0.2555 |
| p(normal) | 0.8438 | 0.839 | 0.04668 | 0.1024 | 0.5982 |
| p(Monte Carlo) | 0.8832 | 0.8821 | 0.0459 | 0.1097 | 0.6719 |
| Jarque-Bera JB | 0.3374 | 0.4758 | 0.9398 | 0.8867 | 0.6582 |
| P(normal) | 0.8448 | 0.7883 | 0.6251 | 0.6419 | 0.7196 |
| p(Monte Carlo) | 0.814 | 0.6636 | 0.1874 | 0.2098 | 0.4449 |


| Asian Game femora |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.9446 | 0.8388 | 0.9306 | 0.8624 | 0.8892 |
| p(normal) | 0.6967 | 0.1274 | 0.5849 | 0.1975 | 0.314 |
| Anderson-Darling A | 0.2245 | 0.5519 | 0.2575 | 0.4484 | 0.3699 |
| p(normal) | 0.6892 | 0.08716 | 0.5667 | 0.1735 | 0.2928 |
| p(Monte Carlo) | 0.767 | 0.0936 | 0.646 | 0.1811 | 0.3258 |
| Jarque-Bera JB | 0.5512 | 1.331 | 0.6188 | 1.007 | 1.076 |
| p(normal) | 0.7591 | 0.514 | 0.7339 | 0.6043 | 0.5839 |
| P(Monte Carlo) | 0.5237 | 0.0725 | 0.4258 | 0.1169 | 0.1065 |
| Asian Game |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.8889 | 0.8384 | 0.9156 | 0.9197 | 0.8723 |
| p(normal) | 0.3125 | 0.1264 | 0.4746 | 0.5033 | 0.2357 |
| Anderson-Darling A | 0.344 | 0.4736 | 0.2802 | 0.299 | 0.3882 |
| p(normal) | 0.3463 | 0.1458 | 0.5105 | 0.4605 | 0.2596 |
| P(Monte Carlo) | 0.3867 | 0.1536 | 0.5696 | 0.5104 | 0.2771 |
| Jarque-Bera JB | 0.6429 | 1.187 | 0.544 | 0.6568 | 0.7454 |
| p(normal) | 0.7251 | 0.5524 | 0.7619 | 0.7201 | 0.6889 |
| p(Monte Carlo) | 0.3936 | 0.0862 | 0.5457 | 0.3737 | 0.2751 |
| Asian Game |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |


| Shapiro-Wilk W | 0.9472 | 0.9475 | 0.9788 | 0.925 I | 0.9079 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| p(normal) | $0.7 \mathrm{I72}$ | 0.7197 | 0.9455 | 0.543 I | 0.4228 |
| Anderson-Darling A | 0.2265 | 0.2913 | 0.1542 | 0.2759 | 0.294 I |
| p(normal) | 0.6814 | 0.4829 | 0.9108 | 0.5 I 83 | 0.4748 |
| p(Monte Carlo) | 0.7643 | 0.5292 | 0.9669 | 0.584 I | 0.526 |
| Jarque-Bera JB | 0.5034 | 0.126 | 0.3602 | 0.589 I | 0.6136 |
| p(normal) | 0.7775 | 0.939 | 0.8352 | 0.7449 | 0.7358 |
| p(Monte Carlo) | 0.5953 | 0.9646 | 0.7878 | 0.4748 | 0.4382 |


| Chester femora |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.9515 | 0.9567 | 0.9554 | 0.9506 | 0.9384 |
| p(normal) | 0.6632 | 0.7305 | 0.7128 | 0.6516 | 0.5017 |
| Anderson-Darling A | 0.2183 | 0.1944 | 0.2082 | 0.3689 | 0.3132 |
| p(normal) | 0.7854 | 0.8581 | 0.8179 | 0.3608 | 0.4973 |
| P(Monte Carlo) | 0.8103 | 0.8775 | 0.8415 | 0.3764 | 0.5183 |
| Jarque-Bera JB | 0.52 | 0.6157 | 0.4589 | 0.007928 | 0.6111 |
| p (normal) | 0.771 | 0.735 | 0.795 | 0.996 | 0.7367 |
| p(Monte Carlo) | 0.681 | 0.5877 | 0.7318 | 0.9967 | 0.5974 |
| Chester |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.8762 | 0.958 | 0.8626 | 0.9388 | 0.9693 |


| P(normal) | 0.09298 | 0.746 | 0.06215 | 0.5062 | 0.8793 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Anderson-Darling A | 0.5993 | 0.2141 | 0.6782 | 0.3757 | 0.184 |
| p(normal) | 0.08921 | 0.799 | 0.05482 | 0.3466 | 0.8845 |
| p(Monte Carlo) | 0.091 | 0.8256 | 0.0577 | 0.3597 | 0.9062 |
| Jarque-Bera JB | 2.082 | 0.5739 | 1.988 | 0.7026 | 0.3764 |
| p (normal) | 0.3531 | 0.7506 | 0.37 | 0.7038 | 0.8284 |
| p(Monte Carlo) | 0.0782 | 0.6334 | 0.0794 | 0.5115 | 0.7925 |
| Chester |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.9792 | 0.9485 | 0.9689 | 0.9684 | 0.9118 |
| p(normal) | 0.9618 | 0.6243 | 0.8751 | 0.8696 | 0.2561 |
| Anderson-Darling A | 0.1846 | 0.279 | 0.1454 | 0.1886 | 0.4184 |
| p(normal) | 0.8828 | 0.5737 | 0.9522 | 0.8731 | 0.269 |
| p (Monte Carlo) | 0.905 | 0.6191 | 0.9751 | 0.8865 | 0.2781 |
| Jarque-Bera JB | 0.2293 | 0.5618 | 0.5448 | 0.1975 | 1.079 |
| P(normal) | 0.8917 | 0.7551 | 0.7616 | 0.906 | 0.583 |
| P(Monte Carlo) | 0.8942 | 0.6261 | 0.6497 | 0.9074 | 0.243 |


| Lyminge femora |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.9742 | 0.9709 | 0.9846 | 0.9701 | 0.9603 |
| P (normal) | 0.4996 | 0.401 | 0.8611 | 0.3771 | 0.183 |


| Anderson-Darling A | 0.3147 | 0.4752 | 0.226 | 0.3845 | 0.6063 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| P(normal) | 0.5302 | 0.2271 | 0.8052 | 0.3774 | 0.1073 |
| p(Monte Carlo) | 0.5533 | 0.2268 | 0.809 | 0.389 | 0.1026 |
| Jarque-Bera JB | 2.499 | 3.354 | 0.888 | 3.45 | 1.528 |
| p (normal) | 0.2867 | 0.187 | 0.6415 | 0.1782 | 0.4658 |
| p(Monte Carlo) | 0.1323 | 0.0815 | 0.557 | 0.0777 | 0.2982 |
| Lyminge |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.9537 | 0.9525 | 0.9666 | 0.9691 | 0.9516 |
| P(normal) | 0.1097 | 0.09974 | 0.2931 | 0.3532 | 0.09293 |
| Anderson-Darling A | 0.6964 | 0.5942 | 0.457 | 0.4119 | 0.4558 |
| p(normal) | 0.06362 | 0.1151 | 0.2519 | 0.3247 | 0.2537 |
| p(Monte Carlo) | 0.0607 | 0.1135 | 0.256 | 0.3334 | 0.2631 |
| Jarque-Bera JB | 2.105 | 2.154 | 1.984 | 3.548 | 10.59 |
| P(normal) | 0.3491 | 0.3407 | 0.3709 | 0.1697 | 0.005018 |
| p(Monte Carlo) | 0.178 | 0.1772 | 0.1939 | 0.0741 | 0.0138 |
| Lyminge |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.9725 | 0.9727 | 0.9705 | 0.9425 | 0.9709 |
| p(normal) | 0.4453 | 0.4534 | 0.3886 | 0.04912 | 0.4001 |
| Anderson-Darling A | 0.3421 | 0.4278 | 0.2718 | 0.6248 | 0.3091 |
| p(normal) | 0.4749 | 0.2971 | 0.653 | 0.09637 | 0.5425 |
| p(Monte Carlo) | 0.4791 | 0.301 | 0.6856 | 0.0972 | 0.5695 |


| Jarque-Bera JB | 1.68 | 0.7134 | 1.489 | 2.40 I | 3.67 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| p (normal) | 0.4316 | 0.7 | 0.475 | 0.30 I | 0.1596 |
| p (Monte Carlo) | 0.2605 | 0.6362 | 0.3158 | 0.147 I | 0.0737 |


| Uley femora |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dd/Bd | SC/Bd | Bd/Dd | SC/GL | Bd/GL |
| Shapiro-Wilk W | 0.9742 | 0.9709 | 0.9846 | 0.9701 | 0.9603 |
| p(normal) | 0.4996 | 0.401 | 0.8611 | 0.3771 | 0.183 |
| Anderson-Darling A | 0.3147 | 0.4752 | 0.226 | 0.3845 | 0.6063 |
| P(normal) | 0.5302 | 0.2271 | 0.8052 | 0.3774 | 0.1073 |
| p(Monte Carlo) | 0.5533 | 0.2268 | 0.809 | 0.389 | 0.1026 |
| Jarque-Bera JB | 2.499 | 3.354 | 0.888 | 3.45 | 1.528 |
| P(normal) | 0.2867 | 0.187 | 0.6415 | 0.1782 | 0.4658 |
| p(Monte Carlo) | 0.1323 | 0.0815 | 0.557 | 0.0777 | 0.2982 |
| Uley |  |  |  |  |  |
|  | Bp/GL | Bd/Lm | Bp/Lm | SC/Lm | SC/Bp |
| Shapiro-Wilk W | 0.9537 | 0.9525 | 0.9666 | 0.9691 | 0.9516 |
| p (normal) | 0.1097 | 0.09974 | 0.2931 | 0.3532 | 0.09293 |
| Anderson-Darling A | 0.6964 | 0.5942 | 0.457 | 0.4119 | 0.4558 |
| p(normal) | 0.06362 | 0.1151 | 0.2519 | 0.3247 | 0.2537 |
| p(Monte Carlo) | 0.0607 | 0.1135 | 0.256 | 0.3334 | 0.2631 |
| Jarque-Bera JB | 2.105 | 2.154 | 1.984 | 3.548 | 10.59 |


| P(normal) | 0.3491 | 0.3407 | 0.3709 | 0.1697 | 0.005018 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| p(Monte Carlo) | 0.178 | 0.1772 | 0.1939 | 0.074 I | 0.0138 |
| Uley |  |  |  |  |  |
|  | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | SC/Dd |
| Shapiro-Wilk W | 0.9725 | 0.9727 | 0.9705 | 0.9425 | 0.9709 |
| P(normal) | 0.4453 | 0.4534 | 0.3886 | 0.04612 | 0.4001 |
| Anderson-Darling A | 0.3421 | 0.4278 | 0.2718 | 0.6248 | 0.3091 |
| P(normal) | 0.4749 | 0.2971 | 0.653 | 0.09637 | 0.5425 |
| p(Monte Carlo) | 0.4791 | 0.301 | 0.6856 | 0.0972 | 0.5695 |
| Jarque-Bera JB | 1.68 | 0.7134 | 1.489 | 2.401 | 3.67 |
| p (normal) | 0.4316 | 0.7 | 0.475 | 0.301 | 0.1596 |
| P(Monte Carlo) | 0.2605 | 0.6362 | 0.3158 | 0.1471 | 0.0737 |

### 4.1.2.4 Tibiotarsus - measurement ratios

| Dorking tibiotarsi |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Dip}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{Dd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ |
| Shapiro-Wilk W | 0.9261 | 0.9615 | 0.9122 | 0.9125 | 0.8808 |
| p (normal) | 0.4455 | 0.8137 | 0.3317 | 0.3334 | 0.1599 |
| Anderson-Darling A | 0.3119 | 0.2309 | 0.3404 | 0.3877 | 0.4958 |
| p (normal) | 0.4814 | 0.7229 | 0.4074 | 0.3067 | 0.1559 |
| p (Monte Carlo) | 0.5115 | 0.7652 | 0.4335 | 0.3232 | 0.1634 |
| Jarque-Bera JB | 0.6362 | 0.1557 | 1.366 | 0.8684 | 1.186 |


| P(normal) | 0.7275 | 0.9251 | 0.505 | 0.6478 | 0.5527 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| p(Monte Carlo) | 0.5286 | 0.9375 | 0.1142 | 0.3226 | 0.1571 |
| Dorking |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.9642 | 0.906 | 0.8533 | 0.955 | 0.9356 |
| P(normal) | 0.8414 | 0.289 | 0.08092 | 0.7453 | 0.5359 |
| Anderson-Darling A | 0.1968 | 0.3453 | 0.5736 | 0.1884 | 0.3079 |
| p(normal) | 0.8389 | 0.3958 | 0.09657 | 0.8627 | 0.4928 |
| p(Monte Carlo) | 0.8681 | 0.4136 | 0.1006 | 0.8966 | 0.5062 |
| Jarque-Bera JB | 0.2889 | 1.372 | 2.513 | 0.6437 | 0.5529 |
| p (normal) | 0.8655 | 0.5036 | 0.2846 | 0.7248 | 0.7585 |
| p(Monte Carlo) | 0.851 | 0.1184 | 0.0426 | 0.531 | 0.6157 |
| Dorking |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.8777 | 0.8168 | 0.8958 | 0.9297 | 0.8674 |
| P(normal) | 0.1485 | 0.03168 | 0.2284 | 0.4788 | 0.1152 |
| Anderson-Darling A | 0.4724 | 0.6888 | 0.4256 | 0.3808 | 0.579 |
| p(normal) | 0.1811 | 0.04666 | 0.243 | 0.3199 | 0.09337 |
| P(Monte Carlo) | 0.1793 | 0.0442 | 0.2681 | 0.3323 | 0.0954 |
| Jarque-Bera JB | 1.117 | 4.239 | 1.566 | 0.1628 | 2.543 |
| P(normal) | 0.572 | 0.1201 | 0.4571 | 0.9218 | 0.2804 |
| p(Monte Carlo) | 0.1777 | 0.0139 | 0.0991 | 0.9338 | 0.0434 |


| Hamburgh tibiotarsi |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W | 0.8079 | 0.958 | 0.6827 | 0.9351 | 0.7633 |
| P(normal) | 0.03479 | 0.791 | 0.001432 | 0.5633 | 0.01146 |
| Anderson-Darling A | 0.7303 | 0.1928 | 1.12 | 0.2611 | 0.839 |
| p(normal) | 0.03335 | 0.8417 | 0.002747 | 0.5978 | 0.01663 |
| P(Monte Carlo) | 0.0315 | 0.8816 | 0.0023 | 0.6679 | 0.0169 |
| Jarque-Bera JB | 2.695 | 0.526 | 6.604 | 0.7279 | 2.443 |
| P(normal) | 0.2599 | 0.7688 | 0.0368 | 0.6949 | 0.2948 |
| p(Monte Carlo) | 0.0324 | 0.6304 | 0.0013 | 0.4039 | 0.0376 |
| Hamburgh |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.9552 | 0.7275 | 0.7933 | 0.9372 | 0.9021 |
| P(normal) | 0.7638 | 0.00459 | 0.02429 | 0.5841 | 0.3019 |
| Anderson-Darling A | 0.1997 | 0.9479 | 0.7295 | 0.2744 | 0.3449 |
| P(normal) | 0.8202 | 0.008276 | 0.03354 | 0.5562 | 0.3838 |
| p(Monte Carlo) | 0.856 | 0.0082 | 0.0346 | 0.611 | 0.4157 |
| Jarque-Bera JB | 0.5547 | 5.561 | 2.082 | 0.5912 | 0.7944 |
| P(normal) | 0.7578 | 0.06201 | 0.3531 | 0.7441 | 0.6722 |
| p(Monte Carlo) | 0.5903 | 0.0039 | 0.0534 | 0.5472 | 0.3431 |
| Hamburgh |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |


| Shapiro-Wilk W | 0.9684 | 0.9388 | 0.948 I | 0.9208 | 0.9356 |
| :---: | :--- | :--- | :--- | :--- | :--- |
| p (normal) | 0.8855 | 0.599 | 0.6916 | 0.4364 | 0.5687 |
| Anderson-Darling A | 0.2088 | 0.2374 | 0.2722 | 0.3219 | 0.3017 |
| p (normal) | 0.7899 | 0.6844 | 0.5626 | 0.4407 | 0.4967 |
| p (Monte Carlo) | 0.8349 | 0.7418 | 0.615 I | 0.474 | 0.5234 |
| Jarque-Bera JB | 0.371 I | 0.6715 | 0.494 I | 0.603 | 0.7749 |
| p (normal) | 0.8307 | 0.7148 | 0.78 II | 0.7397 | 0.6788 |
| p (Monte Carlo) | 0.7862 | 0.457 I | 0.6677 | 0.5409 | 0.355 |


| Red Junglefowl tibiotarsi |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W | 0.8953 | 0.9254 | 0.9587 | 0.898 | 0.9838 |
| p(normal) | 0.2618 | 0.4748 | 0.7976 | 0.2772 | 0.9793 |
| Anderson-Darling A | 0.3982 | 0.382 | 0.1813 | 0.4368 | 0.1352 |
| p(normal) | 0.2767 | 0.306 | 0.8738 | 0.217 | 0.9597 |
| P(Monte Carlo) | 0.2985 | 0.3237 | 0.9112 | 0.2355 | 0.9867 |
| Jarque-Bera JB | 0.583 | 0.6602 | 0.5043 | 0.7026 | 0.2571 |
| p(normal) | 0.7471 | 0.7188 | 0.7771 | 0.7038 | 0.8794 |
| p (Monte Carlo) | 0.5593 | 0.4796 | 0.652 | 0.4377 | 0.8788 |
| Red Junglefowl |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.9086 | 0.9742 | 0.9716 | 0.9152 | 0.7833 |
| p (normal) | 0.3444 | 0.9288 | 0.9101 | 0.3921 | 0.01891 |


| Anderson-Darling A | 0.3841 | 0.1441 | 0.1755 | 0.4471 | 0.767 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| P(normal) | 0.3021 | 0.9452 | 0.887 | 0.2032 | 0.02637 |
| p(Monte Carlo) | 0.3216 | 0.9788 | 0.9219 | 0.2151 | 0.024 |
| Jarque-Bera JB | 1.128 | 0.3438 | 0.2551 | 0.4138 | 3.976 |
| P(normal) | 0.569 | 0.8421 | 0.8802 | 0.8131 | 0.137 |
| p(Monte Carlo) | 0.146 | 0.8198 | 0.8776 | 0.7502 | 0.0117 |
| Red Junglefowl |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.8405 | 0.8524 | 0.891 | 0.9227 | 0.8305 |
| P(normal) | 0.07626 | 0.1009 | 0.2392 | 0.4519 | 0.06014 |
| Anderson-Darling A | 0.5725 | 0.537 | 0.4064 | 0.3029 | 0.6306 |
| p(normal) | 0.09177 | 0.1153 | 0.263 | 0.4932 | 0.06322 |
| p(Monte Carlo) | 0.0895 | 0.1187 | 0.2841 | 0.5245 | 0.0653 |
| Jarque-Bera JB | 1.869 | 1.003 | 1.101 | 0.5592 | 3.161 |
| P(normal) | 0.3928 | 0.6057 | 0.5767 | 0.7561 | 0.2058 |
| p(Monte Carlo) | 0.0586 | 0.2013 | 0.157 | 0.5845 | 0.0237 |


| Old English Game tibiotarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :---: |
|  | Bd/Dip | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{Dd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ |  |
| Shapiro-Wilk W | 0.9086 | 0.934 | 0.909 | 0.9047 | 0.88 I 2 |  |
| p(normal) | 0.2714 | 0.4886 | 0.274 | 0.2467 | 0.1346 |  |
| Anderson-Darling A | 0.5259 | 0.2998 | 0.5125 | 0.424 | 0.5337 |  |
| p(normal) | 0.1337 | 0.5161 | 0.1457 | 0.2536 | 0.1272 |  |


| P(Monte Carlo) | 0.1445 | 0.546 | 0.1522 | 0.267 | 0.1344 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Jarque-Bera JB | 1.19 | 0.5268 | 0.8712 | 1.156 | 1.052 |
| P(normal) | 0.5516 | 0.7684 | 0.6469 | 0.5611 | 0.591 |
| p(Monte Carlo) | 0.1785 | 0.6542 | 0.3468 | 0.1875 | 0.2316 |
| Old English Game |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.937 | 0.849 | 0.9023 | 0.912 | 0.9433 |
| P(normal) | 0.52 | 0.05656 | 0.2324 | 0.2952 | 0.5909 |
| Anderson-Darling A | 0.2698 | 0.7796 | 0.4133 | 0.4037 | 0.2881 |
| p(normal) | 0.5938 | 0.02795 | 0.2706 | 0.2869 | 0.541 |
| p(Monte Carlo) | 0.645 | 0.03 | 0.2811 | 0.3104 | 0.5806 |
| Jarque-Bera JB | 0.53 | 1.466 | 0.8802 | 0.8113 | 0.6202 |
| P(normal) | 0.7672 | 0.4805 | 0.644 | 0.6666 | 0.7334 |
| P(Monte Carlo) | 0.6511 | 0.1186 | 0.3391 | 0.3905 | 0.5703 |
| Old English Game |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.9879 | 0.9475 | 0.9902 | 0.9764 | 0.9059 |
| p(normal) | 0.9936 | 0.6392 | 0.997 | 0.943 | 0.2539 |
| Anderson-Darling A | 0.1345 | 0.3059 | 0.117 | 0.182 | 0.4478 |
| p(normal) | 0.9659 | 0.5063 | 0.984 | 0.8848 | 0.2191 |
| p(Monte Carlo) | 0.9866 | 0.536 | 0.9961 | 0.9074 | 0.231 |
| Jarque-Bera JB | 0.2511 | 0.5667 | 0.2831 | 0.2173 | 0.9153 |
| p(normal) | 0.882 | 0.7532 | 0.868 | 0.8971 | 0.6328 |


| P (Monte Carlo) | 0.8809 | 0.6145 | 0.8578 | 0.9005 | 0.3174 |
| :--- | :--- | :--- | :--- | :--- | :--- |


| Silkie tibiotarsi |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W | 0.9482 | 0.7469 | 0.9006 | 0.9295 | 0.9369 |
| p(normal) | 0.7132 | 0.01179 | 0.3346 | 0.5464 | 0.611 |
| Anderson-Darling A | 0.2546 | 0.9087 | 0.3281 | 0.231 | 0.2674 |
| P(normal) | 0.6015 | 0.009392 | 0.4072 | 0.69 | 0.5599 |
| P(Monte Carlo) | 0.6642 | 0.0096 | 0.4395 | 0.7474 | 0.6171 |
| Jarque-Bera JB | 0.5671 | 1.19 | 0.6407 | 0.5806 | 0.373 |
| p (normal) | 0.7531 | 0.5515 | 0.7259 | 0.7481 | 0.8298 |
| P(Monte Carlo) | 0.5405 | 0.1129 | 0.4559 | 0.5365 | 0.7789 |
| Silkie |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.8392 | 0.9353 | 0.9528 | 0.9265 | 0.8512 |
| P(normal) | 0.1283 | 0.6217 | 0.7628 | 0.5212 | 0.126 |
| Anderson-Darling A | 0.5399 | 0.2314 | 0.2565 | 0.2753 | 0.5011 |
| p(normal) | 0.0945 | 0.6618 | 0.5698 | 0.5383 | 0.1332 |
| p (Monte Carlo) | 0.0969 | 0.7388 | 0.6477 | 0.6081 | 0.1364 |
| Jarque-Bera JB | 0.7646 | 0.5143 | 0.1884 | 0.6642 | 0.9001 |
| P(normal) | 0.6823 | 0.7733 | 0.9101 | 0.7174 | 0.6376 |
| p(Monte Carlo) | 0.2529 | 0.5935 | 0.937 | 0.4261 | 0.2095 |
| Silkie |  |  |  |  |  |


|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| :---: | :--- | :--- | :--- | :--- | :--- |
| Shapiro-Wilk W | 0.9713 | 0.8767 | $0.88 \mathrm{I7}$ | 0.9257 | 0.9678 |
| p (normal) | 0.9074 | 0.2122 | 0.2769 | 0.5475 | 0.882 |
| Anderson-Darling A | 0.1823 | 0.4487 | 0.3447 | 0.2727 | 0.1778 |
| p(normal) | 0.8605 | 0.1891 | 0.3448 | 0.5253 | 0.8731 |
| p(Monte Carlo) | 0.9078 | 0.1903 | 0.3838 | 0.591 | 0.914 |
| Jarque-Bera JB | 0.2338 | 0.8344 | 0.604 | 0.5064 | 0.4428 |
| p(normal) | 0.8897 | 0.6589 | 0.7393 | 0.7763 | 0.8014 |
| p(Monte Carlo) | 0.897 | 0.2539 | 0.45 | 0.5957 | 0.7072 |


| Asian Game tibiotarsi |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W | 0.8454 | 0.9709 | 0.9065 | 0.894 | 0.8287 |
| P(normal) | 0.1445 | 0.8986 | 0.4136 | 0.3399 | 0.1049 |
| Anderson-Darling A | 0.5464 | 0.2301 | 0.3831 | 0.3886 | 0.514 |
| P(normal) | 0.09045 | 0.6668 | 0.2685 | 0.259 | 0.1126 |
| p(Monte Carlo) | 0.0942 | 0.7469 | 0.2992 | 0.2862 | 0.1198 |
| Jarque-Bera JB | 1.313 | 0.06018 | 0.6339 | 0.3023 | 1.298 |
| p(normal) | 0.5187 | 0.9704 | 0.7284 | 0.8597 | 0.5226 |
| p(Monte Carlo) | 0.0733 | 0.9881 | 0.4132 | 0.8488 | 0.0721 |
| Asian Game |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.9696 | 0.9368 | 0.8595 | 0.9769 | 0.83I |


| P(normal) | 0.89 | 0.6332 | 0.1874 | 0.9353 | 0.1095 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Anderson-Darling A | 0.2308 | 0.293 | 0.4245 | 0.1616 | 0.5129 |
| p(normal) | 0.6641 | 0.4779 | 0.2039 | 0.8963 | 0.1134 |
| p(Monte Carlo) | 0.7384 | 0.5228 | 0.2232 | 0.952 | 0.1168 |
| Jarque-Bera JB | 0.04896 | 0.4885 | 1.213 | 0.3995 | 1.384 |
| P(normal) | 0.9758 | 0.7833 | 0.5453 | 0.819 | 0.5006 |
| p(Monte Carlo) | 0.9907 | 0.6253 | 0.0864 | 0.7413 | 0.0633 |
| Asian Game |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.9629 | 0.928 | 0.9653 | 0.9574 | 0.9831 |
| p(normal) | 0.8417 | 0.565 | 0.8597 | 0.7994 | 0.9658 |
| Anderson-Darling A | 0.1802 | 0.3112 | 0.2016 | 0.1959 | 0.1461 |
| P(normal) | 0.8512 | 0.4266 | 0.7785 | 0.7993 | 0.9274 |
| p (Monte Carlo) | 0.9 | 0.4793 | 0.853 | 0.8631 | 0.9779 |
| Jarque-Bera JB | 0.4176 | 0.5413 | 0.3844 | 0.4615 | 0.3617 |
| P(normal) | 0.8115 | 0.7629 | 0.8251 | 0.7939 | 0.8346 |
| p(Monte Carlo) | 0.7148 | 0.5393 | 0.7583 | 0.6577 | 0.7926 |


| Chester tibiotarsi |  |  |  |  |  |  | Bd/Dip | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{Dd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ |
| :---: | :--- | :--- | :--- | :--- | :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 0.947 | 0.9674 | 0.8757 | 0.95 I 3 | 0.9149 |  |  |  |  |  |  |
| Shapiro-Wilk W | 0.594 I | 0.8812 | 0.07717 | 0.656 | 0.2463 |  |  |  |  |  |  |
| p(normal) | 0.407 I | 0.195 | 0.5984 | 0.2958 | 0.4464 |  |  |  |  |  |  |
| Anderson-Darling A |  |  |  |  |  |  |  |  |  |  |  |


| P(normal) | 0.2934 | 0.8605 | 0.09239 | 0.5349 | 0.2319 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| p(Monte Carlo) | 0.3097 | 0.8822 | 0.0951 | 0.5739 | 0.254 |
| Jarque-Bera JB | 0.2336 | 0.5871 | 1.583 | 0.601 | 0.5066 |
| P(normal) | 0.8898 | 0.7456 | 0.4531 | 0.7404 | 0.7762 |
| P(Monte Carlo) | 0.887 | 0.6226 | 0.1286 | 0.6203 | 0.6884 |
| Chester |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |
| Shapiro-Wilk W | 0.9576 | 0.8711 | 0.9187 | 0.9551 | 0.9715 |
| P(normal) | 0.7489 | 0.0675 | 0.2751 | 0.712 | 0.926 |
| Anderson-Darling A | 0.2353 | 0.6247 | 0.4004 | 0.3667 | 0.1911 |
| P(normal) | 0.7326 | 0.07866 | 0.3053 | 0.3716 | 0.8707 |
| P(Monte Carlo) | 0.7615 | 0.0786 | 0.3176 | 0.3886 | 0.8945 |
| Jarque-Bera JB | 0.5438 | 1.401 | 0.5661 | 0.2074 | 0.5497 |
| P(normal) | 0.7619 | 0.4964 | 0.7535 | 0.9015 | 0.7597 |
| p(Monte Carlo) | 0.6643 | 0.1533 | 0.6333 | 0.9061 | 0.6544 |
| Chester |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.9792 | 0.9489 | 0.959 | 0.8994 | 0.9345 |
| P(normal) | 0.9804 | 0.621 | 0.7695 | 0.1557 | 0.4297 |
| Anderson-Darling A | 0.1566 | 0.2313 | 0.3005 | 0.7025 | 0.2708 |
| P(normal) | 0.9352 | 0.7467 | 0.5249 | 0.0488 I | 0.6064 |
| p(Monte Carlo) | 0.9565 | 0.77 | 0.5539 | 0.0504 | 0.6453 |
| Jarque-Bera JB | 0.1964 | 0.5462 | 0.5713 | 0.7861 | 0.6859 |


| p (normal) | 0.9065 | 0.761 | 0.7515 | 0.675 | 0.7097 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| p (Monte Carlo) | 0.9067 | 0.6522 | 0.6401 | 0.4647 | 0.5405 |


| Lyminge tibiotarsi |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W |  |  | 0.9524 |  | $0.9 / 55$ |
| p(normal) |  |  | 0.169 |  | $\mathbf{0 . 0 1 5 7 4}$ |
| Anderson-Darling A |  |  | 0.5529 |  | 0.9128 |
| p(normal) |  |  | 0.1419 |  | $\mathbf{0 . 0 I 7 6 9}$ |
| p(Monte Carlo) |  |  | 0.145 |  | $\mathbf{0 . 0 2 0 8}$ |
| Jarque-Bera JB |  |  | 2.605 |  | 4.649 |
| p(normal) |  |  | 0.2718 |  | 0.09783 |
| p(Monte Carlo) |  |  | 0.1059 |  | 0.0514 |
| Lyminge |  |  |  |  |  |
|  |  | Bd/La | Dd/La | SC/La | Bd/Dd |
| Shapiro-Wilk W |  | 0.9641 | 0.9038 |  | 0.9647 |
| p(normal) |  | 0.3543 | $\mathbf{0 . 0 0 7 7 6 5}$ |  | 0.3668 |
| Anderson-Darling A |  | 0.3762 | 0.9992 |  | 0.5225 |
| p(normal) |  | 0.3912 | $\mathbf{0 . 0 1 0 7}$ |  | 0.17 |
| p(Monte Carlo) |  | 0.3961 | $\mathbf{0 . 0 0 9 2}$ |  | 0.176 |
| Jarque-Bera JB |  | 1.691 | 5.691 |  | 0.215 |
| p(normal) |  | 0.4293 | 0.05809 |  | 0.8981 |
| p(Monte Carlo) |  | 0.2328 | $\mathbf{0 . 0 3 7 8}$ |  | 0.8918 |


| Lyminge |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.9399 | 0.9344 | 0.935 | 0.984 I | 0.8696 |
| p(normal) | 0.07437 | 0.05204 | 0.05394 | 0.9061 | $\mathbf{0 . 0 0 I I 3 7}$ |
| Anderson-Darling A | 0.6687 | 0.9825 | 0.7946 | 0.2313 | 1.097 |
| p(normal) | 0.07331 | $\mathbf{0 . 0 1 7 7 9}$ | $\mathbf{0 . 0 3 5 2 I}$ | 0.7853 | $\mathbf{0 . 0 0 6 0 7 5}$ |
| p(Monte Carlo) | 0.0734 | $\mathbf{0 . 0 1 1 9}$ | $\mathbf{0 . 0 3 7 4}$ | 0.7898 | $\mathbf{0 . 0 0 5 3}$ |
| Jarque-Bera JB | 7.546 | 2.871 | 6.538 | 0.2616 | 19.32 |
| p(normal) | $\mathbf{0 . 0 2 2 9 8}$ | 0.238 | $\mathbf{0 . 0 3 8 0 4}$ | 0.8774 | $\mathbf{6 . 3 8 E - 0 5}$ |
| p(Monte Carlo) | $\mathbf{0 . 0 2 2 3}$ | 0.098 I | $\mathbf{0 . 0 2 7 9}$ | 0.864 | $\mathbf{0 . 0 0 2 9}$ |


| Uley tibiotarsi |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL |
| Shapiro-Wilk W | 0.9973 | 0.7735 | 0.9764 | 0.8895 | 0.9203 |
| P(normal) | 0.9908 | 0.06257 | 0.8804 | 0.3807 | 0.5386 |
| Anderson-Darling A | 0.1648 | 0.5391 | 0.1926 | 0.3101 | 0.3101 |
| P(normal) | 0.8383 | 0.06178 | 0.7255 | 0.34 | 0.3399 |
| P(Monte Carlo) | 0.9608 | 0.0571 | 0.857 | 0.4286 | 0.4269 |
| Jarque-Bera JB | 0.2227 | 0.8478 | 0.3217 | 0.5064 | 0.3828 |
| P(normal) | 0.8946 | 0.6545 | 0.8514 | 0.7763 | 0.8258 |
| p(Monte Carlo) | 0.937 | 0.0551 | 0.8046 | 0.401 | 0.7071 |
| Uley |  |  |  |  |  |
|  | Bd/La | Dd/La | SC/La | Bd/Dd | Dd/Dip |


| Shapiro-Wilk W | 0.7527 | 0.9612 | 0.952 | 0.8808 | 0.8257 |
| :---: | :---: | :---: | :---: | :---: | :---: |
| P(normal) | 0.04093 | 0.7864 | 0.7288 | 0.342 | 0.1568 |
| Anderson-Darling A | 0.5854 | 0.2042 | 0.2526 | 0.3724 | 0.4344 |
| p(normal) | 0.04355 | 0.6738 | 0.5067 | 0.2152 | 0.1339 |
| p(Monte Carlo) | 0.0388 | 0.8182 | 0.6365 | 0.246 | 0.1502 |
| Jarque-Bera JB | 0.8804 | 0.3889 | 0.2952 | 0.5478 | 0.7268 |
| P(normal) | 0.6439 | 0.8233 | 0.8628 | 0.7604 | 0.6953 |
| p(Monte Carlo) | 0.0394 | 0.7107 | 0.8439 | 0.3211 | 0.1213 |
| Uley |  |  |  |  |  |
|  | Dip/GL | SC/Dip | Dip/La | La/GL | SC/Dd |
| Shapiro-Wilk W | 0.8702 | 0.8327 | 0.8705 | 0.9771 | 0.8697 |
| P(normal) | 0.2983 | 0.1749 | 0.2997 | 0.8845 | 0.2967 |
| Anderson-Darling A | 0.3627 | 0.4077 | 0.3521 | 0.1816 | 0.3414 |
| p(normal) | 0.2313 | 0.1647 | 0.2503 | 0.7729 | 0.2708 |
| p(Monte Carlo) | 0.2727 | 0.1852 | 0.2978 | 0.899 | 0.3272 |
| Jarque-Bera JB | 0.6396 | 0.6109 | 0.6031 | 0.3521 | 0.5352 |
| P(normal) | 0.7263 | 0.7368 | 0.7397 | 0.8386 | 0.7652 |
| p(Monte Carlo) | 0.1875 | 0.2275 | 0.2366 | 0.7531 | 0.3488 |

### 4.1.2.5 Tarsometatarsi - measurement ratios

| Dorking tarsometatarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| Shapiro-Wilk W | 0.8424 | 0.8492 | 0.8023 | 0.8604 | 0.7412 | 0.9172 |
| p (normal) | 0.06 I 37 | 0.07298 | $\mathbf{0 . 0 2 I 7 I}$ | 0.09684 | $\mathbf{0 . 0 0 4 2 8 3}$ | 0.3697 |
| Anderson-Darling A | 0.6016 | 0.5335 | 0.735 | 0.5264 | 1.093 | 0.3975 |
| p (normal) | 0.08092 | 0.122 | $\mathbf{0 . 0 3 4 8 6}$ | 0.1278 | $\mathbf{0 . 0 0 3 6 5 9}$ | 0.289 |
| p (Monte Carlo) | 0.0794 | 0.128 | $\mathbf{0 . 0 3 4}$ | 0.1355 | $\mathbf{0 . 0 0 3 8}$ | 0.3025 |
| Jarque-Bera JB | 1.998 | 3.165 | 5.349 | 3.278 | 2.239 | 0.831 |
| p(normal) | 0.3682 | 0.2055 | $\mathbf{0 . 0 6 8 9 5}$ | 0.1942 | $\mathbf{0 . 3 2 6 4}$ | 0.66 |
| p (Monte Carlo) | 0.0608 | $\mathbf{0 . 0 2 7 7}$ | $\mathbf{0 . 0 0 8 3}$ | $\mathbf{0 . 0 2 7 2}$ | $\mathbf{0 . 0 5 4 4}$ | 0.3424 |


| Hamburgh tarsometatarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| Shapiro-Wilk W | 0.97 | 0.991 | 0.9357 | 0.8773 | $0.86 / 5$ | 0.94 I 3 |
| p (normal) | 0.8984 | 0.9965 | 0.5689 | 0.1774 | 0.1242 | 0.6243 |
| Anderson-Darling A | 0.1925 | 0.1234 | 0.2878 | 0.453 | 0.6565 | 0.3068 |
| p (normal) | 0.8426 | 0.975 | 0.5233 | 0.1957 | 0.05355 | 0.482 |
| p(Monte Carlo) | 0.876 | 0.9948 | 0.5716 | 0.2053 | 0.053 I | 0.5072 |
| Jarque-Bera JB | 0.4391 | 0.1918 | 0.3428 | 0.9094 | 0.9742 | 0.1897 |
| p (normal) | 0.8029 | 0.9086 | 0.8425 | 0.6346 | 0.6144 | 0.9095 |
| p (Monte Carlo) | 0.716 I | 0.9206 | 0.8173 | 0.2474 | 0.207 I | 0.9226 |


| Red Junglefowl tarsometatarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| Shapiro-Wilk W | 0.9618 | 0.9437 | 0.9403 | 0.9652 | 0.888 I | 0.87 I 5 |
| p(normal) | 0.8273 | 0.648 | 0.6143 | 0.8583 | 0.2245 | 0.156 |
| Anderson-Darling A | 0.2024 | 0.350 I | 0.3 I 44 | 0.2365 | 0.4992 | 0.5091 |
| p(normal) | $0.8 \mathrm{II5}$ | 0.3718 | 0.4499 | 0.6878 | 0.1448 | 0.1357 |
| p(Monte Carlo) | 0.8456 | 0.4023 | 0.4847 | 0.7342 | 0.1486 | 0.1448 |
| Jarque-Bera JB | 0.5335 | 0.1989 | 0.3809 | 0.238 | 1.285 | 1.824 |
| p(normal) | 0.7659 | 0.9053 | 0.8266 | 0.8878 | 0.5261 | 0.4017 |
| p(Monte Carlo) | 0.6199 | 0.9183 | 0.7755 | 0.895 | 0.1136 | 0.0644 |


| Old English Game tarsometatarsi |  |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |  |
| Shapiro-Wilk W | 0.8535 | 0.9246 | 0.9465 | 0.9146 | 0.8924 | 0.9559 |  |
| p(normal) | 0.0639 | 0.397 | 0.6277 | 0.314 I | 0.1802 | 0.7385 |  |
| Anderson-Darling A | 0.568 | 0.354 I | 0.246 | 0.4448 | 0.4623 | 0.1902 |  |
| p(normal) | 0.1046 | 0.3852 | 0.6778 | 0.2232 | 0.200 I | 0.8643 |  |
| p(Monte Carlo) | 0.1062 | 0.4038 | 0.7184 | 0.226 | 0.2033 | 0.895 |  |
| Jarque-Bera JB | 2.639 | 0.7569 | 0.7346 | 0.9128 | I .088 | 0.6202 |  |
| p(normal) | 0.2673 | 0.6849 | 0.6926 | 0.6336 | 0.5803 | 0.7334 |  |
| p(Monte Carlo) | 0.0459 | 0.446 | 0.4663 | 0.3176 | 0.2203 | 0.569 |  |


| Silkie tarsometatarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| Shapiro-Wilk W | 0.9366 | 0.9544 | 0.9495 | 0.942 | 0.9373 | 0.8932 |
| p(normal) | 0.608 I | 0.7694 | 0.7253 | 0.6567 | 0.6145 | 0.292 |
| Anderson-Darling A | 0.2385 | 0.2277 | 0.224 I | 0.291 I | 0.2465 | 0.33 |
| p(normal) | 0.66 II | 0.7027 | 0.7166 | 0.5065 | 0.6308 | 0.4025 |
| p(Monte Carlo) | 0.7274 | 0.764 | 0.7766 | 0.5385 | 0.698 | 0.4355 |
| Jarque-Bera JB | 0.4527 | 0.4776 | 0.6166 | 0.5475 | 0.6005 | 0.7538 |
| p(normal) | 0.7975 | 0.7876 | 0.7347 | 0.7605 | 0.7406 | 0.686 |
| p(Monte Carlo) | 0.7025 | 0.6634 | 0.4972 | 0.5676 | 0.5078 | 0.3282 |


| Asian Game tarsometatarsi |  |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- | :---: |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |  |
| Shapiro-Wilk W | 0.9477 | 0.8434 | 0.8029 | 0.9316 | 0.8845 | 0.9289 |  |
| p(normal) | 0.7216 | 0.1392 | 0.06244 | 0.5924 | 0.2904 | 0.5718 |  |
| Anderson-Darling A | 0.2525 | 0.5413 | 0.589 | 0.3056 | 0.3322 | 0.2492 |  |
| p(normal) | 0.583 | 0.09362 | 0.06788 | 0.4418 | 0.3734 | 0.5946 |  |
| p(Monte Carlo) | 0.6726 | 0.0965 | 0.0665 | 0.4904 | 0.4159 | 0.6785 |  |
| Jarque-Bera JB | 0.4305 | I .418 | I .449 | 0.5784 | 0.6788 | 0.6197 |  |
| p(normal) | 0.8064 | 0.4922 | 0.4847 | 0.7489 | 0.7122 | 0.7335 |  |
| p(Monte Carlo) | 0.7013 | 0.061 I | 0.058 I | 0.4903 | 0.3585 | 0.4179 |  |


| Chester tarsometatarsi |  |  |  |  |  |  |
| :---: | :--- | :--- | :--- | :--- | :--- | :--- |
|  | $\mathrm{Bd} / \mathrm{Bp}$ | $\mathrm{SC} / \mathrm{Bd}$ | $\mathrm{SC} / \mathrm{GL}$ | $\mathrm{Bp} / \mathrm{GL}$ | $\mathrm{Bd} / \mathrm{GL}$ | $\mathrm{SC} / \mathrm{Bp}$ |
| Shapiro-Wilk W | 0.8763 | 0.8843 | 0.935 | 0.9334 | 0.9866 | 0.9543 |
| p(normal) | 0.1436 | 0.174 I | 0.53 | 0.5143 | 0.9895 | 0.737 I |
| Anderson-Darling A | 0.4968 | 0.4468 | $0.33 \mathrm{I4}$ | 0.343 | 0.139 I | 0.232 I |
| p(normal) | 0.1549 | 0.2 I 29 | 0.4295 | 0.4012 | 0.957 I | 0.7 I 86 |
| p(Monte Carlo) | 0.162 I | 0.2247 | 0.4589 | 0.4265 | 0.9832 | 0.7544 |
| Jarque-Bera JB | I .04 | 0.9229 | 0.7632 | 0.665 I | 0.2255 | 0.1843 |
| p(normal) | 0.5944 | 0.6304 | 0.6828 | 0.717 I | 0.8934 | 0.912 |
| p(Monte Carlo) | 0.2088 | 0.2824 | 0.409 I | 0.4994 | 0.8964 | 0.9254 |


| Lyminge tarsometatarsi |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| Shapiro-Wilk W | 0.9721 | 0.9733 | 0.9664 | 0.9882 | 0.9664 | 0.9877 |
| P(normal) | 0.3044 | 0.3393 | 0.1834 | 0.9053 | 0.1823 | 0.8913 |
| Anderson-Darling A | 0.3745 | 0.3997 | 0.5922 | 0.2211 | 0.5806 | 0.161 |
| p(normal) | 0.4019 | 0.3502 | 0.1181 | 0.8221 | 0.1238 | 0.9436 |
| P(Monte Carlo) | 0.4073 | 0.3588 | 0.1143 | 0.8236 | 0.1291 | 0.9606 |
| Jarque-Bera JB | 2.818 | 3.045 | 1.002 | 0.2088 | 0.5821 | 0.3819 |
| p (normal) | 0.2444 | 0.2182 | 0.6059 | 0.9008 | 0.7475 | 0.8262 |
| p(Monte Carlo) | 0.1208 | 0.1006 | 0.517 | 0.8947 | 0.6997 | 0.804 |


| Uley tarsometatarsi |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| Shapiro-Wilk W | 0.906 | 0.9054 | 0.8545 | 0.8753 | 0.9543 | 0.9482 |
| p(normal) | 0.3265 | 0.3226 | 0.1059 | 0.1697 | 0.7542 | 0.6927 |
| Anderson-Darling A | 0.4082 | 0.3588 | 0.5549 | 0.4501 | 0.2629 | 0.2215 |
| P(normal) | 0.26 | 0.3528 | 0.1028 | 0.1993 | 0.5917 | 0.7445 |
| P(Monte Carlo) | 0.2752 | 0.3753 | 0.1087 | 0.2101 | 0.6605 | 0.7877 |
| Jarque-Bera JB | 1.154 | 0.6631 | I.04I | 0.8701 | 0.1594 | 0.5105 |
| P(normal) | 0.5615 | 0.7178 | 0.5943 | 0.6472 | 0.9234 | 0.7747 |
| p(Monte Carlo) | 0.1327 | 0.4715 | 0.1833 | 0.2758 | 0.938 | 0.6401 |

## 4.I.3 Group means for measurement ratios - modern and archaeological chickens

Bold $=$ highest group mean of that ratio; italic $=$ lowest group mean of that ratio.
4.1.3.1 Coracoid

| Coracoid | Lm/GL | Bf/Bb | Bb/GL | Bb/Lm | Bf/GL | Bf/Lm |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 95.07 | 78.67 | 29.34 | 30.87 | 23.08 | 24.29 |
| Dorking | 96.27 | 83.74 | 27.98 | 29.06 | 23.42 | 24.32 |
| Hamburgh | $\mathbf{9 6}$ |  |  |  |  |  |
| RJF | 94.93 | 81.23 | 25.89 | 27.28 | 21.04 | 22.17 |
| O E Game | 94.97 | 84.20 | 27.70 | 29.17 | 23.33 | 24.57 |
| Silkie | 93.07 | 81.50 | 29.10 | 31.26 | 23.70 | 25.47 |
| Asian Game | 93.28 | 80.85 | $\mathbf{3 0 . 8 0}$ | $\mathbf{3 3 . 0 1}$ | $\mathbf{2 4 . 8 8}$ | $\mathbf{2 6 . 6 7}$ |
| Uley | 95.27 | 81.94 | 27.02 | 28.36 | 22.12 | 21.23 |
| Lyminge | 95.31 | 82.98 | 26.24 | 27.54 | 21.76 | 22.84 |
| Chester | 95.06 | 83.43 | 27.19 | 28.62 | 22.69 | 23.88 |
| Coppergate | 95.25 | 84.20 | 27.14 | 28.49 | 22.85 | 23.99 |
| Fishbourne | 95.14 | $\mathbf{8 6 . 4 5}$ | 24.70 | 25.96 | 21.32 | 22.41 |
| Flixborough | 95.17 | 85.47 | 26.38 | 27.72 | 22.54 | 23.69 |

### 4.1.3.2 Humerus

| Humerus | Bd/Bp | SC/GL | Bp/GL | Bd/GL | SC/Bp | SC/Bd |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 78.96 | 9.76 | $\mathbf{2 8 . 4 3}$ | 22.43 | 34.35 | 43.54 |
| Dorking | 79.61 | 9.21 | 26.09 | 20.77 | 35.29 | 44.33 |
| Hamburgh | 80.57 | 9.51 | 25.56 | 20.59 | $\mathbf{3 7 . 2 0}$ | 46.17 |
| RJF | 77.98 | 9.95 | 27.23 | 21.22 | 36.55 | 46.90 |
| O E Game | $\mathbf{8 1 . 3 7}$ | 9.74 | 27.82 | $\mathbf{2 2 . 6 3}$ | 35.02 | 43.06 |
| Silkie | 79.84 | 9.57 | 28.28 | 22.58 | 33.86 | 42.42 |
| Asian Game | 79.68 | 9.73 | 26.71 | 21.28 | 36.45 | 45.76 |
| Uley | 78.07 | $\mathbf{9 . 9 0}$ | 27.40 | 21.38 | 36.13 | 46.30 |
| Lyminge | 78.98 | 9.67 | 27.30 | 21.55 | 35.42 | 44.87 |
| Chester | 7 |  |  |  |  |  |

### 4.1.3.3 Femur

| Femur | Dd/Bd | SC/Bd | SC/GL | Bd/GL | Bp/GL | Bd/Lm | Bp/Lm |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 82.98 | 43.92 | 9.34 | 21.27 | 21.02 | 23.08 | 22.81 |
| Dorking | 84.43 | 46.01 | 8.97 | 19.50 | 19.90 | 20.86 | 21.29 |
| Hamburgh | 83.08 | 45.98 | 8.60 | 18.71 | 19.23 | 19.85 | 20.40 |
| RJF | 83.31 |  |  |  |  |  |  |
| O E Game | $\mathbf{8 4 . 7 3}$ | 46.37 | 9.26 | 19.97 | 20.21 | 21.44 | 21.70 |
| Silkie | 83.52 | 44.26 | 9.23 | 20.83 | 20.80 | 22.43 | 22.40 |
| Asian Game | 84.11 | 43.45 | $\mathbf{9 . 4 1}$ | $\mathbf{2 1 . 7 0}$ | $\mathbf{2 1 . 2 3}$ | $\mathbf{2 3 . 3 7}$ | $\mathbf{2 2 . 8 6}$ |
| Uley | 81.60 | 45.57 | 8.80 | 19.33 | 19.54 | 20.62 | 20.85 |


| Lyminge | 84.25 | 44.79 | 8.69 | 19.43 | 19.92 | 20.80 | 21.33 |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Chester | 82.62 | 44.31 | 8.68 | 19.60 | 20.01 | 21.00 | 21.44 |
| Femur - cont |  |  |  |  |  |  |  |
|  | $\mathbf{~ S C / L m}$ | SC/Bp | Dd/Bp | Dp/Dd | Dd/GL | Dd/Lm | Sc/Dd |
| Dorking | $\mathbf{1 0 . 1 3}$ | 44.44 | 83.99 | $\mathbf{8 4 . 9 0}$ | 17.65 | 19.15 | 52.97 |
| Hamburgh | 9.59 | 45.06 | 82.69 | 83.86 | 16.45 | 17.60 | 54.53 |
| RJF | 9.12 | 44.71 | 80.79 | 82.62 | 15.51 | 16.45 | 55.53 |
| O E Game | 9.94 | 45.87 | 83.75 | 82.97 | 16.92 | 18.16 | 54.79 |
| Silkie | 9.94 | 44.32 | 84.00 | 80.24 | 17.39 | 18.73 | 53.05 |
| Asian Game | 9.57 | 44.33 | $\mathbf{8 5 . 9 3}$ | 81.89 | $\mathbf{1 8 . 2 4}$ | 19.64 | 51.72 |
| Uley | 9.39 | 41.80 | 80.66 | 83.71 | 15.76 | 16.82 | $\mathbf{5 5 . 8 7}$ |
| Lyminge | 9.31 | 43.69 | 82.17 | 81.82 | 16.36 | 17.52 | 53.22 |
| Chester | 9.30 | 43.43 | 80.96 | 83.63 | 16.18 | 17.34 | 53.68 |

### 4.1.3.4 Tibiotarsus

| Tibiotarsus | Bd/Dip | Bd/GL | Dd/GL | SC/Bd | SC/GL | Bd/La | Dd/La | SC/La | Bd/Dd |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | 58.32 | 11.93 | 11.68 | 52.44 | 6.25 | 12.45 | 12.19 | 6.52 | $\mathbf{1 0 2 . 2 2}$ |
| Dorking | 53.17 | 9.89 | 10.73 | 58.14 | 5.73 | 10.27 | 11.14 | 5.95 | 92.31 |
| Hamburgh | 5.14 | 10 |  |  |  |  |  |  |  |
| RJF | 56.90 | 10.14 | 10.62 | 56.16 | 5.69 | 10.52 | 11.02 | 5.91 | 95.59 |
| O E Game | 53.82 | 10.39 | 10.95 | 56.67 | 5.87 | 10.79 | 11.37 | 6.10 | 94.77 |
| Silkie | $\mathbf{6 1 . 1 6}$ | $\mathbf{1 2 . 2 2}$ | $\mathbf{1 2 . 0 0}$ | 54.94 | $\mathbf{6 . 7 1}$ | $\mathbf{1 2 . 7 0}$ | $\mathbf{1 2 . 4 0}$ | $\mathbf{6 . 8 6}$ | 101.94 |
| Asian Game | 54.22 | 11.12 | 11.40 | $\mathbf{5 8 . 4 1}$ | 6.49 | 11.58 | 11.87 | 6.76 | 97.52 |
| Uley | 54.25 | 10.09 | 10.55 | 55.41 | 5.59 | 10.44 | 10.92 | 5.78 | 95.64 |


| Lyminge | - | - | 11.00 | - | 5.45 | - | 11.48 | 5.69 | - |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Chester | 56.53 | 10.51 | 10.98 | 53.84 | 5.65 | 10.89 | 11.38 | 5.86 | 95.76 |
|  |  |  |  |  |  |  |  |  |  |
|  | Dd/Dip | Dip/GL | SC/Dip | Dip/La | La/GL | Sc/Dd |  |  |  |
| Dorking | 57.07 | 20.46 | 30.55 | 21.36 | 95.80 | 53.52 |  |  |  |
| Hamburgh | 57.63 | 18.63 | 30.78 | 19.34 | 96.30 | 53.45 |  |  |  |
| RJF | 59.65 | 17.83 | 31.92 | 18.49 | 96.41 | 53.67 |  |  |  |
| O E Game | 56.88 | 19.28 | 30.44 | 20.02 | 96.30 | 53.58 |  |  |  |
| Silkie | $\mathbf{6 0 . 0 5}$ | 20.00 | $\mathbf{3 3 . 5 5}$ | 20.61 | 96.49 | 55.84 |  |  |  |
| Asian Game | 55.60 | $\mathbf{2 0 . 5 2}$ | 31.66 | $\mathbf{2 1 . 3 7}$ | 96.05 | $\mathbf{5 6 . 9 6}$ |  |  |  |
| Uley | 56.77 | 18.59 | 30.05 | 19.24 | $\mathbf{9 6 . 6 2}$ | 52.95 |  |  |  |
| Lyminge | 59.47 | 18.52 | 29.47 | 19.33 | 95.79 | 49.57 |  |  |  |
| Chester | 59.04 | 18.60 | 30.40 | 19.28 | 96.45 | 51.53 |  |  |  |

### 4.1.3.5 Tarsometatarsus

## Tarsometatarsus

| Tarsometatarsus |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Bd/Bp | SC/Bd | SC/GL | Bp/GL | Bd/GL | SC/Bp |
| Dorking | 101.92 | 48.88 | 9.54 | 19.19 | $\mathbf{I 9 . 5 5}$ | 49.74 |
| Hamburgh | $\mathbf{1 0 7 . 8 1}$ | 46.30 | 8.52 | 17.12 | 18.40 | 49.8 I |
| RJF | 96.90 | 49.83 | 8.59 | 17.8 I | 17.21 | 48.27 |
| O E Game | 101.91 | 49.90 | 8.89 | 17.50 | 17.82 | 50.83 |
| Silkie | 93.60 | 53.19 | $\mathbf{1 0 . 1 I}$ | $\mathbf{2 0 . 4 2}$ | 19.13 | 49.57 |
| Asian Game | 97.5 I | $\mathbf{5 4 . 1 4}$ | 9.98 | 18.93 | 18.44 | $\mathbf{5 2 . 6 8}$ |
| Uley | 97.67 | 51.62 | 8.58 | 17.06 | 16.63 | 50.43 |


| Lyminge | 99.46 | 47.55 | 8.42 | 17.83 | 17.72 | 47.25 |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: |
| Chester | 102.36 | 47.74 | 8.44 | 17.29 | 17.69 | 48.87 |

4.I.4 Selected results of pairwise Permanova tests for measurement ratios - modern
4.1.4.1 Coracoid

| P-values of Permanova for Lm/GL v Bb/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 3 2 4}$ | $\mathbf{0 . 0 0 0 4}$ | 0.0554 | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 8 3}$ |
| Hamburgh | $\mathbf{0 . 0 3 2 4}$ |  | $\mathbf{0 . 0 0 3 4}$ | 0.1236 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 7}$ |
| RJF | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 3 4}$ |  | $\mathbf{0 . 0 3 6 7}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | 0.0554 | 0.1236 | $\mathbf{0 . 0 3 6 7}$ |  | $\mathbf{0 . 0 0 2 0}$ | $\mathbf{0 . 0 0 0 8}$ |
| Silkie | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 2 0}$ |  | $\mathbf{0 . 0 4 1 9}$ |
| Asian Game | $\mathbf{0 . 0 0 8 3}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 4 1 9}$ |  |


| P-values of Permanova for $\mathrm{Bb} / \mathrm{GL} \mathrm{v} \mathrm{Bb} / \mathrm{Lm}$ |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 2 1 8}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 4 5 7}$ | 0.601 I | $\mathbf{0 . 0 2 7 2}$ |
| Hamburgh | $\mathbf{0 . 0 2 1 8}$ |  | $\mathbf{0 . 0 0 8 0}$ | 0.8057 | $\mathbf{0 . 0 0 4 0}$ | $\mathbf{0 . 0 0 0 5}$ |
| RJF | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 8 0}$ |  | $\mathbf{0 . 0 3 2 6}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | $\mathbf{0 . 0 4 5 7}$ | 0.8057 | $\mathbf{0 . 0 3 2 6}$ |  | $\mathbf{0 . 0 2 5 5}$ | $\mathbf{0 . 0 0 2 3}$ |
| Silkie | 0.601 I | $\mathbf{0 . 0 0 4 0}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 2 5 5}$ |  | $\mathbf{0 . 0 1 4 6}$ |
| Asian Game | $\mathbf{0 . 0 2 7 2}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 1 4 6}$ |  |


| P-values of Permanova for $\mathrm{Bf} / \mathrm{Bb} \mathrm{vb} / \mathrm{GL}$ |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 4 5}$ | $\mathbf{0 . 0 0 8 0}$ | $\mathbf{0 . 0 0 2 3}$ | 0.1563 | 0.1465 |
| Hamburgh | $\mathbf{0 . 0 0 4 5}$ |  | $\mathbf{0 . 0 3 6 8}$ | 0.8767 | 0.1999 | $\mathbf{0 . 0 1 9 4}$ |
| RJF | $\mathbf{0 . 0 0 8 0}$ | $\mathbf{0 . 0 3 6 8}$ |  | $\mathbf{0 . 0 3 4 2}$ | 0.0904 | $\mathbf{0 . 0 0 0 5}$ |
| O E Game | $\mathbf{0 . 0 0 2 3}$ | 0.8767 | $\mathbf{0 . 0 3 4 2}$ |  | 0.1179 | $\mathbf{0 . 0 0 6 4}$ |
| Silkie | 0.1563 | 0.1999 | 0.0904 | 0.1179 |  | 0.3940 |
| Asian Game | 0.1465 | $\mathbf{0 . 0 1 9 4}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 6 4}$ | 0.394 |  |

### 4.1.4.2 Humerus

| P-values of Permanova for Bp/GL v SC/Bd |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 6 2}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 2 3}$ | 0.5717 | 0.3522 |
| Hamburgh | $\mathbf{0 . 0 0 6 2}$ |  | $\mathbf{0 . 0 2 5 8}$ | $\mathbf{0 . 0 0 3 3}$ | $\mathbf{0 . 0 2 5 5}$ | $\mathbf{0 . 0 0 3 8}$ |
| RJF | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 2 5 8}$ |  | $\mathbf{0 . 0 3 8 9}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 1 0}$ |
| O E Game | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 0 3 3}$ | $\mathbf{0 . 0 3 8 9}$ |  | $\mathbf{0 . 0 0 2 7}$ | $\mathbf{0 . 0 0 0 8}$ |
| Silkie | 0.5717 | $\mathbf{0 . 0 2 5 5}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 2 7}$ |  | 0.5725 |
| Asian Game | 0.3522 | $\mathbf{0 . 0 0 3 8}$ | $\mathbf{0 . 0 0 1 0}$ | $\mathbf{0 . 0 0 0 8}$ | 0.5725 |  |


| P-values of Permanova for Bp/GL v Bd/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 3 1}$ | 0.1614 | 0.8695 |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ |  | 0.2063 | $\mathbf{0 . 0 3 0 1}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 5}$ |
| RJF | $\mathbf{0 . 0 0 0 3}$ | 0.2063 |  | $\mathbf{0 . 0 0 4 0}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 8}$ |
| O E Game | $\mathbf{0 . 0 0 3 1}$ | $\mathbf{0 . 0 3 0 1}$ | $\mathbf{0 . 0 0 4 0}$ |  | $\mathbf{0 . 0 1 3 2}$ | $\mathbf{0 . 0 2 1 6}$ |
| Silkie | 0.1614 | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 3 2}$ |  | 0.5794 |
| Asian Game | 0.8695 | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 2 1 6}$ | 0.5794 |  |


| P-values of Permanova for Bp/GL v SC/Bp |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 7}$ | 0.3590 | 0.6927 |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 1 4 0}$ | $\mathbf{0 . 0 1 3 4}$ | $\mathbf{0 . 0 4 0 5}$ | $\mathbf{0 . 0 0 1 2}$ |
| RJF | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 1 4 0}$ |  | $\mathbf{0 . 0 1 2 4}$ | $\mathbf{0 . 0 0 2 9}$ | $\mathbf{0 . 0 0 0 8}$ |
| O E Game | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 1 3 4}$ | $\mathbf{0 . 0 1 2 4}$ |  | 0.0780 | $\mathbf{0 . 0 0 2 9}$ |
| Silkie | 0.3590 | $\mathbf{0 . 0 4 0 5}$ | $\mathbf{0 . 0 0 2 9}$ | 0.0780 |  | 0.2548 |
| Asian Game | 0.6927 | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 2 9}$ | 0.2548 |  |


| P-values of Permanova for Bd/GL v SC/Bp |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 2 4}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 3}$ | 0.4538 | 0.6557 |
| Hamburgh | $\mathbf{0 . 0 0 2 4}$ |  | $\mathbf{0 . 0 1 2 9}$ | $\mathbf{0 . 0 4 2 9}$ | $\mathbf{0 . 0 2 0 9}$ | $\mathbf{0 . 0 0 3 9}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 2 9}$ |  | 0.2197 | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 0 1 2}$ |
| O E Game | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 4 2 9}$ | 0.2197 |  | $\mathbf{0 . 0 1 8 3}$ | $\mathbf{0 . 0 0 1 1}$ |
| Silkie | 0.4538 | $\mathbf{0 . 0 2 0 9}$ | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 1 8 3}$ |  | 0.3133 |
| Asian Game | 0.6557 | $\mathbf{0 . 0 0 3 9}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 1 1}$ | 0.3133 |  |

### 4.1.4.3 Femur

| P-values of Permanova for Bd/Lm v SC/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 2}$ | 0.1018 | 0.7049 |
| Hamburgh | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 3 1 4}$ | 0.1569 | $\mathbf{0 . 0 0 5 2}$ | $\mathbf{0 . 0 0 1 5}$ |
| RJF | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 3 1 4}$ |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 5}$ |
| O E Game | $\mathbf{0 . 0 0 0 2}$ | 0.1569 | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 3 2 7}$ | $\mathbf{0 . 0 0 3 1}$ |
| Silkie | 0.1018 | $\mathbf{0 . 0 0 5 2}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 3 2 7}$ |  | 0.1140 |
| Asian Game | 0.7049 | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 3 1}$ | 0.1140 |  |


| P-values of Permanova for Bd/Lm v Bd/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ | 0.0660 | 0.4370 |
| Hamburgh | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 4 2 8}$ | 0.1630 | $\mathbf{0 . 0 0 2 9}$ | $\mathbf{0 . 0 0 1 2}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 4 2 8}$ |  | $\mathbf{0 . 0 0 1 0}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | $\mathbf{0 . 0 0 0 3}$ | 0.1630 | $\mathbf{0 . 0 0 1 0}$ |  | $\mathbf{0 . 0 1 8 2}$ | $\mathbf{0 . 0 0 2 3}$ |
| Silkie | 0.0660 | $\mathbf{0 . 0 0 2 9}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 1 8 2}$ |  | 0.1020 |
| Asian Game | 0.4370 | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 2 3}$ | 0.1020 |  |


| P-values of Permanova for Dd/GL v Bd/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 2 4}$ | 0.1773 | 0.2591 |
| Hamburgh | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 0 6 5}$ | 0.1495 | $\mathbf{0 . 0 0 2 4}$ | $\mathbf{0 . 0 0 1 3}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 6 5}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | $\mathbf{0 . 0 0 2 4}$ | 0.1495 | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 2 5 8}$ | $\mathbf{0 . 0 0 3 1}$ |
| Silkie | 0.1773 | $\mathbf{0 . 0 0 2 4}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 2 5 8}$ |  | 0.0692 |
| Asian Game | 0.2591 | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 3 1}$ | 0.0692 |  |


| P-values of Permanova for Dd/Lm v Bd/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 7}$ | 0.1043 | 0.3528 |
| Hamburgh | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 0 3 4}$ | 0.1292 | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 9}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 3 4}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 4}$ |
| O E Game | $\mathbf{0 . 0 0 1 7}$ | 0.1292 | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 2 8 8}$ | $\mathbf{0 . 0 0 3 9}$ |


| Silkie | 0.1043 | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 2 8 8}$ |  | 0.0685 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| Asian Game | 0.3528 | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 3 9}$ | 0.0685 |  |


| P-values of Permanova for Bd/Lm v Bp/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 7}$ | 0.1135 | 0.6589 |
| Hamburgh | $\mathbf{0 . 0 0 0 4}$ |  | 0.0241 | $\mathbf{0 . 2 4 5 I}$ | $\mathbf{0 . 0 0 5 4}$ | $\mathbf{0 . 0 0 0 4}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 2 4 1}$ |  | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 2}$ |
| O E Game | $\mathbf{0 . 0 0 0 7}$ | 0.245 I | $\mathbf{0 . 0 0 1 3}$ |  | $\mathbf{0 . 0 4 4 2}$ | $\mathbf{0 . 0 0 3 4}$ |
| Silkie | 0.1135 | $\mathbf{0 . 0 0 5 4}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 4 4 2}$ |  | 0.1149 |
| Asian Game | 0.6589 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 3 4}$ | 0.1149 |  |


| P-values of Permanova for SC/Lm v Bd/Lm |  |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: | :---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |  |
| Dorking |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 7}$ | 0.1216 | 0.7386 |  |
| Hamburgh | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 2 8 7}$ | 0.1536 | $\mathbf{0 . 0 0 6 2}$ | $\mathbf{0 . 0 0 0 7}$ |  |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 2 8 7}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 4}$ |  |
| O E Game | $\mathbf{0 . 0 0 0 7}$ | 0.1536 | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 3 8 8}$ | $\mathbf{0 . 0 0 3 4}$ |  |
| Silkie | 0.1216 | $\mathbf{0 . 0 0 6 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 3 8 8}$ |  | 0.1237 |  |
| Asian Game | 0.7386 | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 3 4}$ | 0.1237 |  |  |


| P-values of Permanova for Dd/GL v Bd/Lm |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 9}$ | 0.0631 | 0.3667 |
| Hamburgh | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 0 4 2}$ | 0.1366 | $\mathbf{0 . 0 0 2 5}$ | $\mathbf{0 . 0 0 1 4}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 4 2}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 6}$ |
| O E Game | $\mathbf{0 . 0 0 0 9}$ | 0.1366 | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 2 1 0}$ | $\mathbf{0 . 0 0 3 3}$ |
| Silkie | 0.0631 | $\mathbf{0 . 0 0 2 5}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 2 1 0}$ |  | 0.0695 |
| Asian Game | 0.3667 | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 3 3}$ | 0.0695 |  |


| P-values of Permanova for Dd/Lm v Bd/Lm |  |  |  |  |  |  |
| :--- | ---: | ---: | :--- | ---: | :--- | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 I}$ | $\mathbf{0 . 0 4 4 5}$ | 0.4836 |
| Hamburgh | $\mathbf{0 . 0 0 0 4}$ |  | $\mathbf{0 . 0 0 3 6}$ | 0.1344 | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 0 1 1}$ |
| RJF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 3 6}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 3}$ |
| O E Game | $\mathbf{0 . 0 0 1 I}$ | 0.1344 | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 2 3 4}$ | $\mathbf{0 . 0 0 3 3}$ |
| Silkie | $\mathbf{0 . 0 4 4 5}$ | $\mathbf{0 . 0 0 1 7}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 2 3 4}$ |  | 0.0744 |
| Asian Game | 0.4836 | $\mathbf{0 . 0 0 1 1}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 3 3}$ | 0.0744 |  |

### 4.1.4.4 Tibiotarsus

| P-values of Permanova for Bd/La v Dip/La |  |  |  |  |  |  |
| :--- | ---: | :--- | ---: | :--- | ---: | ---: |
|  | Dorking | RJF | O E Game | Silkie | Asian Game | Hamburgh |
| Dorking |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 5}$ I | $\mathbf{0 . 0 0 0 1}$ |
| RJF | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 6 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 1 7 8}$ |
| O E Game | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 6 2}$ |  | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 2 1 1}$ | 0.1239 |
| Silkie | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 5}$ |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 1}$ |
| Asian Game | $\mathbf{0 . 0 0 5 1}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 2 1 I}$ | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 0 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 7 8}$ | 0.1239 | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ |  |


| P-values of Permanova for Bd/Dip v SC/GL |  |  |  |  |  |  |
| :--- | ---: | :--- | ---: | :--- | ---: | ---: |
|  | Dorking | RJF | O E Game | Silkie | Asian Game | Hamburgh |
| Dorking |  | 0.1945 | $\mathbf{0 . 0 0 2 1}$ | $\mathbf{0 . 0 2 9 2}$ | $\mathbf{0 . 0 0 4 5}$ | $\mathbf{0 . 0 0 8 1}$ |
| RJF | 0.1945 |  | $\mathbf{0 . 0 1 9 1}$ | $\mathbf{0 . 0 0 1 6}$ | $\mathbf{0 . 0 2 6 9}$ | $\mathbf{0 . 0 3 8 9}$ |
| O E Game | $\mathbf{0 . 0 0 2 1}$ | $\mathbf{0 . 0 1 9 1}$ |  | $\mathbf{0 . 0 0 0 2}$ | 0.5795 | 0.6943 |
| Silkie | $\mathbf{0 . 0 2 9 2}$ | $\mathbf{0 . 0 0 1 6}$ | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 0 9}$ |
| Asian Game | $\mathbf{0 . 0 0 4 5}$ | $\mathbf{0 . 0 2 6 9}$ | 0.5795 | $\mathbf{0 . 0 0 1}$ |  | 0.5072 |
| Hamburgh | $\mathbf{0 . 0 0 8 1}$ | $\mathbf{0 . 0 3 8 9}$ | 0.6943 | $\mathbf{0 . 0 0 0 9}$ | 0.5072 |  |

### 4.1.4.5 Tarsometatarsus

| P-values of Permanova for SC/GL v Bp/GL |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | Dorking | Hamburgh | RJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 2 2}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 4 7}$ | 0.2783 |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ |  | 0.3515 | 0.2973 | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 2}$ |
| RJF | $\mathbf{0 . 0 0 2 2}$ | 0.3515 |  | 0.6274 | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 2 4 3}$ |
| O E Game | $\mathbf{0 . 0 0 0 2}$ | 0.2973 | 0.6274 |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 2 4}$ |
| Silkie | $\mathbf{0 . 0 0 4 7}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 2 1 1}$ |
| Asian Game | 0.2783 | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 2 4 3}$ | $\mathbf{0 . 0 1 2 4}$ | $\mathbf{0 . 0 2 1 1}$ |  |


| P-values of Permanova for $\mathrm{Bd} / \mathrm{Bp} \mathrm{v} \mathrm{Bd} / \mathrm{GL}$ |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | :--- | ---: |
|  | Dorking | Hamburgh | lJF | O E Game | Silkie | Asian Game |
| Dorking |  | $\mathbf{0 . 0 2 5 4}$ | 0.1119 | 0.294 | $\mathbf{0 . 0 1 1 6}$ | 0.1204 |
| Hamburgh | $\mathbf{0 . 0 2 5 4}$ |  | $\mathbf{0 . 0 0 8 5}$ | $\mathbf{0 . 0 2 7 2}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 9 2}$ |
| RJF | 0.1119 | $\mathbf{0 . 0 0 8 5}$ |  | 0.0664 | $\mathbf{0 . 1 1 8 5}$ | 0.6834 |
| O E Game | 0.294 | $\mathbf{0 . 0 2 7 2}$ | 0.0664 |  | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 3 1 1}$ |
| Silkie | $\mathbf{0 . 0 1 1 6}$ | $\mathbf{0 . 0 0 1 8}$ | 0.1185 | $\mathbf{0 . 0 0 1 2}$ |  | 0.1859 |
| Asian Game | 0.1204 | $\mathbf{0 . 0 0 9 2}$ | 0.6834 | $\mathbf{0 . 0 3 1 1}$ | 0.1859 |  |

## 4.I. 5 DFA classification modern breeds/types

Discriminant function analysis of all measurement ratios of modern chicken breeds/types - coracoid: classification before and after crossvalidation.

### 4.1.5.1 Modern Coracoid

| Modern coracoids - see Table I5 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | Dorking |
| e00I | Dorking | Dorking | Asian Game |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | RJF | RJF | RJF |
| e013 | O E Game | O E Game | O E Game |
| e014 | Dorking | Dorking | Silkie |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Asian Game | Asian Game |
| k00I | Asian Game | Silkie | Silkie |
| n00I | O E Game | O E Game | Hamburgh |
| r65I | Hamburgh | RJF | RJF |
| r657 | Asian Game | Asian Game | Asian Game |
| r658 | Asian Game | Dorking | Dorking |
| r660 | Silkie | Silkie | Silkie |
| r66I | Silkie | Silkie | Asian Game |


| Modern coracoids - see Table I5 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r662 | Asian Game | Asian Game | Asian Game |
| r663 | O E Game | RJF | RJF |
| r666 | Silkie | Silkie | Dorking |
| r667 | O E Game | O E Game | O E Game |
| r723 | Dorking | Silkie | Silkie |
| r724 | Dorking | Dorking | Asian Game |
| r732 | O E Game | O E Game | Hamburgh |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | O E Game | O E Game |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | O E Game |
| t022 | Hamburgh | Dorking | Dorking |
| t023 | Asian Game | Asian Game | Asian Game |
| t024 | Asian Game | Silkie | Silkie |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Asian Game | Asian Game |
| t059 | RJF | RJF | RJF |
| t060 | Hamburgh | O E Game | O E Game |
| t065 | Dorking | Dorking | Dorking |
|  |  |  |  |


| Modern coracoids - see Table I5 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| tI43 | RJF | RJF | RJF |
| tl44 | RJF | RJF | RJF |
| t146 | RJF | O E Game | O E Game |
| w5 18 | O E Game | RJF | RJF |
| w5 I9 | RJF | RJF | RJF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Dorking | Dorking |
| w6II | O E Game | Hamburgh | Hamburgh |
| w6l2 | O E Game | O E Game | O E Game |
| z00I | RJF | RJF | O E Game |

### 4.1.5.2 Modern Humerus

| Modern humeri - see Table 20 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Silkie | Silkie |
| e00I | Dorking | Silkie | Silkie |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | RJF | RJF | RJF |
| eOI3 | O E Game | Silkie | Silkie |
| e014 | Dorking | Silkie | Silkie |


| Modern humeri - see Table 20 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| h003 | Silkie | Silkie | O E Game |
| h0II | Dorking | Dorking | O E Game |
| k00I | Asian Game | Hamburgh | Hamburgh |
| n00I | O E Game | O E Game | Dorking |
| r65I | Hamburgh | Hamburgh | Silkie |
| r657 | Asian Game | Asian Game | Asian Game |
| r658 | Asian Game | Asian Game | Asian Game |
| r660 | Silkie | Dorking | Dorking |
| r66I | Silkie | Silkie | Dorking |
| r662 | Asian Game | Silkie | Silkie |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Silkie |
| r667 | O E Game | RJF | RJF |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Asian Game | Asian Game |
| r732 | O E Game | O E Game | Dorking |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | RJF | RJF |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | O E Game | O E Game |
|  |  |  |  |


| Modern humeri - see Table 20 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t007 | Silkie | Dorking | Dorking |
| t022 | Hamburgh | Hamburgh | Hamburgh |
| t023 | Asian Game | Silkie | Silkie |
| t024 | Asian Game | Asian Game | Asian Game |
| t032 | Silkie | Asian Game | Asian Game |
| t034 | Silkie | Asian Game | Asian Game |
| t04I | O E Game | Hamburgh | Hamburgh |
| t059 | RJF | RJF | RJF |
| t060 | Hamburgh | RJF | RJF |
| t065 | Dorking | Asian Game | Asian Game |
| t143 | RJF | RJF | RJF |
| t144 | RJF | O E Game | O E Game |
| tl45 | RJF | RJF | RJF |
| t146 | RJF | Hamburgh | Hamburgh |
| tl47 | Hamburgh | Hamburgh | Hamburgh |
| w5 I8 | O E Game | O E Game | O E Game |
| w5 I9 | RJF | RJF | RJF |
| w528 | Dorking | Silkie | Silkie |
| w537 | Dorking | Dorking | O E Game |
| w6 I I | O E Game | O E Game | O E Game |
| w6I2 | O E Game | Hamburgh | Hamburgh |
|  |  |  |  |


| Modern humeri - see Table 20 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| z001 | RJF | RJF | RJF |

### 4.1.5.3 Modern Femur

| Modern femora - see Table 24 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | Dorking |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | RJF |
| e010 | RJF | RJF | Hamburgh |
| e013 | O E Game | O E Game | O E Game |
| e014 | Dorking | Dorking | O E Game |
| h003 | Silkie | Silkie | Silkie |
| h0I I | Dorking | Dorking | Dorking |
| k00I | Asian Game | Asian Game | Dorking |
| n00I | O E Game | O E Game | Hamburgh |
| r65 I | Hamburgh | Dorking | Dorking |
| r657 | Asian Game | Asian Game | Silkie |
| r658 | Asian Game | Asian Game | Silkie |
| r660 | Silkie | Silkie | Silkie |
| r66 I | Silkie | Silkie | Silkie |


| Modern femora - see Table 24 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r662 | Asian Game | O E Game | O E Game |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Silkie |
| r667 | O E Game | O E Game | Silkie |
| r723 | Dorking | Dorking | Asian Game |
| r724 | Dorking | Asian Game | Asian Game |
| r732 | O E Game | Silkie | Silkie |
| r735 | O E Game | Hamburgh | Hamburgh |
| r736 | Hamburgh | Hamburgh | O E Game |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r741 | Hamburgh | RJF | RJF |
| r742 | Hamburgh | Hamburgh | O E Game |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | O E Game | Silkie |
| t023 | Asian Game | Dorking | Dorking |
| t024 | Asian Game | Asian Game | Asian Game |
| t032 | Silkie | Silkie | Asian Game |
| t034 | Silkie | Silkie | Dorking |
| t04I | O E Game | O E Game | Silkie |
| t059 | RJF | RJF | RJF |
| t060 | Hamburgh | Hamburgh | O E Game |
|  |  |  |  |


| Modern femora - see Table 24 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t065 | Dorking | Dorking | Asian Game |
| t143 | RJF | RJF | RJF |
| t144 | RJF | RJF | O E Game |
| t145 | RJF | Hamburgh | Hamburgh |
| t146 | RJF | RJF | Hamburgh |
| t147 | Hamburgh | Hamburgh | Hamburgh |
| w518 | O E Game | O E Game | RJF |
| w519 | RJF | RJF | Hamburgh |
| w528 | Dorking | Dorking | Silkie |
| w537 | Dorking | Dorking | Silkie |
| w611 | O E Game | Hamburgh | Hamburgh |
| w612 | O E Game | O E Game | Hamburgh |
| z00I | RJF | RJF | RJF |

### 4.1.5.4 Modern Tibiotarsus

| Modern tibiotarsi: all ratios - see Table 29 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | Dorking |
| e00I | Dorking | Dorking | Dorking |
| e010 | RJF | RJF | Hamburgh |
| e013 | O E Game | Hamburgh | Hamburgh |
| e014 | Dorking | Dorking | Dorking |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Dorking | Asian Game |
| k00I | Asian Game | O E Game | O E Game |
| n00I | O E Game | Dorking | Dorking |
| r65 I | Hamburgh | Hamburgh | Asian Game |
| r657 | Asian Game | Asian Game | Asian Game |
| r658 | Asian Game | Asian Game | Asian Game |
| r660 | Silkie | Silkie | Silkie |
| r66I | Silkie | Silkie | Silkie |
| r662 | Asian Game | O E Game | O E Game |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Asian Game |
| r667 | O E Game | O E Game | O E Game |
| r723 | Dorking | Dorking | Dorking |


| Modern tibiotarsi: all ratios - see Table 29 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | Dorking | Dorking |
| r735 | O E Game | Hamburgh | Hamburgh |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r741 | Hamburgh | Hamburgh | RJF |
| r742 | Hamburgh | O E Game | O E Game |
| t007 | Silkie | Silkie | Hamburgh |
| t022 | Hamburgh | Hamburgh | O E Game |
| $\mathbf{t 0 2 3}$ | Asian Game | Asian Game | Asian Game |
| $\mathbf{t 0 2 4}$ | Asian Game | Asian Game | Asian Game |
| $\mathbf{t 0 3 2}$ | Silkie | Silkie | Silkie |
| t034 | Silkie | Dorking | Dorking |
| t04I | O E Game | Hamburgh | Hamburgh |
| t059 | RJF | RJF | O E Game |
| t060 | Hamburgh | Hamburgh | O E Game |
| t065 | Dorking | Dorking | O E Game |
| $\mathbf{t l 4 3}$ | RJF | RJF | RJF |
| $\mathbf{t l 4 4 ~}$ | RJF | RJF | RJF |
| $\mathbf{t l 4 5 ~}$ | RJF | RJF | RJF |
| t146 | RJF | Hamburgh | Hamburgh |
|  |  |  |  |


| Modern tibiotarsi: all ratios - see Table 29 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t147 | Hamburgh | Hamburgh | RJF |
| w5 I8 | O E Game | O E Game | O E Game |
| w5I9 | RJF | RJF | Asian Game |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Dorking | Dorking |
| w6II | O E Game | O E Game | RJF |
| w6I2 | O E Game | O E Game | O E Game |
| z00I | RJF | RJF | RJF |


| Modern tibiotarsi: six ratio combinations - see Table 30 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | Dorking |
| e00I | Dorking | Dorking | Dorking |
| e010 | RJF | RJF | Hamburgh |
| e013 | O E Game | Hamburgh | Hamburgh |
| e014 | Dorking | Dorking | Dorking |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Silkie | Silkie |
| k00l | Asian Game | Asian Game | O E Game |
| n00I | O E Game | Dorking | Dorking |


| Modern tibiotarsi: six ratio combinations - see Table 30 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r65 I | Hamburgh | Hamburgh | Asian Game |
| r657 | Asian Game | Asian Game | Asian Game |
| r658 | Asian Game | Asian Game | Asian Game |
| r660 | Silkie | Silkie | Silkie |
| r661 | Silkie | Silkie | Silkie |
| r662 | Asian Game | O E Game | O E Game |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Silkie |
| r667 | O E Game | O E Game | O E Game |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | Asian Game | Asian Game |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74l | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | O E Game | O E Game |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | O E Game | O E Game |
| t023 | Asian Game | Asian Game | Asian Game |
| t024 | Asian Game | Asian Game | Asian Game |
|  |  |  |  |


| Modern tibiotarsi: six ratio combinations - see Table 30 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t032 | Silkie | Silkie | Dorking |
| t034 | Silkie | Dorking | Dorking |
| t04l | O E Game | Hamburgh | Hamburgh |
| t059 | RJF | RJF | RJF |
| t060 | Hamburgh | Hamburgh | Hamburgh |
| t065 | Dorking | Dorking | O E Game |
| t143 | RJF | RJF | RJF |
| t144 | RJF | RJF | RJF |
| t145 | RJF | RJF | RJF |
| t146 | RJF | RJF | O E Game |
| t147 | Hamburgh | RJF | RJF |
| w5I8 | O E Game | O E Game | O E Game |
| w5I9 | RJF | RJF | RJF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Dorking | Silkie |
| w6II | O E Game | Hamburgh | Hamburgh |
| w6I2 | O E Game | O E Game | Hamburgh |
| z00I | RJF | RJF | RJF |
|  |  |  |  |

### 4.1.5.5 Modern Tarsometatarsus

| Modern tarsometatarsi - see Table 35 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Silkie | Silkie |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | RJF |
| e0I0 | RJF | O E Game | O E Game |
| e0I3 | O E Game | O E Game | RJF |
| e014 | Dorking | Asian Game | Asian Game |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Dorking | Dorking |
| k00I | Asian Game | O E Game | O E Game |
| n00I | O E Game | RJF | RJF |
| r65I | Hamburgh | Dorking | Dorking |
| r657 | Asian Game | Asian Game | Dorking |
| r658 | Asian Game | Asian Game | Asian Game |
| r660 | Silkie | Dorking | Dorking |
| r66I | Silkie | Dorking | Dorking |
| r662 | Asian Game | Asian Game | Asian Game |
| r663 | O E Game | Asian Game | Asian Game |
| r666 | Silkie | Asian Game | Asian Game |
| r667 | O E Game | RJF | RJF |
|  |  |  |  |


| Modern tarsometatarsi - see Table 35 |  |  |  |
| :--- | :--- | :--- | :--- |
| r723 | Dorking | Asian Game | Asian Game |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | Asian Game | Asian Game |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Dorking |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | O E Game | O E Game |
| t023 | Asian Game | Asian Game | O E Game |
| t024 | Asian Game | Asian Game | Silkie |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t04 I | O E Game | O E Game | O E Game |
| t059 | RJF | RJF | RJF |
| t065 | Dorking | O E Game | O E Game |
| t143 | RJF | Hamburgh | Hamburgh |
| tl44 | RJF | O E Game | O E Game |
| t145 | RJF | RJF | RJF |
| t146 | RJF | O E Game | O E Game |
| t147 | Hamburgh | RJF | RJF |
|  |  |  |  |


| Modern tarsometatarsi - see Table 35 |  |  |  |
| :--- | :--- | :--- | :--- |
| w5 18 | O E Game | Dorking | Dorking |
| w5 19 | RJF | RJF | RJF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Dorking | Dorking |
| w6II | O E Game | RJF | RJF |
| w6 12 | O E Game | O E Game | O E Game |
| z00I | RJF | Silkie | Silkie |

4.I.6 DFA classification archaeological

### 4.1.6.1 Coracoid

| Roman coracoids - see Table I6 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| FB I | Fishbourne | Fishbourne | Fishbourne |
| FB2 | Fishbourne | Uley | Uley |
| FB3 | Fishbourne | Fishbourne | Fishbourne |
| FB4 | Fishbourne | Fishbourne | Fishbourne |
| FB5 | Fishbourne | Uley | Uley |
| FB6 | Fishbourne | Fishbourne | Fishbourne |
| FB7 | Fishbourne | Fishbourne | Fishbourne |
| FB8 | Fishbourne | Fishbourne | Fishbourne |


| Roman coracoids - see Table I6 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| FB9 | Fishbourne | Fishbourne | Fishbourne |
| FBI0 | Fishbourne | Uley | Uley |
| FB I I | Fishbourne | Fishbourne | Fishbourne |
| FB I2 | Fishbourne | Fishbourne | Fishbourne |
| FBI3 | Fishbourne | Uley | Uley |
| FB I4 | Fishbourne | Fishbourne | Fishbourne |
| U4 | Uley | Uley | Uley |
| U23 | Uley | Uley | Uley |
| U25 | Uley | Uley | Uley |
| U3I | Uley | Uley | Uley |
| U40 | Uley | Uley | Uley |
| U43 | Uley | Uley | Uley |
| U50 | Uley | Uley | Uley |
| U57 | Uley | Uley | Fishbourne |
| U6I | Uley | Uley | Uley |
| U75 | Uley | Uley | Uley |
| U9 I | Uley | Uley | Uley |
| U96 | Uley | Uley | Uley |
| U110 | Uley | Uley | Fishbourne |
| U1 17 | Uley | Uley | Uley |
| U12 I | Uley | Uley | Uley |
|  |  |  |  |


| Roman coracoids - see Table 16 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| UI27 | Uley | Fishbourne | Fishbourne |
| U139 | Uley | Uley | Uley |
| U15 I | Uley | Uley | Uley |
| U163 | Uley | Uley | Uley |
| U180 | Uley | Uley | Uley |
| UI86 | Uley | Fishbourne | Fishbourne |
| U198 | Uley | Uley | Uley |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| Y528 | Coppergate | Coppergate | Coppergate |
| Y529 | Coppergate | Lyminge | Lyminge |
| Y530 | Coppergate | Coppergate | Coppergate |
| Y533 | Coppergate | Flixborough | Flixborough |
| Y537 | Coppergate | Flixborough | Flixborough |
| Y54I | Coppergate | Flixborough | Flixborough |
| Y542 | Coppergate | Lyminge | Lyminge |
| Y543 | Coppergate | Lyminge | Lyminge |
| Y545 | Coppergate | Lyminge | Lyminge |
| Y548 | Coppergate | Flixborough | Flixborough |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| Y55I | Coppergate | Lyminge | Lyminge |
| Y552 | Coppergate | Flixborough | Flixborough |
| Y553 | Coppergate | Coppergate | Coppergate |
| Y554 | Coppergate | Coppergate | Coppergate |
| Y555 | Coppergate | Coppergate | Coppergate |
| Y557 | Coppergate | Lyminge | Lyminge |
| Y558 | Coppergate | Flixborough | Flixborough |
| Y559 | Coppergate | Lyminge | Lyminge |
| Y560 | Coppergate | Coppergate | Coppergate |
| Y56I | Coppergate | Coppergate | Coppergate |
| Y563 | Coppergate | Coppergate | Coppergate |
| Y564 | Coppergate | Flixborough | Flixborough |
| Y565 | Coppergate | Coppergate | Coppergate |
| Y567 | Coppergate | Coppergate | Coppergate |
| Y568 | Coppergate | Lyminge | Lyminge |
| Y570 | Coppergate | Coppergate | Coppergate |
| Y57I | Coppergate | Coppergate | Coppergate |
| Y573 | Coppergate | Coppergate | Coppergate |
| Y577 | Coppergate | Coppergate | Lyminge |
| Y578 | Coppergate | Lyminge | Lyminge |
| Y580 | Coppergate | Coppergate | Coppergate |
|  |  |  |  |
|  |  | Cor |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| Y58I | Coppergate | Lyminge | Lyminge |
| Y582 | Coppergate | Lyminge | Lyminge |
| Y583 | Coppergate | Coppergate | Coppergate |
| Y584 | Coppergate | Flixborough | Flixborough |
| Y585 | Coppergate | Flixborough | Flixborough |
| Y586 | Coppergate | Coppergate | Coppergate |
| Y587 | Coppergate | Flixborough | Flixborough |
| Y589 | Coppergate | Coppergate | Coppergate |
| Y593 | Coppergate | Flixborough | Flixborough |
| Y594 | Coppergate | Lyminge | Lyminge |
| Y595 | Coppergate | Coppergate | Coppergate |
| Y596 | Coppergate | Flixborough | Flixborough |
| Y600 | Coppergate | Coppergate | Coppergate |
| Y602 | Coppergate | Coppergate | Coppergate |
| Y603 | Coppergate | Lyminge | Lyminge |
| Y604 | Coppergate | Coppergate | Coppergate |
| Y607 | Coppergate | Coppergate | Coppergate |
| Y608 | Coppergate | Coppergate | Coppergate |
| Y6II | Coppergate | Coppergate | Coppergate |
| Y612 | Coppergate | Coppergate | Coppergate |
| Y613 | Coppergate | Coppergate | Coppergate |
|  |  |  |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| Y6I5 | Coppergate | Coppergate | Lyminge |
| FX338 | Flixborough | Flixborough | Flixborough |
| FX339 | Flixborough | Flixborough | Coppergate |
| FX344 | Flixborough | Lyminge | Lyminge |
| FX345 | Flixborough | Lyminge | Lyminge |
| FX346 | Flixborough | Lyminge | Lyminge |
| FX35I | Flixborough | Flixborough | Flixborough |
| FX357 | Flixborough | Lyminge | Lyminge |
| FX358 | Flixborough | Coppergate | Coppergate |
| FX36I | Flixborough | Flixborough | Coppergate |
| FX362 | Flixborough | Flixborough | Flixborough |
| FX363 | Flixborough | Coppergate | Coppergate |
| FX370 | Flixborough | Lyminge | Lyminge |
| FX37I | Flixborough | Flixborough | Flixborough |
| FX377 | Flixborough | Flixborough | Flixborough |
| FX383 | Flixborough | Flixborough | Flixborough |
| FX385 | Flixborough | Lyminge | Lyminge |
| FX390 | Flixborough | Coppergate | Coppergate |
| FX39l | Flixborough | Coppergate | Coppergate |
| FX392 | Flixborough | Coppergate | Coppergate |
| FX393 | Flixborough | Lyminge | Lyminge |
|  |  |  |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| FX396 | Flixborough | Lyminge | Lyminge |
| FX397 | Flixborough | Flixborough | Flixborough |
| FX398 | Flixborough | Flixborough | Flixborough |
| FX40I | Flixborough | Flixborough | Flixborough |
| FX402 | Flixborough | Coppergate | Coppergate |
| FX403 | Flixborough | Flixborough | Flixborough |
| FX404 | Flixborough | Lyminge | Lyminge |
| FX405 | Flixborough | Flixborough | Flixborough |
| L5 | Lyminge | Coppergate | Coppergate |
| Li | Lyminge | Lyminge | Lyminge |
| L54 | Lyminge | Coppergate | Coppergate |
| Lii | Lyminge | Coppergate | Coppergate |
| L56 | Lyminge | Lyminge | Lyminge |
| L57 | Lyminge | Lyminge | Lyminge |
| LI0I | Lyminge | Coppergate | Coppergate |
| LII5 | Lyminge | Flixborough | Flixborough |
| LI27 | Lyminge | Coppergate | Coppergate |
| LI34 | Lyminge | Lyminge | Lyminge |
| LI47 | Lyminge | Flixborough | Flixborough |
| LI49 | Lyminge | Lyminge | Lyminge |
| LI52 | Lyminge | Flixborough | Flixborough |
|  |  |  |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| L162 | Lyminge | Lyminge | Lyminge |
| L169 | Lyminge | Coppergate | Coppergate |
| L222 | Lyminge | Flixborough | Flixborough |
| L224 | Lyminge | Lyminge | Lyminge |
| L226 | Lyminge | Lyminge | Lyminge |
| L273 | Lyminge | Lyminge | Lyminge |
| L340 | Lyminge | Coppergate | Coppergate |
| L34I | Lyminge | Lyminge | Lyminge |
| L346 | Lyminge | Flixborough | Flixborough |
| L385 | Lyminge | Lyminge | Flixborough |
| L408 | Lyminge | Lyminge | Lyminge |
| Liii | Lyminge | Lyminge | Lyminge |
| L477 | Lyminge | Lyminge | Lyminge |
| L507 | Lyminge | Lyminge | Lyminge |
| L508 | Lyminge | Lyminge | Flixborough |
| L509 | Lyminge | Lyminge | Lyminge |
| L519 | Lyminge | Lyminge | Coppergate |
| L530 | Lyminge | Lyminge | Lyminge |
| L537 | Lyminge | Flixborough | Flixborough |
| L560 | Lyminge | Lyminge | Lyminge |
| L614 | Lyminge | Flixborough | Flixborough |
|  |  |  |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| L617 | Lyminge | Flixborough | Flixborough |
| L702 | Lyminge | Coppergate | Coppergate |
| L708 | Lyminge | Lyminge | Lyminge |
| L710 | Lyminge | Lyminge | Lyminge |
| L7II | Lyminge | Lyminge | Lyminge |
| L7I6 | Lyminge | Lyminge | Lyminge |
| L74I | Lyminge | Flixborough | Flixborough |
| L759 | Lyminge | Flixborough | Flixborough |
| L78I | Lyminge | Lyminge | Lyminge |
| L787 | Lyminge | Lyminge | Lyminge |
| L79I | Lyminge | Lyminge | Lyminge |
| L797 | Lyminge | Lyminge | Lyminge |
| L8I6 | Lyminge | Coppergate | Coppergate |
| L823 | Lyminge | Coppergate | Coppergate |
| Lvi | Lyminge | Coppergate | Coppergate |
| L88I | Lyminge | Lyminge | Lyminge |
| L893 | Lyminge | Lyminge | Flixborough |
| L90I | Lyminge | Coppergate | Coppergate |
| L916 | Lyminge | Flixborough | Flixborough |
| L9I7 | Lyminge | Lyminge | Lyminge |
| LABGI | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Saxon coracoids -see Table I7 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Jackknifed |
| LABG2 | Lyminge | Lyminge | Lyminge |
| LABG7 | Lyminge | Lyminge | Lyminge |
| LABG8 | Lyminge | Lyminge | Coppergate |
| LABG9 | Lyminge | Lyminge | Lyminge |
| LABGI0 | Lyminge | Lyminge | Lyminge |

### 4.1.6.2 Humeri

| All archaeological humeri-see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| CII | Chester | Lyminge | Lyminge |
| C42 | Chester | Lyminge | Lyminge |
| C43 | Chester | Chester | Uley |
| C44 | Chester | Chester | Lyminge |
| C45 | Chester | Chester | Chester |
| C46 | Chester | Lyminge | Lyminge |
| C95 | Chester | Chester | Lyminge |
| CI09 | Chester | Chester | Lyminge |
| CI33 | Chester | Uley | Uley |
| C2I2 | Chester | Chester | Lyminge |
| C2I3 | Chester | Uley | Uley |


| All archaeological humeri - see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| C2I4 | Chester | Chester | Uley |
| L3I | Lyminge | Lyminge | Lyminge |
| L37 | Lyminge | Lyminge | Lyminge |
| L43 | Lyminge | Uley | Uley |
| L44 | Lyminge | Uley | Uley |
| L45 | Lyminge | Uley | Uley |
| L46 | Lyminge | Lyminge | Lyminge |
| L47 | Lyminge | Uley | Uley |
| L48 | Lyminge | Uley | Uley |
| L99 | Lyminge | Uley | Uley |
| LI00 | Lyminge | Chester | Chester |
| LI I3 | Lyminge | Lyminge | Lyminge |
| LI I6 | Lyminge | Chester | Chester |
| LI35 | Lyminge | Chester | Chester |
| LI68 | Lyminge | Lyminge | Lyminge |
| LI99 | Lyminge | Uley | Uley |
| L230 | Lyminge | Lyminge | Uley |
| L26I | Lyminge | Uley | Uley |
| L276 | Lyminge | Lyminge | Lyminge |
| L306 | Lyminge | Lyminge | Uley |
| L307 | Lyminge | Uley | Uley |


| All archaeological humeri - see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L366 | Lyminge | Lyminge | Lyminge |
| L369 | Lyminge | Lyminge | Lyminge |
| L37I | Lyminge | Lyminge | Lyminge |
| L400 | Lyminge | Uley | Uley |
| L4I2 | Lyminge | Lyminge | Lyminge |
| L44I | Lyminge | Lyminge | Lyminge |
| L453 | Lyminge | Lyminge | Lyminge |
| L478 | Lyminge | Chester | Chester |
| L479 | Lyminge | Chester | Chester |
| L486 | Lyminge | Lyminge | Lyminge |
| L53I | Lyminge | Uley | Uley |
| L645 | Lyminge | Lyminge | Lyminge |
| L646 | Lyminge | Chester | Chester |
| L647 | Lyminge | Lyminge | Lyminge |
| L700 | Lyminge | Lyminge | Lyminge |
| L70I | Lyminge | Lyminge | Lyminge |
| L704 | Lyminge | Chester | Chester |
| L7I2 | Lyminge | Lyminge | Lyminge |
| L7I3 | Lyminge | Lyminge | Lyminge |
| L7I4 | Lyminge | Uley | Uley |
| L7I5 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| All archaeological humeri - see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L73I | Lyminge | Lyminge | Lyminge |
| L786 | Lyminge | Lyminge | Lyminge |
| L802 | Lyminge | Chester | Chester |
| L803 | Lyminge | Lyminge | Lyminge |
| L8IO | Lyminge | Chester | Chester |
| L8I I | Lyminge | Lyminge | Lyminge |
| L8I3 | Lyminge | Lyminge | Lyminge |
| L8I4 | Lyminge | Lyminge | Lyminge |
| L840 | Lyminge | Lyminge | Lyminge |
| L849 | Lyminge | Lyminge | Lyminge |
| L85 I | Lyminge | Uley | Uley |
| L886 | Lyminge | Chester | Chester |
| L888 | Lyminge | Lyminge | Lyminge |
| L902 | Lyminge | Lyminge | Lyminge |
| L9I9 | Lyminge | Uley | Uley |
| L257 | Lyminge | Lyminge | Lyminge |
| L243 | Lyminge | Chester | Chester |
| L264 | Lyminge | Lyminge | Lyminge |
| L999 | Lyminge | Chester | Chester |
| L229 | Lyminge | Chester | Chester |
| L237 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| All archaeological humeri - see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L262 | Lyminge | Lyminge | Lyminge |
| U3 | Uley | Lyminge | Lyminge |
| U7 | Uley | Uley | Uley |
| UI0 | Uley | Chester | Chester |
| U2I | Uley | Uley | Uley |
| U34 | Uley | Uley | Uley |
| U35 | Uley | Uley | Uley |
| U55 | Uley | Uley | Lyminge |
| U7I | Uley | Lyminge | Lyminge |
| U72 | Uley | Chester | Chester |
| U77 | Uley | Chester | Chester |
| U8I | Uley | Uley | Uley |
| U97 | Uley | Chester | Chester |
| UI09 | Uley | Uley | Uley |
| UI24 | Uley | Uley | Lyminge |
| UI28 | Uley | Chester | Chester |
| UI29 | Uley | Chester | Chester |
| U148 | Uley | Lyminge | Lyminge |
| UI49 | Uley | Uley | Chester |
| UI55 | Uley | Chester | Chester |
| UI58 | Uley | Uley | Uley |
|  |  |  |  |


| All archaeological humeri - see Table 2I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| UI67 | Uley | Lyminge | Lyminge |
| UI75 | Uley | Uley | Uley |
| UI78 | Uley | Uley | Uley |
| UI87 | Uley | Uley | Uley |

4.1.6.3 Femora

| All archaeological femora - see Table 25 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L2 | Lyminge | Chester | Chester |
| LII | Lyminge | Lyminge | Lyminge |
| L28 | Lyminge | Lyminge | Uley |
| L38 | Lyminge | Lyminge | Uley |
| L63 | Lyminge | Lyminge | Lyminge |
| L65 | Lyminge | Lyminge | Chester |
| L409 | Lyminge | Lyminge | Lyminge |
| L5I0 | Lyminge | Lyminge | Chester |
| L552 | Lyminge | Uley | Uley |
| L553 | Lyminge | Lyminge | Lyminge |
| L565 | Lyminge | Lyminge | Lyminge |
| L59I | Lyminge | Chester | Chester |


| All archaeological femora - see Table 25 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L616 | Lyminge | Lyminge | Lyminge |
| L657 | Lyminge | Lyminge | Lyminge |
| L667 | Lyminge | Chester | Chester |
| L698 | Lyminge | Lyminge | Uley |
| L699 | Lyminge | Uley | Uley |
| L705 | Lyminge | Uley | Uley |
| L706 | Lyminge | Lyminge | Chester |
| L709 | Lyminge | Lyminge | Lyminge |
| L720 | Lyminge | Uley | Uley |
| L729 | Lyminge | Lyminge | Lyminge |
| L730 | Lyminge | Lyminge | Uley |
| L746 | Lyminge | Chester | Chester |
| L750 | Lyminge | Lyminge | Lyminge |
| L782 | Lyminge | Uley | Uley |
| L788 | Lyminge | Uley | Uley |
| L792 | Lyminge | Chester | Chester |
| L798 | Lyminge | Lyminge | Chester |
| L80I | Lyminge | Chester | Chester |
| L8I5 | Lyminge | Lyminge | Chester |
| L857 | Lyminge | Lyminge | Chester |
| L863 | Lyminge | Lyminge | Lyminge |


| All archaeological femora - see Table 25 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L882 | Lyminge | Chester | Chester |
| L913 | Lyminge | Lyminge | Lyminge |
| L914 | Lyminge | Uley | Uley |
| ABG7 | Lyminge | Lyminge | Lyminge |
| ABG8 | Lyminge | Lyminge | Uley |
| ABG9 | Lyminge | Lyminge | Lyminge |
| C00I | Chester | Lyminge | Lyminge |
| C009 | Chester | Uley | Uley |
| C030 | Chester | Chester | Chester |
| C032 | Chester | Lyminge | Lyminge |
| C08I | Chester | Chester | Lyminge |
| CI5I | Chester | Chester | Lyminge |
| CI52 | Chester | Chester | Uley |
| CI65 | Chester | Chester | Lyminge |
| CI95 | Chester | Chester | Chester |
| C209 | Chester | Chester | Uley |
| C22I | Chester | Lyminge | Lyminge |
| U013 | Uley | Uley | Uley |
| U022 | Uley | Uley | Uley |
| U048 | Uley | Uley | Uley |
| U049 | Uley | Uley | Lyminge |
|  |  |  |  |


| All archaeological femora - see Table 25 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| U082 | Uley | Uley | Lyminge |
| U089 | Uley | Uley | Uley |
| U094 | Uley | Uley | Uley |
| UI04 | Uley | Lyminge | Lyminge |
| UIII | Uley | Uley | Uley |
| UII3 | Uley | Uley | Chester |
| UII6 | Uley | Uley | Chester |
| UI23 | Uley | Uley | Lyminge |
| UI45 | Uley | Chester | Chester |
| UI65 | Uley | Uley | Uley |
| UI73 | Uley | Lyminge | Lyminge |
| UI90 | Uley | Uley | Uley |
| UI94 | Uley | Chester | Chester |

### 4.1.6.4 Tibiotarsi

| All archaeological tibiotarsi - see Table 3 I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| C024 | Chester | Uley | Lyminge |
| C026 | Chester | Chester | Chester |
| C028 | Chester | Chester | Lyminge |


| All archaeological tibiotarsi - see Table 3 I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| CI00 | Chester | Chester | Chester |
| CI08 | Chester | Chester | Chester |
| CI32 | Chester | Chester | Lyminge |
| CI46 | Chester | Lyminge | Lyminge |
| CI50 | Chester | Chester | Chester |
| CI70 | Chester | Uley | Uley |
| CI75 | Chester | Chester | Chester |
| CI76 | Chester | Chester | Chester |
| CI77 | Chester | Chester | Chester |
| L50 | Lyminge | Lyminge | Lyminge |
| L5 I | Lyminge | Chester | Chester |
| L52 | Lyminge | Lyminge | Lyminge |
| LIII | Lyminge | Lyminge | Lyminge |
| LI42 | Lyminge | Lyminge | Lyminge |
| LI63 | Lyminge | Chester | Chester |
| LI93 | Lyminge | Lyminge | Lyminge |
| LI97 | Lyminge | Lyminge | Lyminge |
| L2I9 | Lyminge | Chester | Chester |
| L22I | Lyminge | Chester | Chester |
| L249 | Lyminge | Lyminge | Lyminge |
| L275 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| All archaeological tibiotarsi - see Table 3 I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L304 | Lyminge | Lyminge | Lyminge |
| L4I4 | Lyminge | Lyminge | Lyminge |
| L423 | Lyminge | Chester | Chester |
| L480 | Lyminge | Lyminge | Lyminge |
| L538 | Lyminge | Lyminge | Lyminge |
| L597 | Lyminge | Lyminge | Lyminge |
| L598 | Lyminge | Lyminge | Chester |
| L665 | Lyminge | Chester | Chester |
| L697 | Lyminge | Lyminge | Lyminge |
| L785 | Lyminge | Lyminge | Lyminge |
| L790 | Lyminge | Lyminge | Lyminge |
| L795 | Lyminge | Lyminge | Lyminge |
| L8I2 | Lyminge | Lyminge | Lyminge |
| L889 | Lyminge | Chester | Chester |
| L898 | Lyminge | Lyminge | Lyminge |
| ABG2 | Lyminge | Lyminge | Lyminge |
| ABG6 | Lyminge | Lyminge | Lyminge |
| ABG7 | Lyminge | Lyminge | Lyminge |
| ABG8 | Lyminge | Lyminge | Chester |
| ABG9 | Lyminge | Lyminge | Chester |
| U0II | Uley | Uley | Uley |
|  |  |  |  |


| All archaeological tibiotarsi - see Table 3 I |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| U028 | Uley | Uley | Uley |
| U029 | Uley | Uley | Uley |
| UI02 | Uley | Chester | Chester |

### 4.1.6.5 Tarsometatarsi

| Archaeological tarsometatarsi - see Table 36 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| C002 | Chester | Uley | Uley |
| C022 | Chester | Lyminge | Lyminge |
| C023 | Chester | Lyminge | Lyminge |
| Cl24 | Chester | Lyminge | Lyminge |
| Cl26 | Chester | Chester | Chester |
| C180 | Chester | Chester | Chester |
| CI93 | Chester | Chester | Chester |
| C217 | Chester | Chester | Chester |
| C218 | Chester | Lyminge | Lyminge |
| L87 | Lyminge | Lyminge | Lyminge |
| L88 | Lyminge | Lyminge | Lyminge |
| LI12 | Lyminge | Uley | Uley |
| LI33 | Lyminge | Lyminge | Lyminge |


| Archaeological tarsometatarsi - see Table 36 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| LI45 | Lyminge | Lyminge | Lyminge |
| LI57 | Lyminge | Lyminge | Lyminge |
| LI64 | Lyminge | Lyminge | Lyminge |
| LI79 | Lyminge | Lyminge | Lyminge |
| LI80 | Lyminge | Uley | Uley |
| L187 | Lyminge | Lyminge | Lyminge |
| L206 | Lyminge | Lyminge | Lyminge |
| L208 | Lyminge | Lyminge | Lyminge |
| L209 | Lyminge | Chester | Chester |
| L210 | Lyminge | Chester | Chester |
| L328 | Lyminge | Lyminge | Lyminge |
| L330 | Lyminge | Lyminge | Lyminge |
| L332 | Lyminge | Lyminge | Lyminge |
| L334 | Lyminge | Chester | Chester |
| L337 | Lyminge | Lyminge | Lyminge |
| L473 | Lyminge | Chester | Chester |
| L52I | Lyminge | Chester | Chester |
| L526 | Lyminge | Lyminge | Lyminge |
| L567 | Lyminge | Lyminge | Lyminge |
| L569 | Lyminge | Chester | Chester |
| L570 | Lyminge | Chester | Chester |
|  |  |  |  |


| Archaeological tarsometatarsi - see Table 36 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L574 | Lyminge | Lyminge | Lyminge |
| L575 | Lyminge | Lyminge | Lyminge |
| L590 | Lyminge | Lyminge | Lyminge |
| L599 | Lyminge | Chester | Chester |
| L6II | Lyminge | Lyminge | Lyminge |
| L6 12 | Lyminge | Lyminge | Lyminge |
| L620 | Lyminge | Chester | Chester |
| L65 I | Lyminge | Chester | Chester |
| L7I8 | Lyminge | Lyminge | Lyminge |
| L783 | Lyminge | Chester | Chester |
| L793 | Lyminge | Lyminge | Lyminge |
| L817 | Lyminge | Lyminge | Lyminge |
| L858 | Lyminge | Lyminge | Lyminge |
| L868 | Lyminge | Lyminge | Lyminge |
| L884 | Lyminge | Lyminge | Lyminge |
| L89 I | Lyminge | Lyminge | Lyminge |
| L894 | Lyminge | Lyminge | Lyminge |
| L899 | Lyminge | Lyminge | Lyminge |
| L904 | Lyminge | Lyminge | Lyminge |
| L915 | Lyminge | Chester | Chester |
| L253 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Archaeological tarsometatarsi - see Table 36 |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L246 | Lyminge | Lyminge | Lyminge |
| L234 | Lyminge | Chester | Chester |
| U79 | Uley | Uley | Uley |
| U80 | Uley | Uley | Uley |
| UI05 | Uley | Uley | Uley |
| UII2 | Uley | Uley | Chester |
| UI54 | Uley | Lyminge | Lyminge |
| UI56 | Uley | Lyminge | Lyminge |
| UI7I | Uley | Uley | Uley |
| UI77 | Uley | Uley | Uley |

## 4.I. 7 Mann-Whitney tests

### 4.1.7.1 Tests to distinguish two Roman coracoid assemblages

| Flixborough v Uley coracoids $-\mathrm{Bb} / \mathrm{GL}$ ratio |  |  |  |
| :--- | :--- | :--- | :--- |
| Fishbourne |  | Uley |  |
| $\mathrm{N}:$ | 14 | $\mathrm{~N}:$ | 22 |
| Mean rank: | 3.86 II | Mean rank: | 14.639 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 34 |  |  |
| $\mathrm{z}:$ | -3.878 | P (same <br> med.): | $\mathbf{0 . 0 0 0 1}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 0}$ |


| Flixborough v Uley coracoids $-\mathrm{Bf} / \mathrm{Bb}$ ratio |  |  |  |
| :--- | :--- | :--- | :--- |
| Fishbourne |  | Uley |  |
| $\mathrm{N}:$ | 14 | $\mathrm{~N}:$ | 22 |
| Mean rank: | 9.2222 | Mean rank: | 9.2778 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 81 |  |  |
| $\mathrm{z}:$ | -2.3526 | P (same <br> med.): | $\mathbf{0 . 0 1 8 6}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 1 8 4}$ |

4.1.7.2 Tests to distinguish male and female - tibiotarsus

| Tibiotarsus Bd/La ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 21 | $\mathrm{~N}:$ | 27 |
| Mean rank: | 13.458 | Mean rank: | 11.042 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 152 |  |  |
| $\mathrm{z}:$ | -2.7233 | P (same <br> med.): | $\mathbf{0 . 0 0 6 4 6 2 5}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 5 2}$ |


| Tibiotarsus Bd/Dip ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 21 | $\mathrm{~N}:$ | 27 |
| Mean rank: | 14.646 | Mean rank: | 9.8542 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 95 |  |  |
| $\mathrm{z}:$ | -3.9071 | P (same <br> med.): | $\mathbf{9 . 3 3 9 5 E - 0 5}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 0 2}$ |


| Tibiotarsus Bd/GL ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 21 | $\mathrm{~N}:$ | 27 |
| Mean rank: | 13.479 | Mean rank: | 11.02 I |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 15 I |  |  |
| $\mathrm{z}:$ | -2.7435 | P (same <br> med.): | $\mathbf{0 . 0 0 6 0 7 9 6}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 4 9}$ |


| Tibiotarsus SC/Bd ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 21 | $\mathrm{~N}:$ | 27 |
| Mean rank: | 6.5208 | Mean rank: | 17.979 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 82 |  |  |
| $\mathrm{z}:$ | -4.1773 | P (same <br> med.): | $\mathbf{2 9 4 9 7 E - 0 5}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 0}$ |


| Tibiotarsus Bd/Dd ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 21 | $\mathrm{~N}:$ | 27 |
| Mean rank: | 13.865 | Mean rank: | 10.635 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 132.5 |  |  |
| $\mathrm{z}:$ | -3.1279 | P (same <br> med.): | $\mathbf{0 . 0 0 1 7 6 0 8}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 1 7}$ |

4.1.7.3 Tests to distinguish male and female - tarsometatarsus

| Tarsometatarsus Bp/GL ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 22 | $\mathrm{~N}:$ | 26 |
| Mean rank: | 13.76 | Mean rank: | 10.74 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 164.5 |  |  |
| $\mathrm{z}:$ | -2.5038 | P (same <br> med.): | $\mathbf{0 . 0 1 2 2 8 8}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 1 0 8}$ |


| Tarsometatarsus Bd/GL ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 22 | $\mathrm{~N}:$ | 26 |
| Mean rank: | 14.667 | Mean rank: | 9.8333 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 12 I |  |  |
| $\mathrm{z}:$ | -3.404 | P (same <br> med.): | $\mathbf{0 . 0 0 0 6 6 4 1 7}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 0 3}$ |


| Tarsometatarsus SC/Bd ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 22 | $\mathrm{~N}:$ | 26 |
| Mean rank: | 9 | Mean rank: | 15.5 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 179 |  |  |
| $\mathrm{z}:$ | -2.2037 | P (same <br> med.): | $\mathbf{0 . 0 2 7 5 4 8}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 2 8 8}$ |


| Tarsometatarsus SC/Bp ratio: tests for equal medians |  |  |  |
| :--- | :--- | :--- | :--- |
| Female |  | Male |  |
| $\mathrm{N}:$ | 22 | $\mathrm{~N}:$ | 26 |
| Mean rank: | 7.9479 | Mean rank: | 16.554 |
|  |  |  |  |
| Mann-Whitney <br> $\mathrm{U}:$ | 128.5 |  |  |
| $\mathrm{z}:$ | -3.2487 | P (same <br> med.): | $\mathbf{0 . 0 0 1 1 5 9 4}$ |
| Monte Carlo <br> permutation: |  | P (same <br> med.): | $\mathbf{0 . 0 0 0 9}$ |

4.I.8 BGPCA loadings - modern breeds/types

### 4.1.8.1 Coracoid

| Coracoid |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| Lm/GL $\times 100$ | -0.24561 | 0.058547 | 0.92804 | 0.2434 | 0.094132 |
| Bf/Bb $\times 100$ | -0.25317 | 0.90998 | -0.12267 | 0.13415 | -0.21501 |
| Bb/GL x 100 | 0.49189 | 0.039557 | 0.29028 | -0.31875 | -0.7549 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.60026 | 0.02256 | 0.010491 | 0.65666 | 0.13475 |
| Bf/GL $\times 100$ | 0.32481 | 0.28972 | 0.19467 | -0.61012 | 0.56924 |
| Bf/Lm $\times 100$ | 0.40965 | 0.28721 | -0.03768 | 0.13312 | 0.18122 |

### 4.1.8.2 Humerus

| Humerus |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| Bd/Bp $\times 100$ | -0.13917 | 0.81919 | 0.40506 | 0.17546 | 0.2153 |
| SC/GL $\times 100$ | -0.00116 | -0.11549 | 0.2827 | 0.4186 | 0.44935 |
| $\mathrm{Bp} / \mathrm{GL} \times 100$ | -0.38136 | -0.44736 | 0.49215 | -0.35466 | 0.42712 |
| Bd/GL $\times 100$ | -0.34333 | -0.13105 | 0.49861 | 0.24497 | -0.73909 |
| SC/Bp $\times 100$ | 0.48943 | 0.16694 | 0.41112 | -0.65388 | -0.15059 |
| SC/Bd $\times 100$ | 0.69122 | -0.26537 | 0.31012 | 0.42503 | 0.019276 |

### 4.1.8.3 Femur

| Femur |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| Dd/Bd $\times 100$ | 0.001907 | 0.015091 | 0.5974 | -0.33756 | 0.52226 |
| SC/Bd $\times 100$ | -0.31419 | 0.069905 | 0.46431 | 0.23393 | 0.19237 |
| SC/GL $\times 100$ | 0.076377 | 0.030773 | 0.077354 | 0.14649 | 0.034263 |
| Bd/GL $\times 100$ | 0.31563 | 0.041769 | -0.04205 | 0.16143 | -0.0934 |
| Bp/GL $\times 100$ | 0.20973 | 0.028853 | -0.00219 | 0.194 | 0.20211 |
| Bd/Lm $\times 100$ | 0.37613 | 0.082199 | -0.05703 | 0.31029 | 0.015245 |
| Bp/Lm $\times 100$ | 0.26305 | 0.068228 | -0.01249 | 0.34328 | 0.34052 |
| SC/Lm $\times 100$ | 0.0993 | 0.049889 | 0.078686 | 0.21822 | 0.090278 |


| $\mathrm{SC} / \mathrm{Bp} \times 100$ | -0.08292 | 0.10504 | 0.39561 | 0.31094 | -0.33054 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| $\mathrm{Dd} / \mathrm{Bp} \times 100$ | 0.443 II | 0.066068 | 0.4458 | -0.31795 | -0.55303 |
| $\mathrm{Dp} / \mathrm{Dd} \times 100$ | $-0.086 \mathrm{I7}$ | 0.97573 | -0.13289 | -0.14727 | 0.025047 |
| $\mathrm{Dd} / \mathrm{GL} \times 100$ | 0.26604 | 0.038234 | 0.088375 | 0.070899 | 0.029873 |
| $\mathrm{Dd} / \mathrm{Lm} \times 100$ | 0.317 I | 0.071294 | 0.085822 | 0.19071 | 0.12911 |
| $\mathrm{SC} / \mathrm{Dd} \times 100$ | -0.38643 | 0.05883 I | 0.14861 | 0.47284 | -0.28613 |

### 4.1.8.4 Tibiotarsus

| Tibiotarsus |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| Bd/Dip $\times 100$ | 0.51804 | -0.41067 | 0.18442 | 0.1146 | -0.16321 |
| Bd/GL $\times 100$ | 0.1653 | 0.10003 | 0.036458 | 0.29788 | 0.085596 |
| Dd/GL $\times 100$ | 0.087291 | 0.073513 | 0.044505 | 0.33369 | 0.058282 |
| SC/Bd $\times 100$ | -0.31999 | 0.15229 | 0.60124 | 0.089789 | -0.31946 |
| SC/GL $\times 100$ | 0.057007 | 0.073705 | 0.092046 | 0.15144 | 0.076685 |
| $\mathrm{Bd} / \mathrm{La} \times 100$ | 0.16465 | 0.11929 | 0.010265 | 0.22073 | -0.1042I |
| Dd/La $\times 100$ | 0.084619 | 0.091419 | 0.020945 | 0.26271 | -0.13197 |
| SC/La $\times 100$ | 0.051574 | 0.088698 | 0.072427 | 0.072324 | -0.07449 |
| Bd/Dd $\times 100$ | 0.70579 | 0.25652 | -0.06049 | -0.37075 | -0.03547 |
| Dd/Dip $\times 100$ | 0.10901 | -0.58456 | 0.20833 | 0.23257 | -0.02842 |
| Dip/GL $\times 100$ | 0.11246 | 0.32521 | 0.008804 | 0.43013 | 0.13668 |
| SC/Dip $\times 100$ | 0.11232 | -0.14337 | 0.44583 | 0.016147 | 0.099444 |


| Dip/La $\times 100$ | 0.11012 | 0.36002 | -0.02595 | 0.33384 | -0.1309 |
| :--- | :--- | :--- | :--- | :--- | :--- |
| La/GL $\times 100$ | -0.0109 | -0.06546 | 0.067252 | 0.12005 | 0.85623 |
| SC/Dd $\times 100$ | 0.081115 | 0.29855 | 0.5795 | -0.36075 | 0.19997 |

### 4.1.8.5 Tarsometatarsus

| Tarsometatarsus |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- |
|  | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| Bd/Bp $\times 100$ | -0.847 IB | 0.38439 | 0.11858 | 0.34708 | -0.00393 |
| SC/Bd $\times 100$ | 0.48242 | 0.54161 | -0.13354 | 0.62968 | 0.089288 |
| SC/GL $\times 100$ | 0.10363 | 0.14843 | 0.294 | -0.01887 | 0.70069 |
| Bp/GL $\times 100$ | 0.18589 | 0.022738 | 0.6466 | 0.19207 | -0.61766 |
| Bd/GL $\times 100$ | 0.032659 | 0.096856 | 0.66783 | -0.23731 | 0.2637 |
| SC/Bp $\times 100$ | 0.05727 | 0.72593 | -0.13262 | -0.62408 | -0.22364 |

## 4.I.9 BGPCA loadings - archaeological

### 4.1.9.1 Coracoids

| Coracoids - Fishbourne and modern BGPA loadings |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Lm} / \mathrm{GL} \times 100$ | -0.15886 | -0.08117 | 0.94432 | 0.043331 | 0.27272 | 0.013748 |
| $\mathrm{Bf} / \mathrm{Bb} \times 100$ | -0.47008 | 0.83459 | -0.01242 | 0.28555 | -0.02753 | -0.00545 |


| $\mathrm{Bb} / \mathrm{GL} \times 100$ | 0.49032 | 0.1343 | 0.24414 | 0.37544 | -0.60081 | 0.42428 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.56942 | 0.16892 | -0.04621 | 0.48061 | 0.48683 | -0.42084 |
| $\mathrm{Bf} / \mathrm{GL} \times 100$ | 0.27697 | 0.33395 | 0.21386 | -0.55661 | -0.36263 | -0.56983 |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.33528 | 0.37253 | -0.02521 | -0.48459 | 0.44203 | 0.56387 |


| Coracoids - Uley and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | :--- | :--- | :--- |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Lm} / \mathrm{GL} \times 100$ | -0.24319 | 0.066677 | 0.92814 | 0.12017 | 0.24495 | 0.023004 |
| $\mathrm{Bf} / \mathrm{Bb} \times 100$ | -0.224 | 0.91752 | -0.12284 | 0.27107 | -0.13762 | -0.02183 |
| $\mathrm{Bb} / \mathrm{GL} \times 100$ | 0.49284 | 0.023659 | 0.29002 | 0.12683 | -0.7142 | 0.38246 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.60023 | 0.002979 | 0.010168 | 0.60776 | 0.29841 | -0.42567 |
| $\mathrm{Bf} / \mathrm{GL} \times 100$ | 0.3346 | 0.27941 | 0.19445 | -0.67519 | -0.0974 | -0.55389 |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.41899 | 0.274 | -0.03796 | -0.26597 | 0.55897 | 0.60393 |


| Coracoids - Flixborough and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | :--- | ---: | ---: | ---: | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Lm} / \mathrm{GL} \times 100$ | -0.22401 | -0.03326 | 0.93454 | 0.050807 | 0.26902 | 0.019651 |
| $\mathrm{Bf} / \mathrm{Bb} \times 100$ | -0.44374 | 0.84203 | -0.07556 | 0.29133 | -0.05669 | -0.01681 |
| $\mathrm{Bb} / \mathrm{GL} \times 100$ | 0.4797 | 0.13227 | 0.27963 | 0.3183 | -0.6447 | 0.39654 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.57971 | 0.15128 | -0.00379 | 0.50773 | 0.44976 | -0.42539 |
| $\mathrm{Bf} / \mathrm{GL} \times 100$ | 0.26552 | 0.33983 | 0.2044 | -0.61346 | -0.2903 | -0.55824 |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.34094 | 0.36608 | -0.0305 | -0.42085 | 0.4714 | 0.59118 |


| Coracoids - Lyminge and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Lm} / \mathrm{GL} \times 100$ | -0.22148 | 0.057652 | 0.93398 | 0.063413 | 0.26641 | 0.017686 |
| $\mathrm{Bf} / \mathrm{Bb} \times 100$ | -0.25876 | 0.90959 | -0.11667 | 0.29447 | -0.07227 | -0.01155 |
| $\mathrm{Bb} / \mathrm{GL} \times 100$ | 0.49842 | 0.040322 | 0.27617 | 0.27791 | -0.6558 | 0.40788 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.59883 | 0.023668 | -0.00725 | 0.53638 | 0.41844 | -0.42189 |
| $\mathrm{Bf} / \mathrm{GL} \times 100$ | 0.33096 | 0.29019 | 0.18861 | -0.61784 | -0.26434 | -0.56488 |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.40918 | 0.28796 | -0.04661 | -0.40324 | 0.49876 | 0.57976 |


| Coracoids - Coppergate and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Lm} / \mathrm{GL} \times 100$ | -0.2443 | 0.019052 | 0.93002 | 0.069167 | 0.26395 | 0.023798 |
| $\mathrm{Bf} / \mathrm{Bb} \times 100$ | -0.35697 | 0.87697 | -0.11 | 0.29043 | -0.07988 | -0.02602 |
| $\mathrm{Bb} / \mathrm{GL} \times 100$ | 0.48569 | 0.092867 | 0.28777 | 0.27305 | -0.67649 | 0.3748 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.59312 | 0.092066 | 0.007068 | 0.52997 | 0.41729 | -0.42976 |
| $\mathrm{Bf} / \mathrm{GL} \times 100$ | 0.29168 | 0.32144 | 0.19699 | -0.6492 | -0.22787 | -0.54719 |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.37435 | 0.33188 | -0.03601 | -0.36604 | 0.49017 | 0.6117 |


| Coracoids - Chester and modern BGPCA loadings |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Lm/GL x 100 | -0.2396 | 0.031273 | 0.93083 | 0.21828 | 0.13927 | 0.090127 |
| Bf/Bb $\times 100$ | -0.31002 | 0.89429 | -0.10804 | 0.17301 | -0.15758 | -0.19418 |
| Bb/GL x 100 | 0.49139 | 0.066016 | 0.28629 | -0.13452 | -0.80135 | -0.10933 |
| $\mathrm{Bb} / \mathrm{Lm} \times 100$ | 0.59751 | 0.059735 | 0.004969 | 0.58993 | 0.33212 | -0.42553 |


| Bf/GL $\times 100$ | 0.30874 | 0.30612 | 0.19616 | -0.73617 | 0.43571 | -0.20174 |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| $\mathrm{Bf} / \mathrm{Lm} \times 100$ | 0.39074 | 0.31247 | -0.03757 | 0.11986 | 0.11601 | 0.84879 |

### 4.1.9.2 Humerus

| Humerus - Uley and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Bd/Bp $\times 100$ | -0.12817 | 0.82094 | 0.40467 | 0.18345 | 0.25241 | -0.22024 |
| SC/GL $\times 100$ | 0.004125 | -0.1146 | 0.28337 | 0.41563 | 0.31391 | 0.79704 |
| Bp/GL $\times 100$ | -0.37352 | -0.44438 | 0.50036 | -0.34171 | 0.48226 | -0.2516 |
| Bd/GL $\times 100$ | -0.33363 | -0.12814 | 0.50637 | 0.22988 | -0.75004 | -0.0212 |
| SC/Bp $\times 100$ | 0.49835 | 0.16631 | 0.40143 | -0.66148 | -0.19024 | 0.29848 |
| SC/Bd | 0.69597 | -0.26715 | 0.29668 | 0.43178 | 0.080124 | -0.40421 |


| Humerus - Lyminge and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | :--- | ---: | ---: | ---: | ---: | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Bd/Bp $\times 100$ | -0.23767 | -0.78025 | 0.43534 | 0.16802 | 0.2268 | -0.25599 |
| SC/GL $\times 100$ | 0.017673 | 0.12504 | 0.27864 | 0.42798 | 0.42695 | 0.7355 |
| Bp/GL $\times 100$ | -0.31467 | 0.5088 | 0.4788 | -0.3662 | 0.43474 | -0.2996 |
| Bd/GL $\times 100$ | -0.31692 | 0.19162 | 0.4967 | 0.25521 | -0.73922 | 0.06747 |
| SC/Bp x 100 | 0.46941 | -0.2141 | 0.41261 | -0.64526 | -0.17092 | 0.34349 |
| SC/Bd | 0.72346 | 0.18477 | 0.29433 | 0.41594 | 0.040241 | -0.42569 |


| Humerus - Chester and modern BGPCA loadings |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Bd/Bp $\times 100$ | -0.15129 | 0.82362 | 0.39162 | 0.17554 | 0.18168 | -0.28561 |
| SC/GL $\times 100$ | -0.00018 | -0.11154 | 0.28406 | 0.42467 | 0.53101 | 0.66675 |
| Bp/GL $\times 100$ | -0.37647 | -0.44459 | 0.49837 | -0.35365 | 0.38749 | -0.37015 |
| Bd/GL x 100 | -0.3428 | -0.1275 | 0.50005 | 0.2411 | -0.72304 | 0.18781 |
| SC/Bp $\times 100$ | 0.48611 | 0.18004 | 0.40944 | -0.65314 | -0.1046 | 0.35513 |
| SC/Bd | 0.69394 | -0.25077 | 0.31604 | 0.42315 | -0.03394 | -0.4189 |

### 4.1.9.3 Femur

| Femur - Uley and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | :--- | :--- | :--- |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Dd/Bd $\times 100$ | 0.11676 | -0.18734 | 0.69196 | -0.35798 | 0.35607 | 0.25259 |
| SC/Bd $\times 100$ | -0.26587 | -0.06029 | 0.46324 | 0.26466 | 0.20202 | -0.3862 |
| SC/GL $\times 100$ | 0.075798 | 0.024634 | 0.046212 | 0.15187 | 0.062758 | -0.16274 |
| Bd/GL $\times 100$ | 0.29186 | 0.087829 | -0.10881 | 0.18756 | -0.04487 | -0.13494 |
| Bp/GL $\times 100$ | 0.20368 | 0.04566 | -0.02984 | 0.12526 | 0.24437 | -0.11688 |
| Bd/Lm $\times 100$ | 0.34864 | 0.13516 | -0.12158 | 0.26491 | 0.14463 | 0.26954 |
| Bp/Lm $\times 100$ | 0.25432 | 0.089897 | -0.03657 | 0.20015 | 0.45193 | 0.17509 |
| SC/Lm $\times 100$ | 0.097521 | 0.045084 | 0.047269 | 0.19393 | 0.15008 | -0.04728 |
| SC/Bp $\times 100$ | -0.07325 | 0.036563 | 0.30227 | 0.49454 | -0.25445 | -0.31157 |
| $\mathrm{Dd} / \mathrm{Bp} \times 100$ | 0.48442 | -0.01576 | 0.36932 | -0.00522 | -0.64687 | 0.20949 |
| $\mathrm{Dp} / \mathrm{Dd} \times 100$ | -0.11964 | 0.95549 | 0.1793 | -0.19975 | -0.01043 | -0.00635 |
| $\mathrm{Dd} / \mathrm{GL} \times 100$ | 0.2681 | 0.037008 | 0.046811 | 0.097619 | 0.022614 | -0.23724 |


| $\mathrm{Dd} / \mathrm{Lm} \times 100$ | 0.3173 | 0.073308 | 0.045367 | 0.16145 | 0.18038 | 0.02924 |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
| $\mathrm{SC} / \mathrm{Dd} \times 100$ | -0.40078 | 0.034652 | 0.096024 | 0.50983 | -0.05208 | 0.65193 |


| Femur - Lyminge and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Dd/Bd $\times 100$ | -0.00761 | 0.005302 | 0.49644 | -0.61367 | 0.35437 | -0.01844 |
| SC/Bd $\times 100$ | -0.29568 | 0.16928 | 0.46504 | 0.070748 | 0.26005 | 0.32079 |
| SC/GL $\times 100$ | 0.084296 | 0.056951 | 0.087394 | 0.11202 | 0.076064 | 0.25785 |
| Bd/GL $\times 100$ | 0.32527 | 0.054813 | -0.02074 | 0.20209 | -0.05361 | 0.50662 |
| Bp/GL $\times 100$ | 0.21358 | 0.029213 | 0.001532 | 0.10357 | 0.23999 | 0.36533 |
| Bd/Lm $\times 100$ | 0.38705 | 0.08933 | -0.04152 | 0.24715 | 0.15893 | -0.2015 |
| Bp/Lm $\times 100$ | 0.26764 | 0.061367 | -0.01643 | 0.13779 | 0.47855 | -0.32353 |
| SC/Lm $\times 100$ | 0.10797 | 0.074566 | 0.085719 | 0.13158 | 0.18132 | -0.07409 |
| SC/Bp $\times 100$ | -0.05233 | 0.23053 | 0.43099 | 0.3126 | -0.1401 | -0.30821 |
| $\mathrm{Dd} / \mathrm{Bp} \times 100$ | 0.45714 | 0.10926 | 0.41784 | -0.1647 | -0.61616 | -0.06911 |
| $\mathrm{Dp} / \mathrm{Dd} \times 100$ | -0.04924 | 0.91554 | -0.31023 | -0.24909 | -0.01963 | 0.020943 |
| $\mathrm{Dd} / \mathrm{GL} \times 100$ | 0.27209 | 0.046895 | 0.085199 | 0.043445 | 0.035509 | 0.35446 |
| $\mathrm{Dd} / \mathrm{Lm} \times 100$ | 0.32402 | 0.074819 | 0.076252 | 0.071233 | 0.22021 | -0.25176 |
| $\mathrm{SC} / \mathrm{Dd} \times 100$ | -0.3574 | 0.18925 | 0.22407 | 0.51289 | -0.06308 | -0.01222 |


| Femur - Chester and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | ---: | ---: | ---: | ---: | ---: | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Dd/Bd $\times 100$ | 0.0448 | 0.45242 | 0.17072 | -0.50668 | 0.49797 | 0.086182 |
| SC/Bd $\times 100$ | -0.26481 | 0.4458 | 0.21993 | 0.13634 | 0.269 | 0.31146 |
| SC/GL $\times 100$ | 0.08555 | 0.065188 | 0.054467 | 0.12497 | 0.072427 | -0.00512 |
| Bd/GL $\times 100$ | 0.31473 | -0.05472 | 0.027242 | 0.18047 | -0.06715 | 0.18554 |
| Bp/GL $\times 100$ | 0.20629 | -0.04123 | 0.01875 | 0.14346 | 0.25216 | -0.34658 |
| Bd/Lm $\times 100$ | 0.37393 | -0.08224 | 0.061003 | 0.31044 | 0.055084 | 0.50866 |
| Bp/Lm $\times 100$ | 0.25795 | -0.068 | 0.051764 | 0.26613 | 0.40801 | -0.12571 |
| SC/Lm $\times 100$ | 0.10848 | 0.059156 | 0.072769 | 0.18445 | 0.1397 | 0.052544 |
| SC/Bp $\times 100$ | -0.03041 | 0.40971 | 0.24444 | 0.30641 | -0.1932 | -0.59281 |
| Dd/Bp $\times 100$ | 0.49296 | 0.38444 | 0.20024 | -0.26389 | -0.55879 | 0.11874 |
| Dp/Dd $\times 100$ | -0.11004 | -0.44046 | 0.88151 | -0.12546 | -0.02406 | -0.00444 |
| Dd/GL $\times 100$ | 0.27346 | 0.044031 | 0.057175 | 0.046202 | 0.063846 | -0.21964 |
| Dd/Lm $\times 100$ | 0.32402 | 0.028111 | 0.087078 | 0.14627 | 0.17761 | -0.03111 |
| SC/Dd $\times 100$ | -0.35355 | 0.24569 | 0.13772 | 0.50191 | -0.17757 | 0.22125 |

### 4.1.9.4 Tarsometatarsus

| Tarsometatarsus - Uley and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | ---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Bd/Bp $\times 100$ | 0.87566 | 0.3417 | -0.01878 | 0.3407 | 0.005382 | $7.82 \mathrm{E}-05$ |
| SC/Bd $\times 100$ | -0.45389 | 0.52913 | -0.24657 | 0.6251 | -0.17934 | 0.17405 |
| SC/GL $\times 100$ | -0.07631 | 0.22573 | 0.25624 | -0.02933 | 0.82829 | 0.43662 |
| Bp/GL $\times 100$ | -0.14384 | 0.20426 | 0.62981 | 0.19795 | 0.11195 | -0.69943 |
| Bd/GL $\times 100$ | 0.011879 | 0.26124 | 0.61389 | -0.25063 | -0.5181 | 0.47277 |
| SC/Bp $\times 100$ | -0.02338 | 0.66509 | -0.3157 | -0.62475 | 0.027921 | -0.25759 |


| Tarsometatarsus - Lyminge and modern BGPCA loadings |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| Bd/Bp $\times 100$ | -0.82806 | 0.43183 | 0.098183 | 0.34368 | 0.003107 | 0.008732 |
| SC/Bd $\times 100$ | 0.50633 | 0.51589 | -0.16452 | 0.62372 | 0.092674 | -0.22979 |
| SC/GL $\times 100$ | 0.11132 | 0.15806 | 0.28413 | -0.03328 | 0.72327 | 0.59806 |
| Bp/GL $\times 100$ | 0.1899 | 0.055264 | 0.64461 | 0.1997 | -0.60032 | 0.38092 |
| Bd/GL $\times 100$ | 0.039711 | 0.1312 | 0.66036 | -0.2433 | 0.23676 | -0.65566 |
| SC/Bp $\times 100$ | 0.089005 | 0.70861 | -0.17597 | -0.62664 | -0.2277 | 0.12026 |

Tarsometatarsus - Chester and modern BGPCA loadings

| Tarsometatarsus - Chester and modern BGPCA loadings |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 | PC 6 |
| $\mathrm{Bd} / \mathrm{Bp} \times 100$ | -0.82534 | 0.43142 | 0.098759 | 0.35051 | -0.00312 | 0.008778 |
| $\mathrm{SC} / \mathrm{Bd} \times 100$ | 0.50673 | 0.50832 | -0.18375 | 0.62578 | 0.091226 | -0.22618 |


| SC/GL $\times 100$ | 0.11494 | 0.16441 | 0.28072 | -0.02024 | 0.69976 | 0.62521 |
| :---: | ---: | ---: | ---: | ---: | ---: | ---: |
| $\mathrm{Bp} / \mathrm{GL} \times 100$ | 0.19838 | 0.062104 | 0.63962 | 0.196 | -0.61758 | 0.35757 |
| $\mathrm{Bd} / \mathrm{GL} \times 100$ | 0.04708 | 0.14361 | 0.65964 | -0.23323 | 0.26456 | -0.64626 |
| $\mathrm{SC} / \mathrm{Bp} \times 100$ | 0.085236 | 0.70991 | -0.18285 | -0.62636 | -0.22498 | 0.11127 |

## Appendix E: Statistical Analysis Geometric Morphometrics

## 5.I Coracoids

## 5.I.I Complete dataset variance percentages

| Modern breed coracoids - complete dataset |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00027255 | 29.36 | 29.36 |
| 2 | 0.00013649 | 14.70 | 44.07 |
| 3 | 0.00011825 | 12.74 | 56.81 |
| 4 | 0.0000826 | 8.90 | 65.71 |
| 5 | 0.00005885 | 6.34 | 72.05 |
| 6 | 0.00004299 | 4.63 | 76.68 |
| 7 | 0.00003247 | 3.50 | 80.18 |
| 8 | 0.00002899 | 3.12 | 83.30 |

## Modern breed coracoids - complete dataset

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 9 | 0.00002503 | 2.70 | 85.99 |
| 10 | 0.00002301 | 2.48 | 88.47 |
| 11 | 0.00001979 | 2.13 | 90.61 |
| 12 | 0.00001775 | 1.91 | 92.52 |
| 13 | 0.00001336 | 1.44 | 93.96 |
| 14 | 0.00001039 | 1.12 | 95.08 |
| 15 | 0.00000933 | 1.01 | 96.08 |
| 16 | 0.00000805 | 0.87 | 96.95 |
| 17 | 0.00000657 | 0.71 | 97.66 |
| 18 | 0.00000534 | 0.58 | 98.23 |
| 19 | 0.00000463 | 0.50 | 98.73 |
| 20 | 0.00000375 | 0.40 | 99.13 |
| 21 | 0.00000332 | 0.36 | 99.49 |
| 22 | 0.00000241 | 0.26 | 99.75 |
| 23 | 0.00000188 | 0.20 | 99.95 |
| 24 | 0.00000044 | 0.05 | 100.00 |

## 5.I.2 Modern breeds/types PCA. Percentages of variance

| Modern breeds/types - coracoids |  |  |  |
| :---: | :---: | :---: | :---: |
| PCs | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00021 I7I | 27.81 | 27.81 |
| 2 | 0.000122 | 16.03 | 43.84 |
| 3 | 0.0000889 | 11.68 | 55.51 |
| 4 | 0.00006625 | 8.70 | 64.21 |
| 5 | 0.00005018 | 6.59 | 70.81 |
| 6 | 0.00004572 | 6.01 | 76.81 |
| 7 | 0.00003266 | 4.29 | 81.10 |
| 8 | 0.00002875 | 3.78 | 84.88 |
| 9 | 0.00002435 | 3.20 | 88.08 |
| 10 | 0.00001894 | 2.49 | 90.56 |
| 11 | 0.00001483 | 1.95 | 92.51 |
| 12 | 0.00001344 | 1.77 | 94.28 |
| 13 | 0.00001032 | 1.36 | 95.63 |
| 14 | 0.00000656 | 0.86 | 96.50 |
| 15 | 0.00000569 | 0.75 | 97.24 |
| 16 | 0.00000528 | 0.69 | 97.94 |
| 17 | 0.0000046 | 0.60 | 98.54 |
| 18 | 0.00000306 | 0.40 | 98.94 |
| 19 | 0.00000294 | 0.39 | 99.33 |


| Modern breeds/types - coracoids |  |  |  |
| :---: | :---: | :---: | :---: |
| PCs | Eigenvalues | \% Variance | Cumulative \% |
| 20 | 0.00000202 | 0.27 | 99.60 |
| 21 | 0.00000162 | 0.21 | 99.81 |
| 22 | 0.0000007 | 0.09 | 99.90 |
| 23 | 0.00000052 | 0.07 | 99.97 |
| 24 | 0.00000025 | 0.03 | 100.00 |

5.I.3 Modern breeds/types. DFA classifications

| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00 I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | OEG |
| e010 | X-B JF | X-B JF | OEG |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65I | Hamburgh | Hamburgh | OEG |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Dorking |
| r66l | Silkie | Silkie | Asian G |


| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | Silkie | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | Hamburgh | Hamburgh |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | X-B JF |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | OEG | OEG |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | X-B JF |
| tl43 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
|  |  |  |  |


| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| n00I | OEG | OEG | Hamburgh |
| w5I8 | OEG | Hamburgh | Hamburgh |
| w5 I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | Hamburgh |
| w6I2 | OEG | OEG | Hamburgh |

## 5.I.4 Modern breeds/types - coracoids. Loadings for BGPCA

| Loadings for Fig, 101. Modern breeds/types - coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coordinates | Landmark | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 |
| ProcCoord1 | 1 | 0.21075 | 0.1405 | 0.28353 | -0.32625 | 0.17053 |
| ProcCoord2 |  | 0.41713 | 0.25826 | 0.32744 | 0.001797 | -0.10888 |
| ProcCoord3 | 2 | 0.16685 | -0.21354 | -0.40488 | 0.17033 | 0.074085 |
| ProcCoord4 |  | -0.12911 | -0.60384 | 0.089878 | -0.17987 | 0.14974 |
| ProcCoord5 | 3 | -0.18037 | 0.063292 | 0.049846 | -0.20034 | 0.039238 |
| ProcCoord6 |  | 0.077486 | 0.14326 | 0.057214 | 0.3327 | -0.01065 |
| ProcCoord7 | 4 | -0.14037 | -0.03477 | 0.073241 | 0.16132 | -0.21389 |
| ProcCoord8 |  | -0.52296 | 0.017333 | -0.11531 | -0.14737 | -0.30008 |
| ProcCoord9 | 5 | 0.18044 | 0.019318 | -0.17306 | -0.04983 | 0.28369 |
| ProcCoord10 |  | -0.01506 | 0.26226 | -0.20489 | -0.06923 | 0.2079 |


| Loadings for Fig, 101. Modern breeds/types - coracoids |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Coordinates | Landmark | PC 1 | PC 2 | PC 3 | PC 4 | PC 5 |
| ProcCoord11 | 6 | 0.026074 | -0.00076 | -0.02677 | 0.15853 | 0.043249 |
| ProcCoord12 |  | -0.16719 | 0.12521 | -0.20067 | 0.085023 | 0.44622 |
| ProcCoord13 | 7 | 0.05078 | 0.26714 | -0.07784 | -0.11194 | -0.35208 |
| ProcCoord14 |  | -0.22255 | 0.16356 | -0.19848 | 0.12146 | -0.01251 |
| ProcCoord15 | 8 | 0.062544 | -0.03849 | 0.24203 | 0.006128 | 0.4143 |
| ProcCoord16 |  | -0.18162 | 0.1531 | -0.12507 | -0.0025 | -0.01752 |
| ProcCoord17 | 9 | -0.07859 | 0.05841 | 0.17706 | 0.21208 | -0.04408 |
| ProcCoord18 |  | -0.03788 | -0.3064 | 0.15854 | 0.22314 | -0.0326 |
| ProcCoord19 | 10 | -0.08395 | 0.018366 | -0.033 | 0.27569 | -0.05421 |
| ProcCoord20 |  | 0.000404 | -0.11335 | 0.38306 | 0.17369 | -0.16734 |
| ProcCoord21 | 11 | 0.011935 | -0.08585 | 0.22607 | -0.05214 | 0.068853 |
| ProcCoord22 |  | 0.15648 | -0.21766 | -0.14677 | 0.12296 | -0.00292 |
| ProcCoord23 | 12 | 0.03233 | -0.20265 | -0.097 | -0.35839 | -0.21723 |
| ProcCoord24 |  | 0.13043 | -0.08354 | -0.03861 | -0.26349 | -0.10986 |
| ProcCoord25 | 13 | 0.21023 | -0.06192 | -0.24998 | -0.10406 | -0.11132 |
| ProcCoord26 |  | 0.12697 | 0.21696 | 0.13492 | -0.27653 | 0.13976 |
| ProcCoord27 | 14 | -0.04716 | 0.070947 | 0.01075 | 0.21885 | -0.10113 |
| ProcCoord28 |  | 0.36748 | -0.01514 | -0.12124 | -0.12177 | -0.18126 |

## 5.I. 5 Saxon coracoids PCA. Percentages of variance

## Saxon coracoids - percentage of variance for first 13 PCs

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 1 | 0.00008013 | 17.127 | 17.127 |
| 2 | 0.00007269 | 15.535 | 32.663 |
| 3 | 0.00005132 | 10.969 | 43.632 |
| 4 | 0.00004517 | 9.654 | 53.286 |
| 5 | 0.00003769 | 8.056 | 61.342 |
| 6 | 0.0000284 | 6.071 | 67.413 |
| 7 | 0.00002543 | 5.436 | 72.848 |
| 8 | 0.00001933 | 4.131 | 76.979 |
| 9 | 0.00001687 | 3.605 | 80.584 |
| 10 | 0.00001485 | 3.174 | 83.758 |
| 11 | 0.00001313 | 2.805 | 86.564 |
| 12 | 0.00001097 | 2.345 | 88.909 |
| 13 | 0.00000927 | 1.98 | 90.889 |

### 5.1.6 Saxon coracoids. DFA classifications

| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L054 | Lyminge | Lyminge | Lyminge |
| LI27 | Lyminge | Lyminge | Lyminge |
| LI34 | Lyminge | Flixborough | Flixborough |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L152 | Lyminge | Lyminge | Coppergate |
| LI69 | Lyminge | Coppergate | Coppergate |
| L222 | Lyminge | Flixborough | Flixborough |
| L226 | Lyminge | Lyminge | Lyminge |
| L340 | Lyminge | Flixborough | Flixborough |
| L346 | Lyminge | Lyminge | Lyminge |
| L477 | Lyminge | Lyminge | Lyminge |
| L509 | Lyminge | Lyminge | Lyminge |
| L519 | Lyminge | Lyminge | Lyminge |
| L530 | Lyminge | Lyminge | Lyminge |
| L702 | Lyminge | Lyminge | Lyminge |
| L7I0 | Lyminge | Flixborough | Flixborough |
| L74I | Lyminge | Coppergate | Coppergate |
| L79I | Lyminge | Lyminge | Lyminge |
| L797 | Lyminge | Lyminge | Lyminge |
| L823 | Lyminge | Lyminge | Coppergate |
| L88I | Lyminge | Flixborough | Flixborough |
| L90I | Lyminge | Lyminge | Coppergate |
| L228 | Lyminge | Coppergate | Coppergate |
| L236 | Lyminge | Lyminge | Lyminge |
| L249 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L255 | Lyminge | Lyminge | Lyminge |
| L26I | Lyminge | Lyminge | Lyminge |
| L005 | Lyminge | Flixborough | Flixborough |
| L057 | Lyminge | Lyminge | Lyminge |
| LI47 | Lyminge | Coppergate | Coppergate |
| L408 | Lyminge | Lyminge | Lyminge |
| L560 | Lyminge | Lyminge | Lyminge |
| L617 | Lyminge | Flixborough | Flixborough |
| L78I | Lyminge | Lyminge | Lyminge |
| L816 | Lyminge | Coppergate | Coppergate |
| L916 | Lyminge | Flixborough | Flixborough |
| L917 | Lyminge | Lyminge | Flixborough |
| Y002 | Coppergate | Lyminge | Lyminge |
| Y003 | Coppergate | Coppergate | Coppergate |
| Y004 | Coppergate | Coppergate | Coppergate |
| Y007 | Coppergate | Coppergate | Coppergate |
| Y0II | Coppergate | Coppergate | Flixborough |
| Y0I5 | Coppergate | Flixborough | Flixborough |
| Y016 | Coppergate | Flixborough | Flixborough |
| Y0I7 | Coppergate | Flixborough | Flixborough |
| Y019 | Coppergate | Coppergate | Coppergate |
|  |  |  |  |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| Y022 | Coppergate | Coppergate | Flixborough |
| Y025 | Coppergate | Lyminge | Lyminge |
| Y026 | Coppergate | Coppergate | Coppergate |
| Y027 | Coppergate | Coppergate | Coppergate |
| Y028 | Coppergate | Coppergate | Coppergate |
| Y029 | Coppergate | Coppergate | Coppergate |
| Y03I | Coppergate | Lyminge | Lyminge |
| Y032 | Coppergate | Coppergate | Coppergate |
| Y033 | Coppergate | Coppergate | Coppergate |
| Y034 | Coppergate | Coppergate | Coppergate |
| Y035 | Coppergate | Lyminge | Lyminge |
| Y037 | Coppergate | Coppergate | Coppergate |
| Y038 | Coppergate | Coppergate | Flixborough |
| Y039 | Coppergate | Coppergate | Coppergate |
| Y04I | Coppergate | Coppergate | Coppergate |
| Y042 | Coppergate | Lyminge | Lyminge |
| Y044 | Coppergate | Coppergate | Coppergate |
| Y045 | Coppergate | Coppergate | Lyminge |
| Y047 | Coppergate | Coppergate | Coppergate |
| Y05 I | Coppergate | Coppergate | Coppergate |
| Y052 | Coppergate | Coppergate | Coppergate |
|  |  |  |  |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| Y054 | Coppergate | Coppergate | Coppergate |
| Y055 | Coppergate | Flixborough | Lyminge |
| Y056 | Coppergate | Flixborough | Flixborough |
| Y057 | Coppergate | Flixborough | Flixborough |
| Y058 | Coppergate | Coppergate | Coppergate |
| Y059 | Coppergate | Flixborough | Flixborough |
| Y060 | Coppergate | Coppergate | Coppergate |
| Y06 I | Coppergate | Coppergate | Coppergate |
| Y063 | Coppergate | Coppergate | Coppergate |
| Y067 | Coppergate | Flixborough | Flixborough |
| Y068 | Coppergate | Lyminge | Lyminge |
| Y069 | Coppergate | Coppergate | Coppergate |
| Y070 | Coppergate | Coppergate | Coppergate |
| Y074 | Coppergate | Coppergate | Coppergate |
| Y076 | Coppergate | Flixborough | Flixborough |
| Y077 | Coppergate | Coppergate | Flixborough |
| Y078 | Coppergate | Coppergate | Flixborough |
| Y08 I | Coppergate | Coppergate | Coppergate |
| Y082 | Coppergate | Coppergate | Coppergate |
| Y085 | Coppergate | Coppergate | Coppergate |
| Y086 | Coppergate | Flixborough | Flixborough |
|  |  |  |  |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| Y087 | Coppergate | Coppergate | Coppergate |
| Y089 | Coppergate | Coppergate | Coppergate |
| F338 | Flixborough | Flixborough | Flixborough |
| F339 | Flixborough | Coppergate | Coppergate |
| F344 | Flixborough | Flixborough | Flixborough |
| F345 | Flixborough | Lyminge | Lyminge |
| F346 | Flixborough | Flixborough | Flixborough |
| F35 I | Flixborough | Flixborough | Flixborough |
| F357 | Flixborough | Flixborough | Flixborough |
| F358 | Flixborough | Coppergate | Coppergate |
| F361 | Flixborough | Coppergate | Coppergate |
| F362 | Flixborough | Coppergate | Coppergate |
| F363 | Flixborough | Coppergate | Coppergate |
| F368 | Flixborough | Flixborough | Flixborough |
| F370 | Flixborough | Flixborough | Flixborough |
| F37I | Flixborough | Flixborough | Coppergate |
| F377 | Flixborough | Lyminge | Lyminge |
| F382 | Flixborough | Flixborough | Flixborough |
| F383 | Flixborough | Flixborough | Lyminge |
| F385 | Flixborough | Lyminge | Lyminge |
| F390 | Flixborough | Lyminge | Lyminge |
|  |  |  |  |


| Saxon coracoids - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| F391 | Flixborough | Coppergate | Coppergate |
| F392 | Flixborough | Lyminge | Lyminge |
| F393 | Flixborough | Flixborough | Flixborough |
| F394 | Flixborough | Flixborough | Coppergate |
| F396 | Flixborough | Flixborough | Lyminge |
| F397 | Flixborough | Flixborough | Flixborough |
| F398 | Flixborough | Flixborough | Flixborough |
| F401 | Flixborough | Flixborough | Coppergate |
| F402 | Flixborough | Coppergate | Coppergate |
| F403 | Flixborough | Coppergate | Coppergate |
| F404 | Flixborough | Flixborough | Flixborough |
| F406 | Flixborough | Flixborough | Coppergate |

## 5.I.7 Uley, Chester and Lyminge. DFA classifications

| Uley, Chester and Lyminge - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| C033 | Chester | Uley | Uley |
| C034 | Chester | Chester | Uley |
| C035 | Chester | Chester | Lyminge |
| C036 | Chester | Chester | Lyminge |


| Uley, Chester and Lyminge - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| C037 | Chester | Lyminge | Lyminge |
| C038 | Chester | Chester | Chester |
| C087 | Chester | Chester | Chester |
| C088 | Chester | Chester | Chester |
| C101 | Chester | Chester | Chester |
| C158 | Chester | Chester | Chester |
| C166 | Chester | Chester | Lyminge |
| C182 | Chester | Chester | Lyminge |
| C219 | Chester | Lyminge | Lyminge |
| U004 | Uley | Uley | Lyminge |
| U023 | Uley | Uley | Uley |
| U025 | Uley | Uley | Lyminge |
| U040 | Uley | Uley | Uley |
| U043 | Uley | Uley | Uley |
| U050 | Uley | Uley | Uley |
| U057 | Uley | Uley | Uley |
| U06 I | Uley | Uley | Uley |
| U075 | Uley | Uley | Chester |
| UII0 | Uley | Uley | Uley |
| U117 | Uley | Uley | Lyminge |
| U127 | Uley | Uley | Uley |
|  |  |  |  |


| Uley, Chester and Lyminge - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| UI39 | Uley | Uley | Lyminge |
| U15 I | Uley | Uley | Uley |
| U180 | Uley | Uley | Uley |
| U186 | Uley | Uley | Uley |
| L228 | Lyminge | Lyminge | Lyminge |
| L236 | Lyminge | Lyminge | Chester |
| L249 | Lyminge | Uley | Uley |
| L255 | Lyminge | Lyminge | Lyminge |
| L26I | Lyminge | Chester | Chester |
| L005 | Lyminge | Lyminge | Lyminge |
| L057 | Lyminge | Lyminge | Lyminge |
| LI47 | Lyminge | Chester | Chester |
| L408 | Lyminge | Chester | Chester |
| L560 | Lyminge | Lyminge | Lyminge |
| L6I7 | Lyminge | Lyminge | Lyminge |
| L78I | Lyminge | Chester | Chester |
| L8I6 | Lyminge | Chester | Chester |
| L916 | Lyminge | Lyminge | Lyminge |
| L9I7 | Lyminge | Lyminge | Lyminge |
| L054 | Lyminge | Uley | Uley |
| LI27 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Uley, Chester and Lyminge - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| LI34 | Lyminge | Uley | Uley |
| L152 | Lyminge | Lyminge | Lyminge |
| LI69 | Lyminge | Lyminge | Chester |
| L222 | Lyminge | Lyminge | Lyminge |
| L226 | Lyminge | Lyminge | Lyminge |
| L340 | Lyminge | Lyminge | Lyminge |
| L346 | Lyminge | Chester | Chester |
| L477 | Lyminge | Lyminge | Lyminge |
| L509 | Lyminge | Chester | Chester |
| L50I9 | Lyminge | Lyminge | Lyminge |
| L530 | Lyminge | Lyminge | Lyminge |
| L702 | Lyminge | Lyminge | Lyminge |
| L703 | Lyminge | Lyminge | Uley |
| L7I0 | Lyminge | Lyminge | Chester |
| L74I | Lyminge | Lyminge | Lyminge |
| L79I | Lyminge | Lyminge | Lyminge |
| L797 | Lyminge | Chester | Chester |
| L823 | Lyminge | Chester | Chester |
| L88I | Lyminge | Lyminge | Uley |
| L90I | Lyminge | Lyminge | Lyminge |
|  |  |  |  |

### 5.1.8 One-way Permanova tests for BGPCAs

| P-values - modern breeds/types |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G |
| Dorking |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 2 8}$ | $\mathbf{0 . 0 0 3 6}$ | 0.5477 | 0.0843 |
| Hamburgh | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 1 3}$ | 0.3561 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 2 4}$ |
| X-B JF | $\mathbf{0 . 0 0 2 8}$ | $\mathbf{0 . 0 0 1 3}$ |  | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 4 4}$ |
| OEG | $\mathbf{0 . 0 0 3 6}$ | 0.3561 | $\mathbf{0 . 0 0 0 8}$ |  | $\mathbf{0 . 0 0 1 9}$ | $\mathbf{0 . 0 0 5 8}$ |
| Silkie | 0.5477 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1 9}$ |  | 0.1626 |
| Asian G | 0.0843 | $\mathbf{0 . 0 0 2 4}$ | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 5 8}$ | 0.1626 |  |


| P-values - modern breeds/types and Uley |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Uley |
| Dorking |  | $\mathbf{0 . 0 1 0 1}$ | $\mathbf{0 . 0 0 1 6}$ | 0.0645 | 0.875 I | 0.1824 | $\mathbf{0 . 0 0 0 2}$ |
| Hamburgh | $\mathbf{0 . 0 1 0 1}$ |  | $\mathbf{0 . 0 0 0 7}$ | 0.516 | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 0 0 9}$ |
| X-B JF | $\mathbf{0 . 0 0 1 6}$ | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 4 9}$ | $\mathbf{0 . 0 0 0 1}$ |
| OEG | 0.0645 | 0.516 | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 1 2 2}$ | $\mathbf{0 . 0 0 8 3}$ | $\mathbf{0 . 0 0 0 1}$ |
| Silkie | 0.8751 | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 1 2 2}$ |  | 0.2385 | $\mathbf{0 . 0 0 0 1}$ |
| Asian G | 0.1824 | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 0 4 9}$ | $\mathbf{0 . 0 0 8 3}$ | 0.2385 |  | $\mathbf{0 . 0 0 0 5}$ |
| Uley | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 5}$ |  |


| P-values - modern breeds/types and Flixborough |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Flixborough |
| Dorking |  | 0.0042 | 0.0018 | 0.0261 | 0.769 | 0.1793 | 0.0001 |
| Hamburgh | 0.0042 |  | 0.0004 | 0.5156 | 0.0005 | 0.0029 | 0.0106 |
| X-B JF | 0.0018 | 0.0004 |  | 0.0001 | 0.0007 | 0.0042 | 0.0001 |
| OEG | 0.0261 | 0.5156 | 0.0001 |  | 0.006 | 0.0035 | 0.0001 |
| Silkie | 0.769 | 0.0005 | 0.0007 | 0.006 |  | 0.2298 | 0.0001 |
| Asian G | 0.1793 | 0.0029 | 0.0042 | 0.0035 | 0.2298 |  | 0.0001 |
| Flixborough | 0.0001 | 0.0106 | 0.0001 | 0.0001 | 0.0001 | 0.0001 |  |


| P-values - modern breeds/types and Coppergate |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Coppergate |
| Dorking |  | $\mathbf{0 . 0 0 2 9}$ | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 1 2 9}$ | 0.7283 | 0.1226 | $\mathbf{0 . 0 0 0 1}$ |
| Hamburgh | $\mathbf{0 . 0 0 2 9}$ |  | $\mathbf{0 . 0 0 1}$ | 0.5149 | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 3 6}$ | 0.1987 |
| X-B JF | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 0 1}$ |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 4 2}$ | $\mathbf{0 . 0 0 0 1}$ |
| OEG | $\mathbf{0 . 0 1 2 9}$ | 0.5149 | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 0 2 1}$ | $\mathbf{0 . 0 0 4}$ | $\mathbf{0 . 0 0 1 6}$ |
| Silkie | 0.7283 | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 2 1}$ |  | 0.1677 | $\mathbf{0 . 0 0 0 1}$ |
| Asian G | 0.1226 | $\mathbf{0 . 0 0 3 6}$ | $\mathbf{0 . 0 0 4 2}$ | $\mathbf{0 . 0 0 4}$ | 0.1677 |  | $\mathbf{0 . 0 0 0 1}$ |
| Coppergate | $\mathbf{0 . 0 0 0 1}$ | 0.1987 | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 6}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ |  |


| P-values - modern breeds/types and Lyminge |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Lyminge |
| Dorking |  | $\mathbf{0 . 0 0 7 4}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 4 8}$ | 0.8227 | 0.1314 | $\mathbf{0 . 0 0 0}$ |
| Hamburgh | $\mathbf{0 . 0 0 7 4}$ |  | $\mathbf{0 . 0 0 1 3}$ | 0.6806 | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 0 1 3}$ |
| X-B JF | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 1 3}$ |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 0 1}$ |
| OEG | $\mathbf{0 . 0 4 8}$ | 0.6806 | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 8 8}$ | $\mathbf{0 . 0 0 3 3}$ | $\mathbf{0 . 0 0 0 1}$ |
| Silkie | 0.8227 | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 8 8}$ |  | 0.1546 | $\mathbf{0 . 0 0 0 1}$ |
| Asian G | 0.1314 | $\mathbf{0 . 0 0 3 2}$ | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 3 3}$ | 0.1546 |  | $\mathbf{0 . 0 0 0 2}$ |
| Lyminge | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0}$ | $\mathbf{0 . 0 0 0 2}$ |  |


| P-values - modern breeds/types and Chester |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Chester |
| Dorking |  | $\mathbf{0 . 0 0 8 2}$ | $\mathbf{0 . 0 0 I I}$ | $\mathbf{0 . 0 4 8 2}$ | 0.6424 | 0.1 I76 | $\mathbf{0 . 0 0 0 2}$ |
| Hamburgh | $\mathbf{0 . 0 0 8 2}$ |  | $\mathbf{0 . 0 0 2 I}$ | 0.7553 | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 3 6}$ | $\mathbf{0 . 0 0 0 4}$ |
| X-B JF | $\mathbf{0 . 0 0 1 I}$ | $\mathbf{0 . 0 0 2 I}$ |  | $\mathbf{0 . 0 0 6}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 0 0 1}$ |
| OEG | $\mathbf{0 . 0 4 8 2}$ | 0.7553 | $\mathbf{0 . 0 0 6}$ |  | $\mathbf{0 . 0 2 8 8}$ | $\mathbf{0 . 0 1 3 5}$ | $\mathbf{0 . 0 0 0 6}$ |
| Silkie | 0.6424 | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 2 8 8}$ |  | 0.3861 | $\mathbf{0 . 0 0 0 1}$ |
| Asian G | 0.1176 | $\mathbf{0 . 0 0 3 6}$ | $\mathbf{0 . 0 0 4 4}$ | $\mathbf{0 . 0 1 3 5}$ | 0.3861 |  | $\mathbf{0 . 0 0 0 8}$ |
| Chester | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 8}$ |  |

### 5.2 Humeri

### 5.2.I Complete dataset variance percentages

| Percentages of variance - humeri |  |  |  |
| :--- | :--- | :--- | :--- |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00033213 | 51.957 | 51.957 |
| 2 | 0.00008355 | 13.071 | 65.028 |
| 3 | 0.00002939 | 4.598 | 69.626 |
| 4 | 0.0000263 | 4.114 | 73.74 |
| 5 | 0.00002097 | 3.281 | 77.021 |
| 6 | 0.00001753 | 2.743 | 79.764 |
| 7 | 0.00001567 | 2.451 | 82.214 |
| 8 | 0.00001408 | 2.203 | 84.418 |
| 9 | 0.00001116 | 1.745 | 86.163 |
| 10 | 0.00000992 | 1.553 | 87.716 |
| 11 | 0.00000937 | 1.465 | 89.181 |
| 12 | 0.00000763 | 1.193 | 90.374 |
| 13 | 0.0000074 | 1.157 | 91.532 |
| 14 | 0.00000637 | 0.997 | 92.529 |
| 15 | 0.00000576 | 0.901 | 93.43 |
| 16 | 0.00000532 | 0.833 | 94.262 |
| 17 | 0.00000427 | 0.668 | 94.931 |
| 18 | 0.00000396 | 0.619 | 95.55 |
|  |  |  |  |


| Percentages of variance - humeri |  |  |  |
| :--- | :--- | :--- | :--- |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 19 | 0.0000033 | $0.5 I 7$ | 96.066 |
| 20 | 0.00000314 | 0.491 | 96.557 |
| 21 | 0.00000278 | 0.435 | 96.993 |
| 22 | 0.00000238 | 0.373 | 97.366 |
| 23 | 0.00000216 | 0.338 | 97.704 |
| 24 | 0.00000196 | 0.306 | 98.01 |
| 25 | 0.00000172 | 0.269 | 98.279 |
| 26 | 0.0000015 | 0.235 | 98.514 |
| 27 | 0.00000138 | 0.216 | 98.73 |
| 28 | 0.00000126 | 0.197 | 98.928 |
| 29 | 0.0000012 | 0.188 | 99.116 |
| 30 | 0.00000113 | 0.177 | 99.293 |
| 31 | 0.00000082 | 0.128 | 99.42 I |
| 32 | 0.00000066 | 0.103 | 99.524 |
| 33 | 0.00000062 | 0.097 | 99.621 |
| 34 | 0.00000056 | 0.088 | 99.709 |
| 35 | 0.00000046 | 0.073 | 99.782 |
| 36 | 0.00000045 | 0.07 | 99.852 |
| 37 | 0.0000003 | 0.047 | 99.899 |
| 38 | 0.00000027 | 0.042 | 99.941 |
| 39 | 0.00000023 | 0.037 | 99.977 |
|  |  |  |  |


| Percentages of variance - humeri |  |  |  |
| :--- | :--- | :--- | :--- |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 40 | 0.00000014 | 0.023 | 100 |

### 5.2.2 Modern breeds/types percentages of variance - humeri

| Percentages of variance - breeds/types - humeri |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00016916 | 36.74 | 36.74 |
| 2 | 0.00008692 | 18.88 | 55.61 |
| 3 | 0.00003577 | 7.77 | 63.38 |
| 4 | 0.00002829 | 6.14 | 69.52 |
| 5 | 0.00002229 | 4.84 | 74.36 |
| 6 | 0.00001877 | 4.08 | 78.44 |
| 7 | 0.00001392 | 3.02 | 81.46 |
| 8 | 0.00001104 | 2.40 | 83.86 |
| 9 | 0.00001019 | 2.21 | 86.07 |
| 10 | 0.00000891 | 1.94 | 88.01 |
| 11 | 0.00000708 | 1.54 | 89.54 |
| 12 | 0.0000064 | 1.39 | 90.93 |
| 13 | 0.00000563 | 1.22 | 92.16 |
| 14 | 0.00000506 | 1.10 | 93.26 |
| 15 | 0.00000462 | 1.00 | 94.26 |

## Percentages of variance - breeds/types - humeri

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 16 | 0.00000386 | 0.84 | 95.10 |
| 17 | 0.00000326 | 0.71 | 95.81 |
| 18 | 0.00000305 | 0.66 | 96.47 |
| 19 | 0.00000279 | 0.61 | 97.07 |
| 20 | 0.0000023 | 0.50 | 97.57 |
| 21 | 0.00000201 | 0.44 | 98.01 |
| 22 | 0.00000153 | 0.33 | 98.34 |
| 23 | 0.00000124 | 0.27 | 98.61 |
| 24 | 0.00000113 | 0.25 | 98.86 |
| 25 | 0.0000009 | 0.20 | 99.05 |
| 26 | 0.00000086 | 0.19 | 99.24 |
| 27 | 0.00000074 | 0.16 | 99.40 |
| 28 | 0.00000058 | 0.13 | 99.53 |
| 29 | 0.00000049 | 0.11 | 99.63 |
| 30 | 0.00000043 | 0.09 | 99.73 |
| 31 | 0.00000035 | 0.08 | 99.80 |
| 32 | 0.00000022 | 0.05 | 99.85 |
| 33 | 0.00000021 | 0.05 | 99.90 |
| 34 | 0.00000017 | 0.04 | 99.93 |
| 35 | 0.00000011 | 0.02 | 99.96 |
| 36 | 0.00000007 | 0.02 | 99.97 |


| Percentages of variance - breeds/types - humeri |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 37 | 0.00000006 | 0.01 | 99.99 |
| 38 | 0.00000003 | 0.01 | 99.99 |
| 39 | 0.00000002 | 0.01 | 100.00 |
| 40 | 0.00000001 | 0.00 | 100.00 |

### 5.2.3 Humeri modern breed classifications

| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Silkie |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | Hamburgh |
| e013 | O E Game | O E Game | O E Game |
| e014 | Dorking | Dorking | Dorking |
| h003 | Silkie | Silkie | Silkie |
| k00I | Asian G | Asian G | O E Game |
| r65 I | Hamburgh | Hamburgh | O E Game |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66I | Silkie | Silkie | Silkie |


| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r662 | Asian G | Asian G | O E Game |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Silkie |
| r667 | O E Game | O E Game | O E Game |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | O E Game | O E Game |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74l | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | Hamburgh |
| t023 | Asian G | Asian G | Asian G |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Dorking |
| t04l | O E Game | O E Game | Hamburgh |
| t060 | Hamburgh | Hamburgh | Hamburgh |
| t065 | Dorking | Dorking | Dorking |
|  |  |  |  |


| Modern breeds/types - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | O E Game |
| t145 | X-B JF | Hamburgh | Hamburgh |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | O E Game | O E Game | O E Game |
| w5 I8 | O E Game | Dorking | Dorking |
| w5I9 | X-B JF | X-B JF | Hamburgh |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Dorking | O E Game |
| w6II | O E Game | O E Game | O E Game |
| w6I2 | O E Game | Hamburgh | Hamburgh |
| a003 | Dorking | Dorking | Asian G |
| h0II | Dorking | Dorking | Dorking |

### 5.2.4 Modern breeds/types loadings for BGPCA

| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoordl | I | 0.11909 | 0.39032 | 0.089013 | 0.074732 | 0.14865 |
| ProcCoord2 |  | 0.29864 | -0.2222 | -0.03841 | 0.12921 | -0.17279 |
| ProcCoord3 | 2 | -0.04502 | -0.15734 | 0.069741 | 0.097231 | -0.00058 |
| ProcCoord4 |  | -0.19241 | -7.63E-06 | 0.064536 | 0.17371 | -0.02933 |


| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoord5 | 3 | 0.13684 | -0.10342 | 0.049278 | -0.03734 | 0.056486 |
| ProcCoord6 |  | -0.08586 | -0.20926 | 0.23406 | 0.060009 | 0.053222 |
| ProcCoord7 | 4 | -0.06307 | -0.07227 | -0.12739 | 0.20017 | 0.31945 |
| ProcCoord8 |  | 0.013657 | -0.07476 | -0.33756 | 0.33999 | 0.12782 |
| ProcCoord9 | 5 | -0.09477 | -0.10284 | 0.20191 | -0.14317 | -0.00888 |
| ProcCoordIO |  | -0.16508 | 0.14216 | 0.12565 | -0.17526 | 0.008231 |
| ProcCoordII | 6 | -0.09567 | -0.09468 | -0.03037 | 0.043517 | 0.11363 |
| ProcCoordI2 |  | -0.24206 | 0.14089 | -0.14758 | 0.14411 | 0.11945 |
| ProcCoord13 | 7 | -0.14837 | -0.18652 | -0.05957 | -0.24246 | 0.081827 |
| ProcCoordl4 |  | -0.10682 | 0.19969 | 0.08392 | -0.13303 | -0.22573 |
| ProcCoord15 | 8 | -0.2723 | -0.07339 | -0.02719 | -0.05428 | -0.03439 |
| ProcCoordl6 |  | -0.04036 | 0.1129 | -0.01992 | 0.071059 | -0.20654 |
| ProcCoordI7 | 9 | -0.15437 | 0.059136 | -0.01158 | -0.17422 | -0.324I3 |
| ProcCoordI8 |  | -0.0838 | 0.18707 | -0.29652 | -0.12535 | 0.25798 |
| ProcCoord19 | 10 | 0.025413 | -0.01745 | -0.00276 | -0.15115 | -0.00275 |
| ProcCoord20 |  | 0.11795 | 0.31091 | -0.03985 | -0.09372 | -0.0855 |
| ProcCoord21 | 11 | 0.22908 | 0.034692 | 0.45081 | 0.1292 | 0.019872 |
| ProcCoord22 |  | -0.1247 | 0.16517 | -0.02629 | -0.0829 | 0.21658 |
| ProcCoord23 | 12 | 0.005688 | 0.013695 | 0.010493 | -0.17454 | 0.043278 |
| ProcCoord24 |  | -0.11783 | -0.00839 | 0.11056 | 0.093894 | 0.05754 |
| ProcCoord25 | 13 | 0.051557 | 0.070803 | -0.10134 | -0.12659 | 0.026091 |
| ProcCoord26 |  | -0.15122 | -0.04689 | 0.20216 | 0.005511 | 0.20553 |
| ProcCoord27 | 14 | 0.062776 | 0.027484 | -0.09346 | -0.09448 | -0.00751 |
| ProcCoord28 |  | -0.14216 | 0.036526 | 0.26749 | 0.055166 | 0.020526 |
| ProcCoord29 | 15 | 0.016534 | 0.055296 | 0.065689 | 0.022656 | 0.01056 |


| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoord30 |  | -0.12316 | -0.10672 | 0.14892 | 0.12131 | -0.15324 |
| ProcCoord31 | 16 | -0.03903 | -0.07719 | 0.05465 | 0.073007 | 0.016766 |
| ProcCoord32 |  | -0.05779 | -0.18019 | -0.04151 | 0.010014 | -0.16004 |
| ProcCoord33 | 17 | -0.02265 | -0.10192 | -0.01361 | 0.093933 | -0.04807 |
| ProcCoord34 |  | 0.002129 | -0.09401 | -0.14045 | -0.04338 | 0.087426 |
| ProcCoord35 | 18 | 0.009259 | -0.10871 | -0.249 | -0.00301 | -0.00677 |
| ProcCoord36 |  | 0.18775 | -0.11982 | -0.19777 | -0.07865 | -0.08792 |
| ProcCoord37 | 19 | 0.14332 | -0.12409 | -0.05559 | 0.24581 | 0.099387 |
| ProcCoord38 |  | 0.24063 | -0.12011 | -0.21751 | -0.1147 | -0.12092 |
| ProcCoord39 | 20 | 0.060542 | 0.074111 | -0.09028 | -0.28002 | -0.1232 |
| ProcCoord40 |  | 0.25408 | 0.16183 | 0.040029 | -0.22985 | 0.13471 |
| ProcCoord41 | 21 | 0.1773 | 0.25701 | 0.015902 | 0.15529 | 0.14176 |
| ProcCoord42 |  | 0.088833 | -0.31409 | 0.055703 | -0.23153 | -0.04542 |
| ProcCoord43 | 22 | -0.10216 | 0.23725 | -0.14535 | 0.34571 | -0.52148 |
| ProcCoord44 |  | 0.42957 | 0.039301 | 0.17033 | 0.1044 | -0.00158 |

### 5.2.5 Archaeological humeri percentages of variance

| Percentages of variance - archaeological humeri |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00003338 | 17.92 | 17.92 |
| 2 | 0.00002537 | 13.62 | 31.53 |
| 3 | 0.00002046 | 10.98 | 42.52 |
| 4 | 0.00001386 | 7.44 | 49.96 |


| Percentages of variance - archaeological humeri |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 5 | 0.00001123 | 6.03 | 55.99 |
| 6 | 0.0000107 | 5.74 | 61.73 |
| 7 | 0.00000928 | 4.98 | 66.71 |
| 8 | 0.00000767 | 4.12 | 70.83 |
| 9 | 0.0000059 | 3.16 | 73.99 |
| 10 | 0.00000547 | 2.94 | 76.93 |
| 11 | 0.00000476 | 2.56 | 79.48 |
| 12 | 0.00000463 | 2.49 | 81.97 |
| 13 | 0.00000424 | 2.28 | 84.25 |
| 14 | 0.00000367 | 1.97 | 86.22 |
| 15 | 0.00000327 | 1.75 | 87.97 |
| 16 | 0.00000276 | 1.48 | 89.45 |
| 17 | 0.00000245 | 1.32 | 90.77 |
| 18 | 0.00000229 | 1.23 | 91.99 |
| 19 | 0.00000191 | 1.03 | 93.02 |
| 20 | 0.00000185 | 1.00 | 94.02 |
| 21 | 0.00000164 | 0.88 | 94.90 |
| 22 | 0.00000142 | 0.76 | 95.66 |
| 23 | 0.0000013 | 0.70 | 96.36 |
| 24 | 0.0000011 | 0.59 | 96.95 |
| 25 | 0.00000084 | 0.45 | 97.40 |
|  |  |  |  |


| Percentages of variance - archaeological humeri |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 26 | 0.00000073 | 0.39 | 97.79 |
| 27 | 0.00000061 | 0.33 | 98.12 |
| 28 | 0.00000059 | 0.32 | 98.44 |
| 29 | 0.00000052 | 0.28 | 98.72 |
| 30 | 0.00000046 | 0.25 | 98.96 |
| 31 | 0.00000039 | 0.21 | 99.17 |
| 32 | 0.00000037 | 0.20 | 99.37 |
| 33 | 0.0000003 | 0.16 | 99.54 |
| 34 | 0.00000022 | 0.12 | 99.65 |
| 35 | 0.0000002 | 0.11 | 99.76 |
| 36 | 0.00000017 | 0.09 | 99.85 |
| 37 | 0.00000014 | 0.07 | 99.92 |
| 38 | 0.00000007 | 0.04 | 99.96 |
| 39 | 0.00000005 | 0.03 | 99.99 |
| 40 | 0.00000003 | 0.02 | 100.00 |

### 5.2.6 Archaeological humeri DFA classifications

| Archaeological humeri - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| u003 | Uley | Uley | Uley |
| u010 | Uley | Chester | Chester |
| u034 | Uley | Lyminge | Lyminge |
| u035 | Uley | Uley | Uley |
| u055 | Uley | Lyminge | Lyminge |
| u07I | Uley | Uley | Lyminge |
| u072 | Uley | Uley | Uley |
| u077 | Uley | Uley | Uley |
| u08I | Uley | Uley | Uley |
| u097 | Uley | Uley | Chester |
| ul09 | Uley | Uley | Uley |
| ul24 | Uley | Uley | Uley |
| ul28 | Uley | Uley | Uley |
| ul29 | Uley | Uley | Uley |
| ul48 | Uley | Uley | Uley |
| ul49 | Uley | Uley | Uley |
| ul55 | Uley | Uley | Uley |
| ul58 | Uley | Uley | Chester |
| ul67 | Uley | Uley | Uley |


| Archaeological humeri - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1031 | Lyminge | Lyminge | Lyminge |
| 1043 | Lyminge | Lyminge | Lyminge |
| 1045 | Lyminge | Uley | Uley |
| 1100 | Lyminge | Lyminge | Lyminge |
| 1168 | Lyminge | Lyminge | Lyminge |
| 1199 | Lyminge | Lyminge | Lyminge |
| 1230 | Lyminge | Lyminge | Lyminge |
| 1276 | Lyminge | Chester | Chester |
| 1307 | Lyminge | Uley | Uley |
| 1366 | Lyminge | Lyminge | Lyminge |
| 1441 | Lyminge | Lyminge | Lyminge |
| 1646 | Lyminge | Chester | Chester |
| 1647 | Lyminge | Lyminge | Lyminge |
| 1700 | Lyminge | Lyminge | Uley |
| 1701 | Lyminge | Lyminge | Lyminge |
| 1712 | Lyminge | Chester | Chester |
| 1713 | Lyminge | Lyminge | Uley |
| 1714 | Lyminge | Lyminge | Lyminge |
| 1786 | Lyminge | Uley | Uley |
| 1802 | Lyminge | Uley | Uley |
| 1814 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Archaeological humeri - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1886 | Lyminge | Uley | Uley |
| 1902 | Lyminge | Lyminge | Chester |
| 1229 | Lyminge | Uley | Uley |
| 1237 | Lyminge | Lyminge | Lyminge |
| 1243 | Lyminge | Lyminge | Lyminge |
| 1250 | Lyminge | Lyminge | Lyminge |
| 1257 | Lyminge | Lyminge | Lyminge |
| 1262 | Lyminge | Lyminge | Lyminge |
| 1264 | Lyminge | Lyminge | Lyminge |
| c01I | Chester | Chester | Uley |
| c042 | Chester | Chester | Uley |
| c043 | Chester | Chester | Chester |
| c044 | Chester | Lyminge | Lyminge |
| c045 | Chester | Chester | Chester |
| c046 | Chester | Lyminge | Lyminge |
| c095 | Chester | Chester | Lyminge |
| cl23 | Chester | Chester | Chester |
| c133 | Chester | Chester | Chester |
| c2I2 | Chester | Chester | Chester |
| c213 | Chester | Chester | Chester |
| c2I4 | Chester | Chester | Lyminge |
|  |  |  |  |

### 5.2.7 One-way Permanova tests for BGPCAs

| P-values - modern breeds/types |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Dorking |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 1 1 5}$ | $\mathbf{0 . 0 3 1 7}$ | $\mathbf{0 . 0 0 0 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 2}$ |  | 0.865 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 3}$ |
| X-B JF | $\mathbf{0 . 0 0 0 4}$ | 0.865 |  | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 2 5}$ |
| O E Game | $\mathbf{0 . 0 1 1 5}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1 8}$ |  | 0.1944 | $\mathbf{0 . 0 0 0 7}$ |
| Silkie | $\mathbf{0 . 0 3 1 7}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 2}$ | 0.1944 |  | $\mathbf{0 . 0 0 0 5}$ |
| Asian G | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 2 5}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 5}$ |  |


| P-values - modern breeds/types and Uley |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Uley | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Uley |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 2 8}$ | $\mathbf{0 . 0 3 4 8}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ |
| Dorking | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 1 3 6}$ | $\mathbf{0 . 0 3 1 2}$ | $\mathbf{0 . 0 0 0 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ |  | 0.8665 | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 4}$ |
| X-B JF | $\mathbf{0 . 0 0 2 8}$ | $\mathbf{0 . 0 0 0 4}$ | 0.8665 |  | $\mathbf{0 . 0 0 1 9}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 3 0}$ |
| O E Game | $\mathbf{0 . 0 3 4 8}$ | $\mathbf{0 . 0 1 3 6}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 9}$ |  | 0.2097 | $\mathbf{0 . 0 0 0 3}$ |
| Silkie | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 3 1 2}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 2}$ | 0.2097 |  | $\mathbf{0 . 0 0 0 6}$ |
| Asian G | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 3}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 6}$ |  |


| P-values - modern breeds/types and Lyminge |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Lyminge | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Lyminge |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 7 4}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 1}$ |
| Dorking | $\mathbf{0 . 0 0 0}$ |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 4 I}$ | $\mathbf{0 . 0 3 5 8}$ | $\mathbf{0 . 0 0 0 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 2}$ |  | 0.9792 | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 4}$ |
| X-B JF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | 0.9792 |  | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 0 1 8}$ |
| O E Game | $\mathbf{0 . 0 0 7 4}$ | $\mathbf{0 . 0 1 4 1}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 1 4}$ |  | 0.2773 | $\mathbf{0 . 0 0 0 3}$ |
| Silkie | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 3 5 8}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 1 4}$ | 0.2773 |  | $\mathbf{0 . 0 0 0 6}$ |
| Asian G | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 6}$ |  |


| P-values - modern breeds/types and Chester |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Chester | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Chester |  | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | 0.8098 | 0.1358 | $\mathbf{0 . 0 0 0 2}$ |
| Dorking | $\mathbf{0 . 0 0 0 8}$ |  | $\mathbf{0 . 0 0 0}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 1 4}$ | $\mathbf{0 . 0 3 4 6}$ | $\mathbf{0 . 0 0 0 1}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ |  | 0.9409 | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 7}$ |
| X-B JF | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 7}$ | 0.9409 |  | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 1 6}$ | $\mathbf{0 . 0 0 2 6}$ |
| O E Game | 0.8098 | $\mathbf{0 . 0 1 4}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 1 5}$ |  | 0.2543 | $\mathbf{0 . 0 0 0 2}$ |
| Silkie | 0.1358 | $\mathbf{0 . 0 3 4 6}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1 6}$ | 0.2543 |  | $\mathbf{0 . 0 0 0 9}$ |
| Asian G | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 2 6}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 9}$ |  |

### 5.3 Tibiotarsi

### 5.3.I Complete dataset variance percentages

| Principal <br> Component | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 1 | 0.00037793 | 50.41 | 50.4 I |
| 2 | 0.00020072 | 26.78 | 77.19 |
| 3 | 0.00004139 | 5.52 | 82.71 |
| 4 | 0.00002817 | 3.76 | 86.47 |
| 5 | 0.00002368 | 3.16 | 89.63 |
| 6 | 0.00001669 | 2.23 | 91.85 |
| 7 | 0.00001304 | 1.74 | 93.59 |
| 8 | 0.00001026 | 1.37 | 94.96 |
| 9 | 0.00000918 | 1.23 | 96.19 |
| 10 | 0.00000754 | 1.01 | 97.19 |
| 11 | 0.00000642 | 0.86 | 98.05 |
| 12 | 0.00000446 | 0.60 | 98.65 |
| 13 | 0.00000319 | 0.43 | 99.07 |
| 14 | 0.00000256 | 0.34 | 99.41 |
| 15 | 0.00000142 | 0.19 | 99.60 |
| 16 | 0.00000125 | 0.17 | 99.77 |
| 17 | 0.00000105 | 0.14 | 99.91 |
| 18 | 0.00000068 | 0.09 | 100.00 |

### 5.3.2 Modern breeds/types percentages of variance - tibiotarsi

| Principal Component | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00015555 | 39.02 | 39.02 |
| 2 | 0.00008713 | 21.85 | 60.87 |
| 3 | 0.00005077 | 12.74 | 73.61 |
| 4 | 0.00002649 | 6.64 | 80.25 |
| 5 | 0.00001732 | 4.35 | 84.60 |
| 6 | 0.00001705 | 4.28 | 88.87 |
| 7 | 0.00001232 | 3.09 | 91.96 |
| 8 | 0.00000943 | 2.37 | 94.33 |
| 9 | 0.0000056 | 1.40 | 95.73 |
| 10 | 0.00000463 | 1.16 | 96.89 |
| 11 | 0.00000393 | 0.99 | 97.88 |
| 12 | 0.00000269 | 0.68 | 98.56 |
| 13 | 0.00000182 | 0.46 | 99.01 |
| 14 | 0.00000123 | 0.31 | 99.32 |
| 15 | 0.00000109 | 0.27 | 99.59 |
| 16 | 0.00000067 | 0.17 | 99.76 |
| 17 | 0.00000059 | 0.15 | 99.91 |
| 18 | 0.00000036 | 0.09 | 100.00 |

### 5.3.3 DFA Classifications - tibiotarsi, modern breeds/types

| Classifications tibiotarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | Dorking |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | O E Game | O E Game | O E Game |
| e014 | Dorking | Asian G | Asian G |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Dorking | Dorking |
| k00I | Asian G | O E Game | O E Game |
| n00I | O E Game | O E Game | Dorking |
| r65I | Hamburgh | Silkie | Silkie |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66I | Silkie | Silkie | Silkie |
| r662 | Asian G | Silkie | Silkie |
| r663 | O E Game | Asian G | Asian G |
| r666 | Silkie | Silkie | Asian G |
|  |  |  |  |


| Classifications tibiotarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r667 | O E Game | O E Game | O E Game |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | O E Game | O E Game |
| r735 | O E Game | Hamburgh | Hamburgh |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t023 | Asian G | Asian G | Asian G |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Dorking |
| t034 | Silkie | Silkie | Silkie |
| t04 | O E Game | O E Game | O E Game |
| t059 | X-B JF | X-B JF | X-B JF |
| t060 | Hamburgh | Hamburgh | Hamburgh |
| t065 | Dorking | Asian G | Asian G |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t145 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | Hamburgh | Hamburgh |
|  |  |  |  |


| Classifications tibiotarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w5 I8 | O E Game | O E Game | O E Game |
| w5 I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Asian G |
| w537 | Dorking | Dorking | Dorking |
| w6 I I | O E Game | O E Game | O E Game |
| w6 12 | O E Game | O E Game | O E Game |

### 5.3.4 Loadings for BGPCA - tibiotarsi modern groups

| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoord | I | -0.02542 | -0.07961 | 0.44988 | -0.30891 | -0.33426 |
| ProcCoord2 |  | 0.28907 | -0.05312 | -0.32249 | 0.11594 | -0.4646 |
| ProcCoord3 | 2 | 0.3283 | 0.17234 | -0.28202 | -0.09252 | 0.33098 |
| ProcCoord4 |  | 0.13532 | 0.002128 | 0.31805 | -0.19134 | 0.41539 |
| ProcCoord5 | 3 | -0.09967 | 0.38527 | 0.050833 | 0.33807 | 0.034675 |
| ProcCoord6 |  | -0.31672 | -0.0265 | 0.16928 | 0.096177 | 0.16414 |
| ProcCoord7 | 4 | -0.56812 | -0.5688I | -0.28264 | 0.068341 | 0.035174 |
| ProcCoord8 |  | -0.15965 | 0.05222 | -0.18131 | -0.2359 | -0.25044 |
| ProcCoord9 | 5 | 0.028535 | -0.08521 | 0.42911 | 0.42707 | -0.1187 |
| ProcCoordI0 |  | -0.18653 | 0.28028 | 0.16937 | 0.19098 | -0.09288 |
| ProcCoordII | 6 | -0.09253 | 0.19624 | -0.15594 | -0.00831 | 0.020384 |


| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoordI2 |  | -0.12147 | 0.17227 | -0.02731 | -0.12516 | 0.049659 |
| ProcCoordI3 | 7 | -0.05088 | 0.10761 | -0.16867 | -0.18052 | 0.12498 |
| ProcCoordI4 |  | -0.02087 | -0.13174 | -0.03404 | -0.09009 | -0.0132 |
| ProcCoordl5 | 8 | -0.09379 | 0.15018 | -0.00608 | 0.072449 | 0.13446 |
| ProcCoordl6 |  | 0.12498 | -0.28286 | 0.12771 | -0.07074 | 0.18966 |
| ProcCoordI7 | 9 | 0.053746 | 0.054591 | 0.10512 | -0.45078 | -0.29406 |
| ProcCoordI8 |  | 0.25103 | -0.29517 | 0.012373 | 0.16723 | 0.15421 |
| ProcCoord19 | 10 | 0.12218 | -0.08892 | -0.11839 | -0.13343 | 0.23164 |
| ProcCoord20 |  | 0.056639 | 0.10305 | 0.011831 | -0.07898 | -0.07393 |
| ProcCoord2I | 11 | 0.39764 | -0.2437 | -0.02119 | 0.26854 | -0.16527 |
| ProcCoord22 |  | -0.0518 | 0.17944 | -0.24346 | 0.22188 | -0.07802 |

### 5.3.5 Archaeological tibiotarsi - percentages of variance

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| I | 0.00010128 | 45.44 | 45.44 |
| 2 | 0.00004536 | 20.35 | 65.79 |
| 3 | 0.00001901 | 8.53 | 74.32 |
| 4 | 0.00001412 | 6.34 | 80.66 |
| 5 | 0.00001071 | 4.81 | 85.46 |
| 6 | 0.00000923 | 4.14 | 89.60 |
| 7 | 0.00000573 | 2.57 | 92.17 |


| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 8 | 0.0000048 | 2.15 | 94.33 |
| 9 | 0.00000371 | 1.66 | 95.99 |
| 10 | 0.00000224 | 1.01 | 96.99 |
| 11 | 0.0000021 | 0.94 | 97.93 |
| 12 | 0.00000168 | 0.75 | 98.69 |
| 13 | 0.00000102 | 0.46 | 99.15 |
| 14 | 0.00000087 | 0.39 | 99.53 |
| 15 | 0.0000006 | 0.27 | 99.80 |
| 16 | 0.00000022 | 0.10 | 99.90 |
| 17 | 0.00000017 | 0.08 | 99.98 |
| 18 | 0.00000004 | 0.02 | 100.00 |

### 5.3.6 Archaeological tibiotarsi - DFA classifications

| Archaeological tibiotarsi - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1050 | Lyminge | Lyminge | Lyminge |
| 1052 | Lyminge | Chester | Chester |
| 1142 | Lyminge | Lyminge | Chester |
| 1219 | Lyminge | Lyminge | Lyminge |
| 1221 | Lyminge | Lyminge | Lyminge |
| 1454 | Lyminge | Chester | Chester |


| Archaeological tibiotarsi - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1790 | Lyminge | Chester | Chester |
| 1795 | Lyminge | Lyminge | Chester |
| 1889 | Lyminge | Lyminge | Lyminge |
| 1920 | Lyminge | Lyminge | Chester |
| 1921 | Lyminge | Lyminge | Lyminge |
| 1922 | Lyminge | Chester | Chester |
| 1923 | Lyminge | Lyminge | Lyminge |
| 1924 | Lyminge | Lyminge | Lyminge |
| 1925 | Lyminge | Lyminge | Lyminge |
| c024 | Chester | Chester | Chester |
| c026 | Chester | Lyminge | Lyminge |
| c028 | Chester | Chester | Lyminge |
| cl00 | Chester | Chester | Chester |
| cl08 | Chester | Chester | Chester |
| cl32 | Chester | Lyminge | Lyminge |
| cl46 | Chester | Lyminge | Lyminge |
| cl50 | Chester | Lyminge | Lyminge |
| cl70 | Chester | Lyminge | Lyminge |
| cl75 | Chester | Chester | Chester |
| cl76 | Chester | Chester | Chester |
| cl77 | Chester | Lyminge | Lyminge |
|  |  |  |  |

### 5.3.7 One-way Permanova tests for BGPCAs

| P-values - modern breeds/types |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Dorking |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 5 2}$ | $\mathbf{0 . 0 0 7 2}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 8 9}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 1 8}$ |
| X-B JF | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 9}$ |
| O E Game | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 8 9}$ | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 4 3}$ |
| Silkie | $\mathbf{0 . 0 0 5 2}$ | $\mathbf{0 . 0 0 1 2}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 5}$ |  | 0.4177 |
| Asian G | $\mathbf{0 . 0 0 7 2}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 4 3}$ | 0.4177 |  |


| P-values - modern breeds/types and Lyminge |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Lyminge | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Lyminge |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 1 9 7}$ | $\mathbf{0 . 0 2 1 8}$ | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 2 7 3}$ |
| Dorking | $\mathbf{0 . 0 0 0}$ |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 0 9 2}$ | $\mathbf{0 . 0 0 8 6}$ |
| Hamburgh | $\mathbf{0 . 0 1 9 7}$ | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 1 5 2}$ | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 2}$ I |
| X-B JF | $\mathbf{0 . 0 2 1 8}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 3}$ |
| O E Game | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 0 0 9}$ | $\mathbf{0 . 0 1 5 2}$ | $\mathbf{0 . 0 0 0 3}$ |  | $\mathbf{0 . 0 0 2 2}$ | $\mathbf{0 . 0 0 3 3}$ |
| Silkie | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 0 9 2}$ | $\mathbf{0 . 0 0 1 5}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 2 2}$ |  | 0.4498 |
| Asian G | $\mathbf{0 . 0 2 7 3}$ | $\mathbf{0 . 0 0 8 6}$ | $\mathbf{0 . 0 0 2 I}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 3 3}$ | 0.4498 |  |


| P-values - modern breeds/types and Chester |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Chester | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Chester |  | $\mathbf{0 . 0 0 0 1}$ | 0.0782 | $\mathbf{0 . 0 1 0 1}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 5 7}$ |
| Dorking | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 5 7}$ | $\mathbf{0 . 0 0 5 5}$ |
| Hamburgh | 0.0782 | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 1 8 7}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 2 3}$ |
| X-B JF | $\mathbf{0 . 0 1 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 8}$ |  | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0}$ | $\mathbf{0 . 0 0 I}$ |
| O E Game | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 1 8 7}$ | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 2}$ |
| Silkie | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 5 7}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 0 6}$ |  | 0.3726 |
| Asian G | $\mathbf{0 . 0 0 5 7}$ | $\mathbf{0 . 0 0 5 5}$ | $\mathbf{0 . 0 0 2 3}$ | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 2 I}$ | 0.3726 |  |

### 5.4 Tarsometatarsi

5.4.I Complete dataset variance percentages

| Percentages of variance - modern tarsometatarsi |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00057823 | 70.50 | 70.50 |
| 2 | 0.00004229 | 5.16 | 75.66 |
| 3 | 0.00003238 | 3.95 | 79.61 |
| 4 | 0.00002908 | 3.55 | 83.15 |
| 5 | 0.0000248 | 3.02 | 86.18 |
| 6 | 0.00001616 | 1.97 | 88.15 |
| 7 | 0.00001231 | 1.50 | 89.65 |


| Percentages of variance - modern tarsometatarsi |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 8 | 0.00001146 | 1.40 | 91.04 |
| 9 | 0.0000105 I | 1.28 | 92.33 |
| 10 | 0.00000888 | 1.08 | 93.4 I |
| 11 | 0.00000735 | 0.90 | 94.31 |
| 12 | 0.00000647 | 0.79 | 95.09 |
| 13 | 0.0000056 | 0.68 | 95.78 |
| 14 | 0.0000044 | 0.54 | 96.31 |
| 15 | 0.00000426 | 0.52 | 96.83 |
| 16 | 0.00000373 | 0.46 | 97.29 |
| 17 | 0.00000358 | 0.44 | 97.72 |
| 18 | 0.00000278 | 0.34 | 98.06 |
| 19 | 0.00000239 | 0.29 | 98.35 |
| 20 | 0.00000214 | 0.26 | 98.61 |
| 21 | 0.00000202 | 0.25 | 98.86 |
| 22 | 0.00000181 | 0.22 | 99.08 |
| 23 | 0.00000156 | 0.19 | 99.27 |
| 24 | 0.00000136 | 0.17 | 99.44 |
| 25 | 0.0000011 | 0.13 | 99.57 |
| 26 | 0.00000099 | 0.12 | 99.69 |
| 27 | 0.00000082 | 0.10 | 99.79 |
| 28 | 0.00000057 | 0.07 | 99.86 |
|  |  |  |  |


| Percentages of variance - modern tarsometatarsi |  |  |  |
| :---: | :---: | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| 29 | 0.00000043 | 0.05 | 99.91 |
| 30 | 0.0000003 | 0.04 | 99.95 |
| 31 | 0.00000028 | 0.03 | 99.98 |
| 32 | 0.00000014 | 0.02 | 100.00 |

5.4.2 Modern breeds/types percentages of variance - tarsometatarsi

| PCs | Eigenvalues | \% Variance | Cumulative \% |
| :--- | :--- | :--- | :--- |
| I | 0.00018863 | 46.24 | 46.24 |
| 2 | 0.00004928 | 12.08 | 58.32 |
| 3 | 0.00003179 | 7.79 | 66.12 |
| 4 | 0.00002575 | 6.31 | 72.43 |
| 5 | 0.00001962 | 4.81 | 77.24 |
| 6 | 0.00001772 | 4.34 | 81.58 |
| 7 | 0.00001195 | 2.93 | 84.51 |
| 8 | 0.00001033 | 2.53 | 87.04 |
| 9 | 0.00000749 | 1.84 | 88.88 |
| 10 | 0.00000715 | 1.75 | 90.63 |
| 11 | 0.00000603 | 1.48 | 92.11 |
| 12 | 0.00000515 | 1.26 | 93.37 |
| 13 | 0.0000039 | 0.96 | 94.33 |


| PCs | Eigenvalues | \% Variance | Cumulative \% |
| :--- | :--- | :--- | :--- |
| 14 | 0.00000334 | 0.82 | 95.15 |
| 15 | 0.00000317 | 0.78 | 95.92 |
| 16 | 0.00000291 | 0.71 | 96.64 |
| 17 | 0.0000025 | 0.61 | 97.25 |
| 18 | 0.00000214 | 0.53 | 97.78 |
| 19 | 0.00000198 | 0.49 | 98.26 |
| 20 | 0.00000129 | 0.32 | 98.58 |
| 21 | 0.0000012 | 0.30 | 98.87 |
| 22 | 0.00000092 | 0.23 | 99.10 |
| 23 | 0.00000088 | 0.22 | 99.31 |
| 24 | 0.00000063 | 0.16 | 99.47 |
| 25 | 0.00000051 | 0.12 | 99.59 |
| 26 | 0.00000047 | 0.12 | 99.71 |
| 27 | 0.00000041 | 0.10 | 99.81 |
| 28 | 0.00000037 | 0.09 | 99.90 |
| 29 | 0.00000015 | 0.04 | 99.94 |
| 30 | 0.00000013 | 0.03 | 99.97 |
| 31 | 0.00000009 | 0.02 | 99.99 |
| 32 | 0.00000004 | 0.01 | 100.00 |
|  |  |  |  |

### 5.4.3 DFA Classifications modern breeds tarsometatarsi

| Classifications tarsometatarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| a003 | Dorking | Dorking | O E Game |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | O E Game | O E Game |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | O E Game | O E Game | Hamburgh |
| e0I4 | Dorking | Dorking | Hamburgh |
| h003 | Silkie | Silkie | Silkie |
| h0II | Dorking | Dorking | Dorking |
| k00I | Asian G | Asian G | Asian G |
| n00I | O E Game | O E Game | O E Game |
| r65 I | Hamburgh | Hamburgh | Dorking |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66 I | Silkie | Silkie | Silkie |
| r662 | Asian G | Dorking | Dorking |
| r663 | O E Game | O E Game | O E Game |
| r666 | Silkie | Silkie | Silkie |
| r667 | O E Game | O E Game | O E Game |


| Classifications tarsometatarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r723 | Dorking | Asian G | Asian G |
| r724 | Dorking | Dorking | Dorking |
| r732 | O E Game | O E Game | O E Game |
| r735 | O E Game | O E Game | O E Game |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74 I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | O E Game |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | X-B JF |
| t023 | Asian G | Asian G | Asian G |
| t024 | Asian G | Asian G | Asian G |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | X-B JF |
| t065 | Dorking | Dorking | Silkie |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| tl45 | X-B JF | X-B JF | O E Game |
| t146 | X-B JF | X-B JF | X-B JF |
| w5I8 | O E Game | Dorking | Dorking |
|  |  |  |  |


| Classifications tarsometatarsi DFA mod breeds |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w5 I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w6II | O E Game | Hamburgh | Hamburgh |
| w612 | O E Game | O E Game | O E Game |

5.4.4 Modern breeds/types loadings for BGPCA

| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoordl | 1 | 0.035578 | -0.13901 | -0.10863 | -0.14485 | -0.2585 |
| ProcCoord2 |  | 0.4073 | -0.02648 | 0.18942 | -0.04784 | -0.22408 |
| ProcCoord3 | 2 | 0.1845 | 0.20115 | -0.25654 | 0.03175 | -0.3216 |
| ProcCoord4 |  | 0.34012 | -0.21308 | 0.00626 | -0.00131 | 0.32286 |
| ProcCoord5 | 3 | 0.051049 | 0.21045 | 0.020279 | -0.149 | 0.11318 |
| ProcCoord6 |  | -0.11263 | -0.1223 | 0.039534 | 0.16297 | 0.21148 |
| ProcCoord7 | 4 | -0.02663 | 0.24568 | 0.16303 | 0.050794 | 0.23577 |
| ProcCoord8 |  | -0.31929 | 0.13269 | 0.076343 | 0.086824 | -0.27154 |
| ProcCoord9 | 5 | -0.23493 | 0.010564 | -0.34591 | -0.006 | 0.36743 |
| ProcCoordI0 |  | -0.31823 | 0.035731 | -0.24659 | 0.10845 | -0.31513 |
| ProcCoordII | 6 | -0.16321 | -0.44129 | 0.34917 | -0.11578 | -0.04378 |
| ProcCoordI2 |  | -0.03009 | 0.030714 | -0.12918 | -0.02765 | -0.0718 |
| ProcCoordl3 | 7 | -0.1324I | -0.2622I | 0.20654 | 0.08694 | -0.12197 |


| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoordI4 |  | 0.093745 | 0.016747 | 0.070279 | -0.02582 | 0.22429 |
| ProcCoordI5 | 8 | -0.03927 | 0.13369 | 0.071948 | 0.20707 | -0.0486 |
| ProcCoordl6 |  | -0.25461 | -0.06063 | -0.2849 | -0.05518 | 0.066043 |
| ProcCoordI7 | 9 | 0.13743 | 0.14348 | -0.24735 | -0.32294 | 0.075741 |
| ProcCoordI8 |  | -0.16528 | -0.09075 | 0.058057 | -0.4 | -0.17662 |
| ProcCoordI9 | 10 | 0.005452 | 0.17087 | -0.02977 | -0.18179 | -0.04548 |
| ProcCoord20 |  | -0.12467 | -0.02748 | 0.18145 | -0.2243 | 0.059563 |
| ProcCoord2I | 11 | 0.069224 | 0.081887 | 0.007444 | -0.22098 | 0.025889 |
| ProcCoord22 |  | -0.03252 | -0.01584 | -0.00554 | -0.09735 | 0.097126 |
| ProcCoord23 | 12 | -0.10855 | 0.055222 | 0.12864 | 0.056716 | 0.064977 |
| ProcCoord24 |  | -0.05554 | 0.040196 | 0.068435 | 0.15638 | 0.008413 |
| ProcCoord25 | 13 | -0.09086 | 0.062633 | 0.11749 | -0.02298 | -0.00168 |
| ProcCoord26 |  | -0.01719 | 0.00959 | -0.06917 | 0.12231 | 0.036752 |
| ProcCoord27 | 14 | -0.12994 | 0.083847 | 0.13184 | 0.006666 | 0.09849 |
| ProcCoord28 |  | 0.083965 | -0.05708 | -0.20666 | 0.17455 | 0.034694 |
| ProcCoord29 | 15 | 0.059697 | -0.13068 | 0.081695 | 0.25155 | 0.098648 |
| ProcCoord30 |  | 0.10851 | -0.04243 | 0.036476 | 0.10539 | -0.08038 |
| ProcCoord3I | 16 | 0.18895 | -0.09718 | 0.009979 | 0.39007 | -0.22155 |
| ProcCoord32 |  | 0.18669 | 0.19191 | -0.08903 | 0.17426 | 0.042868 |
| ProcCoord33 | 17 | 0.21796 | -0.46272 | -0.32974 | -0.12677 | -0.05739 |
| ProcCoord34 |  | 0.01123 | -0.08479 | 0.032815 | -0.01148 | 0.14672 |
| ProcCoord35 | 18 | -0.02404 | 0.13362 | 0.029885 | 0.20954 | 0.040411 |


| Coordinates | Landmark | PC I | PC 2 | PC 3 | PC 4 | PC 5 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| ProcCoord36 |  | 0.1985 | $\mathbf{0 . 2 8 3 2 8}$ | 0.27201 | -0.2002 | -0.11127 |

### 5.4.5 Archaeological tarsometatarsi - percentages of variance

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 1 | 0.00003928 | 22.78 | 22.78 |
| 2 | 0.00002501 | 14.51 | 37.29 |
| 3 | 0.00001852 | 10.74 | 48.04 |
| 4 | 0.00001564 | 9.07 | 57.11 |
| 5 | 0.00001118 | 6.48 | 63.59 |
| 6 | 0.00000974 | 5.65 | 69.24 |
| 7 | 0.00000768 | 4.46 | 73.70 |
| 8 | 0.00000607 | 3.52 | 77.21 |
| 9 | 0.00000565 | 3.28 | 80.49 |
| 10 | 0.00000514 | 2.98 | 83.47 |
| 11 | 0.00000383 | 2.22 | 85.69 |
| 12 | 0.00000312 | 1.81 | 87.50 |
| 13 | 0.00000288 | 1.67 | 89.17 |
| 14 | 0.00000274 | 1.59 | 90.76 |
| 15 | 0.0000025 | 1.45 | 92.21 |
| 16 | 0.00000213 | 1.24 | 93.45 |
| 17 | 0.00000189 | 1.10 | 94.55 |


| PC | Eigenvalues | \% Variance | Cumulative \% |
| :---: | :---: | :---: | :---: |
| 18 | 0.00000175 | 1.02 | 95.56 |
| 19 | 0.00000131 | 0.76 | 96.32 |
| 20 | 0.00000128 | 0.74 | 97.06 |
| 21 | 0.00000093 | 0.54 | 97.60 |
| 22 | 0.00000083 | 0.48 | 98.08 |
| 23 | 0.00000067 | 0.39 | 98.47 |
| 24 | 0.00000061 | 0.35 | 98.82 |
| 25 | 0.00000047 | 0.27 | 99.10 |
| 26 | 0.00000043 | 0.25 | 99.34 |
| 27 | 0.00000036 | 0.21 | 99.55 |
| 28 | 0.00000034 | 0.20 | 99.75 |
| 29 | 0.00000017 | 0.10 | 99.85 |
| 30 | 0.00000012 | 0.07 | 99.92 |
| 31 | 0.00000008 | 0.05 | 99.97 |
| 32 | 0.00000006 | 0.03 | 100.00 |

5.4.6 Archaeological tarsometatarsi - DFA classifications

| Archaeological tarsometatarsi - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L087 | Lyminge | Lyminge | Chester |
| L088 | Lyminge | Chester | Chester |
| LII2 | Lyminge | Chester | Chester |
| LI33 | Lyminge | Lyminge | Lyminge |
| LI45 | Lyminge | Lyminge | Lyminge |
| LI57 | Lyminge | Lyminge | Lyminge |
| LI64 | Lyminge | Lyminge | Lyminge |
| LI79 | Lyminge | Lyminge | Lyminge |
| LI80 | Lyminge | Chester | Chester |
| LI87 | Lyminge | Chester | Chester |
| L206 | Lyminge | Lyminge | Lyminge |
| L208 | Lyminge | Lyminge | Lyminge |
| L209 | Lyminge | Uley | Uley |
| L2I0 | Lyminge | Chester | Chester |
| L234 | Lyminge | Lyminge | Lyminge |
| L246 | Lyminge | Lyminge | Lyminge |
| L253 | Lyminge | Chester | Chester |
| L328 | Lyminge | Lyminge | Lyminge |
| L330 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Archaeological tarsometatarsi - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L332 | Lyminge | Chester | Chester |
| L334 | Lyminge | Lyminge | Lyminge |
| L337 | Lyminge | Lyminge | Lyminge |
| L473 | Lyminge | Lyminge | Lyminge |
| L5I I | Lyminge | Lyminge | Lyminge |
| L52 I | Lyminge | Chester | Chester |
| L526 | Lyminge | Chester | Chester |
| L569 | Lyminge | Chester | Chester |
| L570 | Lyminge | Chester | Chester |
| L574 | Lyminge | Lyminge | Lyminge |
| L575 | Lyminge | Lyminge | Lyminge |
| L590 | Lyminge | Lyminge | Lyminge |
| L599 | Lyminge | Lyminge | Lyminge |
| L6II | Lyminge | Lyminge | Lyminge |
| L6I2 | Lyminge | Lyminge | Lyminge |
| L620 | Lyminge | Lyminge | Lyminge |
| L65 I | Lyminge | Lyminge | Lyminge |
| L7I8 | Lyminge | Lyminge | Lyminge |
| L783 | Lyminge | Lyminge | Lyminge |
| L793 | Lyminge | Lyminge | Lyminge |
| L8I7 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| Archaeological tarsometatarsi - DFA classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L858 | Lyminge | Lyminge | Lyminge |
| L868 | Lyminge | Chester | Chester |
| L884 | Lyminge | Lyminge | Lyminge |
| L891 | Lyminge | Lyminge | Lyminge |
| L899 | Lyminge | Lyminge | Lyminge |
| L904 | Lyminge | Lyminge | Lyminge |
| L915 | Lyminge | Uley | Uley |
| U079 | Uley | Uley | Uley |
| U080 | Uley | Uley | Uley |
| UI05 | Uley | Uley | Uley |
| U112 | Uley | Chester | Chester |
| UI7I | Uley | Uley | Chester |
| C002 | Chester | Chester | Uley |
| C022 | Chester | Chester | Lyminge |
| C023 | Chester | Lyminge | Lyminge |
| CI24 | Chester | Chester | Chester |
| CI26 | Chester | Chester | Chester |
| CI80 | Chester | Uley | Uley |
| C193 | Chester | Chester | Chester |
| C217 | Chester | Uley | Uley |
| C218 | Chester | Lyminge | Lyminge |
|  |  |  |  |

### 5.4.7 One-way Permanova tests for BGPCAs

| P-values - modern breeds/types |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G |
| Dorking |  | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 1 8}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 4 5 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 8}$ |  | $\mathbf{0 . 0 0 4 2}$ | 0.1578 | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 9 3}$ |
| X-B JF | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 4 2}$ |  | $\mathbf{0 . 0 1 5 7}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 5}$ |
| O E Game | $\mathbf{0 . 0 0 1 8}$ | 0.1578 | $\mathbf{0 . 0 1 5 7}$ |  | $\mathbf{0 . 0 0 0 2}$ | 0.1515 |
| Silkie | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 4}$ | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 2}$ |  | $\mathbf{0 . 0 0 0 8}$ |
| Asian G | $\mathbf{0 . 0 4 5 3}$ | $\mathbf{0 . 0 0 9 3}$ | $\mathbf{0 . 0 0 0 5}$ | 0.1515 | $\mathbf{0 . 0 0 0 8}$ |  |


| P-values - modern breeds/types and Uley |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Uley |
| Dorking |  | $\mathbf{0 . 0 0 1}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 2 I}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 3 6 5}$ | $\mathbf{0 . 0 0 1 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 1}$ |  | $\mathbf{0 . 0 0 1 4}$ | 0.1595 | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 1 7 6}$ | $\mathbf{0 . 0 0 7 3}$ |
| X-B JF | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 1 4}$ |  | $\mathbf{0 . 0 1 9 7}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 1 1}$ | 0.1185 |
| O E Game | $\mathbf{0 . 0 0 2 1}$ | 0.1595 | $\mathbf{0 . 0 1 9 7}$ |  | $\mathbf{0 . 0 0 0 5}$ | 0.1654 | $\mathbf{0 . 0 1 2 7}$ |
| Silkie | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 1 4}$ |
| Asian G | $\mathbf{0 . 0 3 6 5}$ | $\mathbf{0 . 0 1 7 6}$ | $\mathbf{0 . 0 0 1 I}$ | 0.1654 | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 2}$ |
| Uley | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 0 7 3}$ | 0.1185 | $\mathbf{0 . 0 1 2 7}$ | $\mathbf{0 . 0 0 1 4}$ | $\mathbf{0 . 0 0 2}$ |  |


| P-values - modern breeds/types and Lyminge |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Lyminge |
| Dorking |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 I I}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 3 2 6}$ | $\mathbf{0 . 0 0 0 1}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 2 7}$ | 0.134 I | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 7 9}$ | $\mathbf{0 . 0 0 0 1}$ |
| X-B JF | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 2 7}$ |  | $\mathbf{0 . 0 3 4 1}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 2 3 I}$ |
| O E Game | $\mathbf{0 . 0 0 I I}$ | 0.134 I | $\mathbf{0 . 0 3 4 I}$ |  | $\mathbf{0 . 0 0 0 1}$ | 0.0949 | $\mathbf{0 . 0 0 0 2}$ |
| Silkie | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 0 5}$ | $\mathbf{0 . 0 0 0 1}$ |
| Asian G | $\mathbf{0 . 0 3 2 6}$ | $\mathbf{0 . 0 0 7 9}$ | $\mathbf{0 . 0 0 0 5}$ | 0.0949 | $\mathbf{0 . 0 0 0 5}$ |  | $\mathbf{0 . 0 0 0 1}$ |
| Lyminge | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 2 3 I}$ | $\mathbf{0 . 0 0 0 2}$ | $\mathbf{0 . 0 0 0 1}$ | $\mathbf{0 . 0 0 0 1}$ |  |


| P-values - modern breeds/types and Chester |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | O E Game | Silkie | Asian G | Chester |
| Dorking |  | $\mathbf{0 . 0 0 0 7}$ | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 2 9}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 4 3 9}$ | $\mathbf{0 . 0 0 0 3}$ |
| Hamburgh | $\mathbf{0 . 0 0 0 7}$ |  | $\mathbf{0 . 0 0 2 3}$ | 0.1537 | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 9 1}$ | $\mathbf{0 . 0 1 5}$ |
| X-B JF | $\mathbf{0 . 0 0 0 8}$ | $\mathbf{0 . 0 0 2 3}$ |  | $\mathbf{0 . 0 1 4}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 2}$ | 0.3107 |
| O E Game | $\mathbf{0 . 0 0 2 9}$ | 0.1537 | $\mathbf{0 . 0 1 4}$ |  | $\mathbf{0 . 0 0 0 1}$ | 0.1514 | 0.0694 |
| Silkie | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 6}$ | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 0 1}$ |  | $\mathbf{0 . 0 0 1 3}$ | $\mathbf{0 . 0 0 0 3}$ |
| Asian G | $\mathbf{0 . 0 4 3 9}$ | $\mathbf{0 . 0 0 9 1}$ | $\mathbf{0 . 0 0 0 2}$ | 0.1514 | $\mathbf{0 . 0 0 1 3}$ |  | $\mathbf{0 . 0 0 1 2}$ |
| Chester | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 1 5}$ | 0.3107 | 0.0694 | $\mathbf{0 . 0 0 0 3}$ | $\mathbf{0 . 0 0 1 2}$ |  |

## Appendix F: Classifying archaeological coracoids

## 6.I Uley

6.I.I Uley with six modern groups

DFA with six modern groups and Uley as named group

| Confusion matrix six modern groups and Uley: before/after c-v |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Uley | Total |
| Dorking | $5 / 4$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | 6 |
| Hamburgh | $0 / 0$ | $5 / 4$ | $0 / 0$ | $1 / 2$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 0$ | $1 / 1$ | $6 / 4$ | $0 / 1$ | $1 / 1$ | $1 / 2$ | 9 |
| Silkie | $1 / I$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 7 |
| Asian G | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $4 / 2$ | $0 / 0$ | 4 |
| Uley | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $15 / 15$ | 16 |
| Total | $7 / 7$ | $5 / 4$ | $7 / 7$ | $7 / 7$ | $6 / 8$ | $5 / 3$ | $18 / 19$ | 55 |

85.45\% correct/74.55\% after cross-validation.

Classification table for DFA with six modern groups and Uley replaced by '?'

| Six modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65I | Hamburgh | Hamburgh | Hamburgh |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66l | Silkie | Silkie | Silkie |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | OEG | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | OEG | Hamburgh |


| Six modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | OEG |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | X-B JF |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | OEG |
| u004 | ? | Hamburgh |  |
|  |  |  |  |


| Six modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| u023 | $?$ | Dorking |  |
| u025 | $?$ | Dorking |  |
| u040 | $?$ | Hamburgh |  |
| u043 | $?$ | Hamburgh |  |
| u050 | $?$ | Dorking |  |
| u057 | $?$ | Hamburgh |  |
| u06I | $?$ | Dorking |  |
| u075 | $?$ | Dorking |  |
| ul10 | $?$ | Hamburgh |  |
| ulI7 | $?$ | OEG |  |
| uI27 | $?$ | OEG |  |
| ul39 | $?$ | Hamburgh |  |
| ul5I | $?$ | OEG |  |
| ul80 | $?$ | Hamburgh |  |
| ul86 | $?$ | Hamburgh |  |

### 6.1.2 Uley with four modern groups

DFA with four modern groups and Uley as named group

| Confusion matrix four modern groups and Uley: before/after c-v |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Uley | Total |
| Dorking | $5 / 3$ | $0 / 1$ | $0 / 0$ | $0 / 1$ | $I / I$ | 6 |
| Hamburgh | $0 / 0$ | $7 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 0$ | $0 / 0$ | $8 / 8$ | $1 / I$ | 9 |
| Uley | $1 / 1$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $15 / 14$ | 16 |
| Total | $6 / 4$ | $7 / 8$ | $6 / 6$ | $8 / 9$ | $17 / 17$ | 44 |

93.18\% correct/84.09\% after cross-validation

Classification table for DFA with four modern groups and Uley replaced by ‘’’

| Four modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| r65I | Hamburgh | Hamburgh | Hamburgh |


| Four modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r663 | OEG | OEG | OEG |
| r667 | OEG | OEG | OEG |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | OEG | OEG |
| r735 | OEG | OEG | OEG |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r741 | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t022 | Hamburgh | Hamburgh | X-B JF |
| t059 | X-B JF | X-B JF | X-B JF |
| t143 | X-B JF | X-B JF | X-B JF |
| tl44 | X-B JF | X-B JF | X-B JF |
| tl46 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w519 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Hamburgh |
| w537 | Dorking | Dorking | Hamburgh |
| w6II | OEG | OEG | OEG |
|  |  |  |  |


| Four modern groups and Uley classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w6I2 | OEG | OEG | Hamburgh |
| u004 | $?$ | OEG |  |
| u023 | $?$ | Dorking |  |
| u025 | $?$ | Dorking |  |
| u040 | $?$ | Hamburgh |  |
| u043 | $?$ | Hamburgh |  |
| u050 | $?$ | Dorking |  |
| u057 | $?$ | OEG |  |
| u06I | $?$ | Dorking |  |
| u075 | $?$ | Dorking |  |
| ul10 | $?$ | Hamburgh |  |
| ul17 | $?$ | OEG |  |
| ul27 | $?$ | OEG |  |
| ul39 | $?$ | Hamburgh |  |
| uI5I | $?$ | OEG |  |
| uI80 | $?$ | Hamburgh |  |
| uI86 | $?$ | Hamburgh |  |

### 6.2 Flixborough

### 6.2.1 Flixborough with six modern groups

DFA with six modern groups and Flixborough as named group

| Confusion matrix six modern groups and Flixborough: before/after c-v |  |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Flixborough | Total |
| Dorking | 5/4 | I/I | 0/0 | 0/I | 0/0 | 0/0 | 0/0 | 6 |
| Hamburgh | 0/0 | $7 / 4$ | 0/0 | 0/2 | 0/0 | 0/0 | 0/1 | 7 |
| X-B JF | 0/0 | 0/0 | 6/6 | 0/0 | 0/0 | 0/0 | 0/0 | 6 |
| OEG | 0/0 | 0/0 | I/I | 5/4 | I/I | I/I | 1/2 | 9 |
| Silkie | I/I | 0/0 | 0/0 | 0/0 | 6/6 | 0/0 | 0/0 | 7 |
| Asian G | I/I | 0/0 | 0/0 | 0/0 | 0/1 | 3/2 | 0/0 | 4 |
| Flixborough | 0/0 | 2/3 | 0/0 | 5/5 | 0/0 | 0/0 | 24/23 | 31 |
| Total | 716 | 10/8 | 7/7 | 10/12 | 7/8 | 4/3 | 25/26 | 70 |

80.00\% correct/70.00\% after cross-validation

Classification table for DFA with six modern groups and Flixborough replaced by ‘’’

| Six modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e0l3 | OEG | OEG | OEG |
| e0l4 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65 I | Hamburgh | Hamburgh | Hamburgh |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66l | Silkie | Silkie | Silkie |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | OEG | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | OEG | Hamburgh |


| Six modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | OEG |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | Hamburgh |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | OEG |
| f338 | ? | Hamburgh |  |
|  |  |  |  |


| Six modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| f339 | $?$ | Hamburgh |  |
| f344 | $?$ | OEG |  |
| f345 | $?$ | OEG |  |
| f346 | $?$ | OEG |  |
| f351 | $?$ | Hamburgh |  |
| f357 | $?$ | Hamburgh |  |
| f358 | $?$ | Hamburgh |  |
| f361 | $?$ | OEG |  |
| f362 | $?$ | OEG |  |
| f363 | $?$ | Hamburgh |  |
| f368 | $?$ | Hamburgh |  |
| f370 | $?$ | OEG |  |
| f37l | $?$ | OEG |  |
| f377 | $?$ | Hamburgh |  |
| f382 | $?$ | Hamburgh |  |
| f383 | $?$ | Hamburgh |  |
| f385 | $?$ | OEG |  |
| f390 | $?$ | OEG |  |
| f39l | $?$ | Hamburgh |  |
| f392 | $?$ |  |  |
| f393 | $?$ |  |  |


| Six modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| $f 394$ | $?$ | Silkie |  |
| $f 396$ | $?$ | Hamburgh |  |
| $f 397$ | $?$ | OEG |  |
| $f 398$ | $?$ | OEG |  |
| $f 401$ | $?$ | OEG |  |
| $f 402$ | $?$ | OEG |  |
| $f 403$ | $?$ | OEG |  |
| $f 404$ | $?$ | OEG |  |
| $f 406$ | $?$ | OEG |  |

### 6.2.2 Flixborough with four modern groups

DFA with four modern groups and Flixborough as named group

| Confusion matrix four modern groups and Flixborough: before/after c-v |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Flixborough | Total |
| Dorking | $5 / 4$ | $I / I$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $7 / 6$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 1$ | $1 / 1$ | $6 / 5$ | $2 / 2$ | 9 |
| Flixborough | $0 / 0$ | $3 / 3$ | $0 / 0$ | $4 / 4$ | $24 / 24$ | 31 |
| Total | $5 / 4$ | 1 I/II | $7 / 7$ | $10 / I I$ | $26 / 26$ | 59 |

81.36\% correct/76.27\% after cross-validation

Classification table for DFA with four modern groups and Flixborough replaced by '?

| Four modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e001 | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| r65I | Hamburgh | Hamburgh | Hamburgh |


| Four modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r663 | OEG | OEG | OEG |
| r667 | OEG | OEG | OEG |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | OEG | OEG |
| r735 | OEG | OEG | OEG |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r741 | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t022 | Hamburgh | Hamburgh | X-B JF |
| t059 | X-B JF | X-B JF | Hamburgh |
| t143 | X-B JF | X-B JF | X-B JF |
| tl44 | X-B JF | X-B JF | X-B JF |
| tl46 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w519 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Hamburgh |
| w537 | Dorking | Dorking | Hamburgh |
| w6II | OEG | OEG | OEG |
|  |  |  |  |


| Four modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w6I2 | OEG | OEG | Hamburgh |
| f338 | $?$ | OEG |  |
| f339 | $?$ | Hamburgh |  |
| f344 | $?$ | OEG |  |
| f345 | $?$ | OEG |  |
| f346 | $?$ | OEG |  |
| f35I | $?$ | Hamburgh |  |
| f357 | $?$ | Hamburgh |  |
| f358 | $?$ | Hamburgh |  |
| f361 | $?$ | OEG |  |
| f362 | $?$ | OEG |  |
| f363 | $?$ | Hamburgh |  |
| f368 | $?$ | OEG |  |
| f370 | $?$ | OEG |  |
| f37I | $?$ | OEG |  |
| f377 | $?$ | OEG |  |
| f382 | $?$ | Hamburgh |  |
| f383 | $?$ | OEG |  |
| f385 | $?$ | $?$ |  |
| f390 | $?$ |  |  |
| f39l | $?$ |  |  |


| Four modern groups and Flixborough classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| f392 | $?$ | Hamburgh |  |
| f393 | $?$ | Hamburgh |  |
| $f 394$ | $?$ | OEG |  |
| $f 396$ | $?$ | Dorking |  |
| f397 | $?$ | OEG |  |
| f398 | $?$ | OEG |  |
| $f 401$ | $?$ | OEG |  |
| $f 402$ | $?$ | OEG |  |
| $f 403$ | $?$ | OEG |  |
| $f 404$ | $?$ | OEG |  |
| $f 406$ | $?$ | OEG |  |

### 6.3 Coppergate

### 6.3.I Coppergate with six modern groups

DFA with six modern groups and Coppergate as named group

| Confusion matrix six modern groups and Coppergate: before/after c-v |  |  |  |  |  |  |  |  |  |
| :--- | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Coppergate | Total |  |
| Dorking | $6 / 3$ | $0 / 1$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / I$ | $0 / 0$ | 6 |  |
| Hamburgh | $0 / 0$ | $6 / 3$ | $0 / 0$ | $0 / 2$ | $0 / 0$ | $0 / 0$ | $1 / 2$ | 7 |  |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 6 |  |
| OEG | $0 / 0$ | $0 / 0$ | $1 / 1$ | $4 / 4$ | $1 / I$ | $1 / I$ | $2 / 2$ | 9 |  |
| Silkie | $1 / I$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 5$ | $0 / 1$ | $0 / 0$ | 7 |  |
| Asian G | $1 / I$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $3 / 2$ | $0 / 0$ | 4 |  |
| Coppergate | $2 / 2$ | $1 / 2$ | $2 / 2$ | $5 / 5$ | $0 / 0$ | $0 / 0$ | $43 / 42$ | 53 |  |
| Total | $10 / 7$ | $7 / 7$ | $9 / 9$ | $9 / 12$ | $7 / 6$ | $4 / 5$ | $46 / 46$ | 92 |  |

80.43\% correct/70.65\% after cross-validation.

Classification table for DFA with six modern groups and Coppergate replaced by ‘?

| Six modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00 I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e0I0 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65I | Hamburgh | Hamburgh | Hamburgh |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66l | Silkie | Silkie | Silkie |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | OEG | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | OEG | Hamburgh |
|  |  |  |  |


| Six modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | OEG |
| t024 | Asian G | Asian G | Dorking |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | X-B JF |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | Hamburgh |
| y002 | ? | OEG |  |
|  |  |  |  |


| Six modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y003 | $?$ | OEG |  |
| y004 | $?$ | OEG |  |
| y007 | $?$ | OEG |  |
| y01I | $?$ | OEG |  |
| y015 | $?$ | Hamburgh |  |
| y016 | $?$ | OEG |  |
| y017 | $?$ | X-B JF |  |
| y019 | $?$ | Hamburgh |  |
| y022 | $?$ | Hamburgh |  |
| y025 | $?$ | Hamburgh |  |
| y026 | $?$ | Hamburgh |  |
| y027 | $?$ | Dorking |  |
| y028 | $?$ | OEG |  |
| y029 | $?$ | OEG |  |
| y03I | $?$ | X-B JF |  |
| y032 | $?$ | OEG |  |
| y033 | $?$ | OEG |  |
| y034 | $?$ | OEG |  |
| y035 | $?$ | OEG |  |
| y037 | $?$ | Hamburgh |  |
| y038 | $?$ | OEG |  |
|  | $?$ |  |  |


| Six modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y039 | $?$ | OEG |  |
| y04I | $?$ | Hamburgh |  |
| y042 | $?$ | OEG |  |
| y044 | $?$ | OEG |  |
| y045 | $?$ | OEG |  |
| y047 | $?$ | OEG |  |
| y05I | $?$ | OEG |  |
| y052 | $?$ | OEG |  |
| y054 | $?$ | OEG |  |
| y055 | $?$ | Hamburgh |  |
| y056 | $?$ | OEG |  |
| y057 | $?$ | OEG |  |
| y058 | $?$ | OEG |  |
| y059 | $?$ | Hamburgh |  |
| y060 | $?$ | OEG |  |
| y06l | $?$ | OEG |  |
| y063 | $?$ | OEG |  |
| y067 | $?$ | Hamburgh |  |
| y068 | $?$ | Hamburgh |  |
| y069 | $?$ | Hamburgh |  |
| y070 | $?$ | Hamburgh |  |
|  | $?$ |  |  |


| Six modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y074 | $?$ | Hamburgh |  |
| y076 | $?$ | Hamburgh |  |
| y077 | $?$ | Hamburgh |  |
| y078 | $?$ | Hamburgh |  |
| y08I | $?$ | Dorking |  |
| y082 | $?$ | Hamburgh |  |
| y085 | $?$ | Hamburgh |  |
| y086 | $?$ | Hamburgh |  |
| y087 | $?$ | OEG |  |
| y089 | $?$ | OEG |  |

6.3.2 Coppergate with four modern groups

DFA with four modern groups and Coppergate as named group

| Confusion matrix four modern groups and Coppergate: before/after c-v |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Coppergate | Total |
| Dorking | $6 / 3$ | $0 / 2$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $6 / 5$ | $0 / 0$ | $0 / 1$ | $1 / 1$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 1$ | $1 / I$ | $6 / 5$ | $2 / 2$ | 9 |
| Coppergate | $2 / 2$ | $3 / 3$ | $1 / 2$ | $6 / 6$ | $4 I / 40$ | 53 |
| Total | $8 / 5$ | $9 / I I$ | $8 / 9$ | $12 / 13$ | $44 / 43$ | 81 |

80.25\% correct/72.84\% after cross-validation.

Classification table for DFA with four modern groups and Coppergate replaced by '?

| Four modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| r65I | Hamburgh | Hamburgh | X-B JF |
| r663 | OEG | OEG | OEG |
| r667 | OEG | OEG | OEG |


| Four modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | OEG | OEG |
| r735 | OEG | OEG | OEG |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t022 | Hamburgh | Hamburgh | X-B JF |
| t059 | X-B JF | X-B JF | X-B JF |
| tl43 | X-B JF | X-B JF | X-B JF |
| tl44 | X-B JF | X-B JF | X-B JF |
| tl46 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Hamburgh |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6l2 | OEG | OEG | Hamburgh |
| y002 | ? | OEG |  |
|  |  |  |  |


| Four modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y003 | $?$ | OEG |  |
| y004 | $?$ | OEG |  |
| y007 | $?$ | Hamburgh |  |
| y01I | $?$ | OEG |  |
| y015 | $?$ | OEG |  |
| y016 | $?$ | OEG |  |
| y017 | $?$ | X-B JF |  |
| y019 | $?$ | OEG |  |
| y022 | $?$ | OEG |  |
| y025 | $?$ | OEG |  |
| y026 | $?$ | Hamburgh |  |
| y027 | $?$ | Dorking |  |
| y028 | $?$ | OEG |  |
| y029 | $?$ | OEG |  |
| y03I | $?$ | X-B JF |  |
| y032 | $?$ | Hamburgh |  |
| y033 | $?$ | OEG |  |
| y034 | $?$ | OEG |  |
| y035 | $?$ | OEG |  |
| y037 | $?$ | Hamburgh |  |
| y038 | $?$ | OEG |  |
|  |  |  |  |


| Four modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y039 | $?$ | OEG |  |
| y04I | $?$ | Hamburgh |  |
| y042 | $?$ | OEG |  |
| y044 | $?$ | OEG |  |
| y045 | $?$ | OEG |  |
| y047 | $?$ | Hamburgh |  |
| y05I | $?$ | OEG |  |
| y052 | $?$ | OEG |  |
| y054 | $?$ | OEG |  |
| y055 | $?$ | Hamburgh |  |
| y056 | $?$ | OEG |  |
| y057 | $?$ | OEG |  |
| y058 | $?$ | OEG |  |
| y059 | $?$ | Hamburgh |  |
| y060 | $?$ | OEG |  |
| y06l | $?$ | OEG |  |
| y063 | $?$ | OEG |  |
| y067 | $?$ | OEG |  |
| $y 068$ | $?$ | OEG |  |
| $y 069$ | $?$ | OEG |  |
| $y 070$ | $?$ | Hamburgh |  |
|  | $?$ |  |  |


| Four modern groups and Coppergate classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| y074 | $?$ | Hamburgh |  |
| y076 | $?$ | Dorking |  |
| y077 | $?$ | OEG |  |
| y078 | $?$ | Hamburgh |  |
| y081 | $?$ | OEG |  |
| y082 | $?$ | Hamburgh |  |
| y085 | $?$ | Hamburgh |  |
| y086 | $?$ | Hamburgh |  |
| y087 | $?$ | OEG |  |
| y089 | $?$ | OEG |  |

### 6.4 Lyminge

### 6.4.I Lyminge with six modern groups

DFA with six modern groups and Lyminge as named group

| Confusion matrix six modern groups and Lyminge: before/after c-v |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Lyminge | Total |
| Dorking | $5 / 4$ | $I / I$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $7 / 5$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 1$ | $1 / 1$ | $7 / 3$ | $0 / 1$ | $1 / I$ | $0 / 2$ | 9 |
| Silkie | $I / I$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 7 |
| Asian G | $I / I$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $3 / 2$ | $0 / 0$ | 4 |
| Lyminge | $2 / 4$ | $0 / 0$ | $1 / 1$ | $1 / 1$ | $0 / 0$ | $0 / 0$ | $33 / 31$ | 37 |
| Total | $9 / 10$ | $8 / 8$ | $8 / 8$ | $8 / 6$ | $6 / 7$ | $4 / 3$ | $33 / 34$ | 76 |

88.16\% correct/75.00\% after cross-validation

Classification table for DFA with six modern groups and Lyminge replaced by '?

| Six modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e0I3 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65 I | Hamburgh | Hamburgh | Hamburgh |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66l | Silkie | Silkie | Silkie |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | OEG | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | OEG | Hamburgh |


| Six modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Hamburgh |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | OEG |
| t024 | Asian G | Asian G | Asian G |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | Hamburgh |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | OEG |
| L228 | ? | Hamburgh |  |
|  |  |  |  |


| Six modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L236 | $?$ | OEG |  |
| L249 | $?$ | OEG |  |
| L255 | $?$ | Dorking |  |
| L26I | $?$ | X-B JF |  |
| L005 | $?$ | Hamburgh |  |
| L057 | $?$ | OEG |  |
| LI47 | $?$ | OEG |  |
| L408 | $?$ | OEG |  |
| L560 | $?$ | Dorking |  |
| L6I7 | $?$ | OEG |  |
| L78I | $?$ | OEG |  |
| L8I6 | $?$ | Hamburgh |  |
| L916 | $?$ | Hamburgh |  |
| L9I7 | $?$ | Hamburgh |  |
| L054 | $?$ | Dorking |  |
| LI27 | $?$ | OEG |  |
| LI34 | $?$ | OEG |  |
| LI52 | $?$ | OEG |  |
| LI69 | $?$ | Hamburgh |  |
| L222 | $?$ | OEG |  |
| L226 | $?$ |  |  |
|  | $?$ |  |  |


| Six modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| L340 | $?$ | Hamburgh |  |
| L346 | $?$ | Hamburgh |  |
| L477 | $?$ | OEG |  |
| L509 | $?$ | Hamburgh |  |
| L5I9 | $?$ | OEG |  |
| L530 | $?$ | Hamburgh |  |
| L702 | $?$ | OEG |  |
| L703 | $?$ | Hamburgh |  |
| L7IO | $?$ | Hamburgh |  |
| L74I | $?$ | OEG |  |
| L79I | $?$ | OEG |  |
| L797 | $?$ | OEG |  |
| L823 | $?$ | Dorking |  |
| L88I | $?$ | Hamburgh |  |
| L90I | $?$ | OEG |  |

### 6.4.2 Lyminge with four modern groups

DFA with four modern groups and Lyminge as named group

| Confusion matrix four modern groups and Lyminge: before/after c-v |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Lyminge | Total |
| Dorking | $4 / 3$ | $1 / 2$ | $0 / 0$ | I/I | $0 / 0$ | 6 |
| Hamburgh | $0 / 0$ | $7 / 7$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $1 / 1$ | $0 / 0$ | $6 / 6$ | $2 / 2$ | 9 |
| Lyminge | $2 / 3$ | $0 / 1$ | $I / I$ | $1 / 2$ | $32 / 29$ | 36 |
| Total | $6 / 6$ | $9 / 11$ | $7 / 7$ | $8 / 9$ | $34 / 31$ | 64 |

85.94\% correct/79.69\% after cross-validation.

Classification table for DFA with four modern groups and Lyminge replaced by '?'

| Four modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| eOI4 | Dorking | Dorking | OEG |
| r65I | Hamburgh | Hamburgh | Hamburgh |


| Four modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r663 | OEG | OEG | OEG |
| r667 | OEG | OEG | OEG |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | OEG | OEG |
| r735 | OEG | OEG | OEG |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | X-B JF |
| t022 | Hamburgh | Hamburgh | X-B JF |
| t059 | X-B JF | X-B JF | Hamburgh |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | X-B JF | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Hamburgh |
| w537 | Dorking | Dorking | Hamburgh |
| w6II | OEG | OEG | OEG |
|  |  |  |  |


| Four modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w6I2 | OEG | OEG | Hamburgh |
| 1228 | $?$ | OEG |  |
| 1236 | $?$ | OEG |  |
| 1249 | $?$ | OEG |  |
| 1255 | $?$ | Dorking |  |
| 1261 | $?$ | X-B JF |  |
| 1005 | $?$ | Hamburgh |  |
| 1057 | $?$ | OEG |  |
| 1147 | $?$ | OEG |  |
| 1408 | $?$ | Oorking |  |
| 1560 | $?$ | OEG |  |
| 1617 | $?$ | OEG |  |
| 1781 | $?$ | Hamburgh |  |
| 1816 | $?$ | Hamburgh |  |
| 1916 | $?$ | Dorking |  |
| 1917 | $?$ | OEG |  |
| 1054 | $?$ | Hamburgh |  |
| 1127 | $?$ | OEG |  |
| 1134 | $?$ | $?$ |  |
| 1152 | $?$ |  |  |
| 1169 | $?$ |  |  |
|  |  |  |  |


| Four modern groups and Lyminge classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1222 | $?$ | OEG |  |
| 1226 | $?$ | OEG |  |
| 1340 | $?$ | Hamburgh |  |
| 1346 | $?$ | OEG |  |
| 1477 | $?$ | OEG |  |
| 1509 | $?$ | OEG |  |
| 1519 | $?$ | Dorking |  |
| 1530 | $?$ | Hamburgh |  |
| 1702 | $?$ | Hamburgh |  |
| 1703 | $?$ | Hamburgh |  |
| 1710 | $?$ | OEG |  |
| 1741 | $?$ | OEG |  |
| 1791 | $?$ | OEG |  |
| 1797 | $?$ | Dorking |  |
| 1823 | $?$ | OEG |  |
| 1881 | $?$ |  |  |
| 1901 | $?$ |  |  |

### 6.5 Chester

### 6.5.I Chester with six modern groups

DFA with six modern groups and Chester as named group

| Confusion matrix six modern groups and Chester: before/after c-v |  |  |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Dorking | Hamburgh | X-B JF | OEG | Silkie | Asian G | Chester | Total |
| Dorking | $5 / 4$ | $0 / 0$ | $0 / 0$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $1 / 1$ | 6 |
| Hamburgh | $0 / 0$ | $6 / 6$ | $0 / 0$ | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | 6 |
| OEG | $0 / 0$ | $0 / 1$ | $0 / 0$ | $7 / 5$ | $0 / 1$ | $1 / I$ | $1 / I$ | 9 |
| Silkie | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $0 / 0$ | 7 |
| Asian G | $1 / 1$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $3 / 3$ | $0 / 0$ | 4 |
| Chester | $1 / 1$ | $1 / 1$ | $1 / 1$ | $0 / 1$ | $0 / 0$ | $0 / 0$ | $10 / 9$ | 13 |
| Total | $8 / 7$ | $7 / 8$ | $7 / 7$ | $8 / 8$ | $6 / 7$ | $4 / 4$ | $12 / I I$ | 52 |
| 8 |  |  |  |  |  |  |  |  |

82.69\% correct/75.00\% after cross-validation.

Classification table for DFA with six modern groups and Chester replaced by '?

| Six modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e00 I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| h003 | Silkie | Dorking | Dorking |
| r65I | Hamburgh | Hamburgh | Hamburgh |
| r657 | Asian G | Asian G | Asian G |
| r658 | Asian G | Asian G | Asian G |
| r660 | Silkie | Silkie | Silkie |
| r66l | Silkie | Silkie | Silkie |
| r662 | Asian G | Asian G | Silkie |
| r663 | OEG | OEG | OEG |
| r666 | Silkie | Silkie | Silkie |
| r667 | OEG | OEG | Silkie |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | Asian G | Asian G |
| r735 | OEG | OEG | Hamburgh |


| Six modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r736 | Hamburgh | Hamburgh | OEG |
| r740 | Hamburgh | Hamburgh | Hamburgh |
| r74I | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | Dorking |
| t007 | Silkie | Silkie | Silkie |
| t022 | Hamburgh | Hamburgh | OEG |
| t024 | Asian G | Asian G | Asian G |
| t032 | Silkie | Silkie | Silkie |
| t034 | Silkie | Silkie | Silkie |
| t059 | X-B JF | X-B JF | X-B JF |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | Hamburgh | X-B JF |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Dorking |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | OEG |
| c033 | ? | Hamburgh |  |
|  |  |  |  |


| Six modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| c034 | $?$ | Hamburgh |  |
| c035 | $?$ | Hamburgh |  |
| c036 | $?$ | Asian G |  |
| c037 | $?$ | Hamburgh |  |
| c038 | $?$ | OEG |  |
| c087 | $?$ | Dorking |  |
| c088 | $?$ | Hamburgh |  |
| cl01 | $?$ | Hamburgh |  |
| cl58 | $?$ | X-B JF |  |
| c166 | $?$ | Hamburgh |  |
| cl82 | $?$ | X-B JF |  |
| c219 | $?$ | OEG |  |

### 6.5.2 Chester with four modern groups

DFA with four modern groups and Chester as named group

| Confusion matrix four modern groups and Chester: before/after c-v |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
|  | Chester | Dorking | Hamburgh | X-B JF | OEG | Total |
| Chester | $\mathrm{II} / \mathrm{IO}$ | $\mathrm{I} / \mathrm{I}$ | $\mathrm{I} / \mathrm{I}$ | $0 / \mathrm{I}$ | $0 / 0$ | I 3 |
| Dorking | $\mathrm{I} / \mathrm{I}$ | $5 / 4$ | $0 / 0$ | $0 / 0$ | $0 / \mathrm{I}$ | 6 |
| Hamburgh | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | $\mathrm{I} / \mathrm{I}$ | 7 |
| X-B JF | $0 / 0$ | $0 / 0$ | $0 / 0$ | $6 / 6$ | $0 / 0$ | 6 |
| OEG | $\mathrm{I} / \mathrm{I}$ | $0 / 0$ | $0 / 0$ | $0 / 0$ | $8 / 8$ | 9 |
| Total | $\mathrm{I} 3 / \mathrm{I} 2$ | $6 / 5$ | $7 / 7$ | $6 / 7$ | $9 / 10$ | 4 I |
| $8780 \%$ |  |  |  |  |  |  |

87.80\% correct/82.93\% after cross-validation

Classification table for DFA with four modern groups and Chester replaced by '?'

| Four modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| c033 | $?$ | Dorking |  |
| c034 | $?$ | Hamburgh |  |
| c035 | $?$ | OEG |  |
| c036 | $?$ | OEG |  |
| c037 | $?$ | Hamburgh |  |
| c038 | $?$ | OEG |  |


| Four modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| c087 | $?$ | Dorking |  |
| c088 | $?$ | Dorking |  |
| cl01 | $?$ | Hamburgh |  |
| c158 | $?$ | Dorking |  |
| c166 | $?$ | Hamburgh |  |
| c182 | $?$ | X-B JF |  |
| c219 | ? | OEG |  |
| e00I | Dorking | Dorking | Dorking |
| e004 | Hamburgh | Hamburgh | Hamburgh |
| e010 | X-B JF | X-B JF | X-B JF |
| e013 | OEG | OEG | OEG |
| e014 | Dorking | Dorking | OEG |
| r65I | Hamburgh | Hamburgh | Hamburgh |
| r663 | OEG | OEG | OEG |
| r667 | OEG | OEG | OEG |
| r723 | Dorking | Dorking | Dorking |
| r724 | Dorking | Dorking | Dorking |
| r732 | OEG | OEG | OEG |
| r735 | OEG | OEG | OEG |
| r736 | Hamburgh | Hamburgh | Hamburgh |
| r740 | Hamburgh | Hamburgh | Hamburgh |
|  |  |  |  |


| Four modern groups and Chester classifications |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| r74 | Hamburgh | Hamburgh | Hamburgh |
| r742 | Hamburgh | Hamburgh | X-B JF |
| t022 | Hamburgh | Hamburgh | Hamburgh |
| t059 | X-B JF | X-B JF | X-B JF |
| t143 | X-B JF | X-B JF | X-B JF |
| t144 | X-B JF | X-B JF | X-B JF |
| t146 | X-B JF | X-B JF | X-B JF |
| n00I | OEG | OEG | OEG |
| w5I8 | OEG | OEG | Dorking |
| w5I9 | X-B JF | X-B JF | X-B JF |
| w528 | Dorking | Dorking | Hamburgh |
| w537 | Dorking | Hamburgh | Hamburgh |
| w6II | OEG | OEG | OEG |
| w6I2 | OEG | OEG | OEG |

## Appendix G - Species differentiation study using GMM

## 7.I Coracoid

| Regression analysis - coracoid (10,000 permutations) |  |
| :--- | :--- |
| Total sums of squares | 0.03105962 |
| Predicted sums of squares | 0.00059640 |
| Residual sums of squares | 0.03046323 |
| Percentage of variance predicted | $1.9202 \%$ |
| P-value | 0.4592 |


| Percentages of variance - pheasants, guinea fowl and Uley coracoid |  |  |  |
| :--- | :--- | :---: | :---: |
| PC | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.0002953 I | 32.96 | 32.96 |
| 2 | 0.00013665 | 15.25 | 48.22 |
| 3 | 0.00009635 | 10.75 | 58.97 |
| 4 | 0.00006549 | 7.31 | 66.28 |
| 5 | 0.00005201 | 5.81 | 72.09 |
| 6 | 0.00004465 | 4.98 | 77.07 |
| 7 | 0.00003566 | 3.98 | 81.05 |
| 8 | 0.00003005 | 3.35 | 84.40 |
| 9 | 0.00002862 | 3.20 | 87.60 |

## Percentages of variance - pheasants, guinea fowl and Uley coracoid

| PC | Eigenvalues | \% Variance | Cumulative \% |
| :--- | :--- | :---: | :---: |
| 10 | 0.00002375 | 2.65 | 90.25 |
| 11 | 0.00001626 | 1.82 | 92.06 |
| 12 | 0.0000136 | 1.52 | 93.58 |
| 13 | 0.00001105 | 1.23 | 94.81 |
| 14 | 0.00000963 | 1.08 | 95.89 |
| 15 | 0.00000785 | 0.88 | 96.76 |
| 16 | 0.00000726 | 0.81 | 97.58 |
| 17 | 0.00000584 | 0.65 | 98.23 |
| 18 | 0.00000425 | 0.47 | 98.70 |
| 19 | 0.00000343 | 0.38 | 99.08 |
| 20 | 0.0000027 | 0.30 | 99.39 |
| 21 | 0.00000212 | 0.24 | 99.62 |
| 22 | 0.00000154 | 0.17 | 99.79 |
| 23 | 0.00000113 | 0.13 | 99.92 |
| 24 | 0.00000073 | 0.08 | 100.00 |


| Permanova of coracoid coordinates |  |
| :--- | :--- |
| Total sum of squares | 0.0439 |
| Within-group sum of squares | 0.03106 |
| F-stat | 9.715 |
| P-value | 0.0001 |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e016 | Pheasant | Pheasant | Pheasant |
| e0187 | Pheasant | Pheasant | Pheasant |
| e0187 | Pheasant | Pheasant | Pheasant |
| e0l9 | Pheasant | Pheasant | Pheasant |
| re020 | Pheasant | Pheasant | Pheasant |
| e02I | Guinea fowl | Uley | Uley |
| e022 | Guinea fowl | Guinea fowl | Guinea fowl |
| e024 | Guinea fowl | Guinea fowl | Guinea fowl |
| e025 | Guinea fowl | Guinea fowl | Guinea fowl |
| e026 | Pheasant | Pheasant | Pheasant |
| e027 | Guinea fowl | Guinea fowl | Guinea fowl |
| e028 | Guinea fowl | Guinea fowl | Guinea fowl |
| r066 | Pheasant | Pheasant | Pheasant |
| t066 | Pheasant | Pheasant | Pheasant |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t067 | Pheasant | Pheasant | Pheasant |
| t069 | Pheasant | Pheasant | Pheasant |
| t073 | Pheasant | Pheasant | Pheasant |
| t074 | Pheasant | Pheasant | Pheasant |
| t079 | Pheasant | Uley | Uley |
| t082 | Pheasant | Pheasant | Pheasant |
| t084 | Pheasant | Pheasant | Pheasant |
| t085 | Pheasant | Pheasant | Pheasant |
| t086 | Pheasant | Pheasant | Pheasant |
| t089 | Pheasant | Pheasant | Pheasant |
| t090 | Pheasant | Pheasant | Pheasant |
| t092 | Pheasant | Pheasant | Pheasant |
| w6I4 | Guinea fowl | Guinea fowl | Guinea fowl |
| w6I5 | Guinea fowl | Guinea fowl | Guinea fowl |
| z003 | Pheasant | Pheasant | Pheasant |
| z004 | Pheasant | Pheasant | Pheasant |
| z005 | Pheasant | Pheasant | Pheasant |
| z006 | Pheasant | Pheasant | Pheasant |
| z007 | Pheasant | Pheasant | Pheasant |
| z008 | Pheasant | Pheasant | Pheasant |
| u004 | Uley | Uley | Uley |
|  |  |  |  |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| u023 | Uley | Uley | Uley |
| u025 | Uley | Uley | Uley |
| u040 | Uley | Uley | Uley |
| u043 | Uley | Uley | Uley |
| u050 | Uley | Uley | Uley |
| u057 | Uley | Uley | Uley |
| u06I | Uley | Uley | Uley |
| u075 | Uley | Uley | Uley |
| ul10 | Uley | Uley | Uley |
| ulI7 | Uley | Uley | Uley |
| ul27 | Uley | Uley | Uley |
| ul39 | Uley | Uley | Uley |
| ul5I | Uley | Uley | Uley |
| ul80 | Uley | Uley | Uley |
| ul86 | Uley | Uley | Uley |

### 7.2 Humerus

| Regression analysis $\boldsymbol{-}$ humerus (10,000 permutations) |  |
| :--- | :--- |
| Total sums of squares | 0.01189089 |
| Predicted sums of squares | 0.00029258 |
| Residual sums of squares | 0.01159831 |
| Percentage of variance predicted | $2.4606 \%$ |
| P-value | 0.1194 |


| Humerus |  |  |  |
| :--- | :--- | :--- | :--- |
| Principal component | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00014434 | 35.436 | 35.436 |
| 2 | 0.00009692 | 23.794 | 59.229 |
| 3 | 0.00004159 | 10.209 | 69.439 |
| 4 | 0.00002312 | 5.676 | 75.114 |
| 5 | 0.00001405 | 3.450 | 78.564 |
| 6 | 0.00001083 | 2.660 | 81.224 |
| 7 | 0.00000924 | 2.269 | 83.493 |
| 8 | 0.00000828 | 2.032 | 85.525 |
| 9 | 0.00000678 | 1.665 | 87.190 |
| 10 | 0.00000593 | 1.455 | 88.645 |
| 11 | 0.00000522 | 1.282 | 89.927 |


| Permanova of humerus coordinates |  |
| :--- | :--- |
| Total sum of squares | 0.02525 |
| Within-group sum of squares | 0.01189 |
| F-stat | 22.1 |
| P-value | 0.0001 |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| u003 | Uley | Uley | Uley |
| u010 | Uley | Uley | Uley |
| u034 | Uley | Uley | Uley |
| u035 | Uley | Uley | Uley |
| u055 | Uley | Uley | Uley |
| u07I | Uley | Uley | Uley |
| u072 | Uley | Uley | Uley |
| u077 | Uley | Uley | Uley |
| u08I | Uley | Uley | Uley |
| u097 | Uley | Uley | Uley |
| ul09 | Uley | Uley | Uley |
| ul24 | Uley | Uley | Uley |
| ul28 | Uley | Uley | Uley |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| ul29 | Uley | Uley | Uley |
| ul48 | Uley | Uley | Uley |
| ul49 | Uley | Uley | Uley |
| ul55 | Uley | Uley | Uley |
| ul58 | Uley | Uley | Uley |
| ul67 | Uley | Uley | Uley |
| e015 | Pheasant | Pheasant | Pheasant |
| e016 | Pheasant | Pheasant | Pheasant |
| e0I7 | Pheasant | Pheasant | Pheasant |
| e018 | Pheasant | Pheasant | Pheasant |
| e019 | Pheasant | Pheasant | Pheasant |
| e020 | Pheasant | Pheasant | Pheasant |
| e02l | Guinea fowl | Guinea fowl | Guinea fowl |
| e022 | Guinea fowl | Guinea fowl | Guinea fowl |
| e023 | Guinea fowl | Guinea fowl | Guinea fowl |
| e024 | Guinea fowl | Guinea fowl | Guinea fowl |
| e025 | Guinea fowl | Guinea fowl | Guinea fowl |
| e026 | Pheasant | Pheasant | Pheasant |
| e027 | Guinea fowl | Guinea fowl | Guinea fowl |
| e028 | Guinea fowl | Pheasant | Pheasant |
| e029 | Black grouse | Black grouse | Black grouse |
|  |  |  |  |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e030 | Black grouse | Black grouse | Black grouse |
| e032 | Black grouse | Black grouse | Black grouse |
| e033 | Black grouse | Black grouse | Black grouse |
| r066 | Pheasant | Pheasant | Pheasant |
| t066 | Pheasant | Pheasant | Pheasant |
| t067 | Pheasant | Pheasant | Pheasant |
| t073 | Pheasant | Pheasant | Pheasant |
| t074 | Pheasant | Pheasant | Pheasant |
| t079 | Pheasant | Pheasant | Pheasant |
| t080 | Pheasant | Pheasant | Pheasant |
| t08I | Pheasant | Pheasant | Pheasant |
| t082 | Pheasant | Pheasant | Pheasant |
| t083 | Pheasant | Pheasant | Pheasant |
| t085 | Pheasant | Pheasant | Pheasant |
| t086 | Pheasant | Pheasant | Pheasant |
| t089 | Pheasant | Pheasant | Pheasant |
| t092 | Pheasant | Pheasant | Pheasant |
| tl25 | Black grouse | Black grouse | Black grouse |
| tl28 | Black grouse | Black grouse | Black grouse |
| tl36 | Black grouse | Black grouse | Black grouse |
| w614 | Guinea fowl | Guinea fowl | Guinea fowl |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| w6I5 | Guinea fowl | Guinea fowl | Guinea fowl |
| w797 | Black grouse | Black grouse | Black grouse |
| z003 | Pheasant | Pheasant | Pheasant |
| z004 | Pheasant | Pheasant | Pheasant |
| z006 | Pheasant | Pheasant | Pheasant |
| z007 | Pheasant | Pheasant | Pheasant |
| z009 | Black grouse | Black grouse | Black grouse |
| z010 | Black grouse | Black grouse | Black grouse |

### 7.3 Tibiotarsus

## Regression analysis - tibiotarsus ( 10,000 permutations)

| Total sums of squares | 0.01486469 |
| :--- | :--- |
| Predicted sums of squares | 0.00012363 |
| Residual sums of squares | 0.01474106 |
| Percentage of variance predicted | $0.8317 \%$ |
| P-value | 0.7716 |


| Tibiotarsus |  |  |  |
| :--- | :--- | :--- | :--- |
| Principal component | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00034629 | 60.322 | 60.322 |
| 2 | 0.00010734 | 18.698 | 79.019 |
| 3 | 0.00003719 | 6.479 | 85.498 |
| 4 | 0.00002199 | 3.831 | 89.330 |
| 5 | 0.00001459 | 2.542 | 91.872 |
| 6 | 0.00001000 | 1.742 | 93.614 |
| 7 | 0.00000851 | 1.482 | 95.096 |
| 8 | 0.00000828 | 2.032 | 85.525 |
| 9 | 0.00000678 | 1.665 | 87.190 |
| 10 | 0.00000593 | 1.455 | 88.645 |
| 11 | 0.00000522 | 1.282 | 89.927 |


| Permanova of tibiotarsus coordinates |  |
| :--- | :--- |
| Total sum of squares | 0.02928 |
| Within-group sum of squares | 0.01486 |
| F-stat | 15.5 I |
| P-value | 0.000 I |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e0I7 | Pheasant | Pheasant | Pheasant |
| e018 | Pheasant | Pheasant | Pheasant |
| e019 | Pheasant | Pheasant | Pheasant |
| e020 | Pheasant | Pheasant | Pheasant |
| e02 I | Guinea fowl | Guinea fowl | Guinea fowl |
| e023 | Guinea fowl | Guinea fowl | Guinea fowl |
| e026 | Pheasant | Pheasant | Pheasant |
| e027 | Guinea fowl | Guinea fowl | Guinea fowl |
| e028 | Guinea fowl | Pheasant | Pheasant |
| e029 | Black grouse | Black grouse | Black grouse |
| e030 | Black grouse | Black grouse | Black grouse |
| e03l | Black grouse | Black grouse | Black grouse |
| e033 | Black grouse | Black grouse | Black grouse |
| r066 | Pheasant | Pheasant | Pheasant |
| t066 | Pheasant | Pheasant | Pheasant |
| t067 | Pheasant | Pheasant | Pheasant |
| t069 | Pheasant | Pheasant | Pheasant |
| t073 | Pheasant | Pheasant | Pheasant |
| t074 | Pheasant | Pheasant | Pheasant |
| t085 | Pheasant | Pheasant | Pheasant |
| t086 | Pheasant | Pheasant | Pheasant |
|  |  |  |  |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| t089 | Pheasant | Pheasant | Pheasant |
| t090 | Pheasant | Pheasant | Pheasant |
| t092 | Pheasant | Pheasant | Pheasant |
| t125 | Black grouse | Black grouse | Black grouse |
| t126 | Black grouse | Black grouse | Black grouse |
| t128 | Black grouse | Black grouse | Black grouse |
| t136 | Black grouse | Black grouse | Black grouse |
| w6I4 | Guinea fowl | Lyminge | Lyminge |
| w6I5 | Guinea fowl | Guinea fowl | Guinea fowI |
| w797 | Black grouse | Black grouse | Black grouse |
| z003 | Pheasant | Pheasant | Pheasant |
| z004 | Pheasant | Pheasant | Pheasant |
| z005 | Pheasant | Pheasant | Pheasant |
| z007 | Pheasant | Pheasant | Pheasant |
| z008 | Pheasant | Pheasant | Pheasant |
| z0I0 | Black grouse | Black grouse | Black grouse |
| I050 | Lyminge | Lyminge | Lyminge |
| I052 | Lyminge | Lyminge | Lyminge |
| II42 | Lyminge | Lyminge | Lyminge |
| I219 | Lyminge | Lyminge | Lyminge |
| I22 I | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| DFA classifications of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1454 | Lyminge | Lyminge | Lyminge |
| 1790 | Lyminge | Lyminge | Lyminge |
| 1795 | Lyminge | Lyminge | Lyminge |
| 1889 | Lyminge | Lyminge | Lyminge |
| 1920 | Lyminge | Lyminge | Lyminge |
| 1921 | Lyminge | Lyminge | Lyminge |
| 1922 | Lyminge | Lyminge | Lyminge |
| 1923 | Lyminge | Lyminge | Lyminge |
| 1924 | Lyminge | Lyminge | Lyminge |
| 1925 | Lyminge | Lyminge | Lyminge |

### 7.4 Tarsometatarsus

| Regression analysis - tarsometatarsus (10,000 permutations) |  |
| :--- | :--- |
| Total sums of squares | 0.01749407 |
| Predicted sums of squares | 0.00037350 |
| Residual sums of squares | 0.01712057 |
| Percentage of variance predicted | $2.1350 \%$ |
| P-value | 0.0480 |


| Tarsometatarsus |  |  |  |
| :--- | :--- | :--- | :--- |
| Principal <br> component | Eigenvalues | \% Variance | Cumulative \% |
| I | 0.00015684 | 46.129 | 46.129 |
| 2 | 0.00003825 | 11.249 | 57.378 |
| 3 | 0.00002299 | 6.762 | 64.141 |
| 4 | 0.00002135 | 6.278 | 70.419 |
| 5 | 0.00001559 | 4.584 | 75.003 |
| 6 | 0.00001350 | 3.971 | 78.975 |
| 7 | 0.00001150 | 3.383 | 82.358 |
| 8 | 0.00000893 | 2.626 | 84.984 |
| 9 | 0.00000781 | 2.296 | 87.280 |
| 10 | 0.00000643 | 1.981 | 89.171 |


| Tarsometatarsus |  |  |  |
| :--- | :--- | :--- | :--- |
| Principal <br> component | Eigenvalues | \% Variance | Cumulative \% |
| II | 0.00000597 | 1.756 | 90.926 |


| Permanova of tarsometatarsus coordinates |  |
| :--- | :--- |
| Total sum of squares | 0.02924 |
| Within-group sum of squares | 0.01712 |
| F-stat | 29.73 |
| P-value | 0.0001 |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e015 | Pheasant | Pheasant | Pheasant |
| e016 | Pheasant | Lyminge | Lyminge |
| e017 | Pheasant | Pheasant | Pheasant |
| e018 | Pheasant | Pheasant | Pheasant |
| e019 | Pheasant | Pheasant | Pheasant |
| e020 | Pheasant | Pheasant | Pheasant |
| e02I | Guinea fowl | Guinea fowl | Guinea fowl |
| e022 | Guinea fowl | Guinea fowl | Guinea fowl |
| e023 | Guinea fowl | Guinea fowl | Guinea fowl |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| e024 | Guinea fowl | Guinea fowl | Guinea fowl |
| e025 | Guinea fowl | Guinea fowl | Guinea fowl |
| e026 | Pheasant | Pheasant | Pheasant |
| e027 | Guinea fowl | Guinea fowl | Guinea fowl |
| e028 | Guinea fowl | Pheasant | Pheasant |
| t066 | Pheasant | Pheasant | Pheasant |
| t069 | Pheasant | Pheasant | Pheasant |
| t073 | Pheasant | Pheasant | Pheasant |
| t074 | Pheasant | Pheasant | Pheasant |
| t079 | Pheasant | Lyminge | Lyminge |
| t080 | Pheasant | Pheasant | Lyminge |
| t08I | Pheasant | Pheasant | Pheasant |
| t082 | Pheasant | Pheasant | Pheasant |
| t083 | Pheasant | Pheasant | Pheasant |
| t085 | Pheasant | Pheasant | Pheasant |
| t086 | Pheasant | Pheasant | Pheasant |
| t089 | Pheasant | Pheasant | Pheasant |
| t090 | Pheasant | Pheasant | Pheasant |
| t092 | Pheasant | Pheasant | Pheasant |
| w6l4 | Guinea fowl | Guinea fowl | Guinea fowl |
| w6l5 | Guinea fowl | Guinea fowl | Guinea fowl |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| z003 | Pheasant | Pheasant | Pheasant |
| z004 | Pheasant | Pheasant | Pheasant |
| z005 | Pheasant | Pheasant | Pheasant |
| z006 | Pheasant | Pheasant | Pheasant |
| z007 | Pheasant | Pheasant | Pheasant |
| z008 | Pheasant | Pheasant | Pheasant |
| 1087 | Lyminge | Lyminge | Lyminge |
| 1088 | Lyminge | Lyminge | Lyminge |
| III2 | Lyminge | Lyminge | Lyminge |
| II33 | Lyminge | Lyminge | Lyminge |
| II45 | Lyminge | Lyminge | Lyminge |
| II57 | Lyminge | Lyminge | Lyminge |
| II64 | Lyminge | Lyminge | Lyminge |
| II79 | Lyminge | Lyminge | Lyminge |
| II80 | Lyminge | Lyminge | Lyminge |
| II87 | Lyminge | Lyminge | Lyminge |
| I206 | Lyminge | Lyminge | Lyminge |
| 1208 | Lyminge | Lyminge | Lyminge |
| 1209 | Lyminge | Lyminge | Lyminge |
| 1210 | Lyminge | Lyminge | Lyminge |
| I2I2 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1234 | Lyminge | Lyminge | Lyminge |
| 1246 | Lyminge | Lyminge | Lyminge |
| 1253 | Lyminge | Lyminge | Lyminge |
| 1272 | Lyminge | Lyminge | Lyminge |
| 1328 | Lyminge | Lyminge | Lyminge |
| 1330 | Lyminge | Lyminge | Lyminge |
| 1332 | Lyminge | Lyminge | Lyminge |
| 1334 | Lyminge | Lyminge | Lyminge |
| 1337 | Lyminge | Lyminge | Lyminge |
| 1473 | Lyminge | Lyminge | Lyminge |
| 1511 | Lyminge | Lyminge | Lyminge |
| 1521 | Lyminge | Lyminge | Lyminge |
| 1526 | Lyminge | Lyminge | Lyminge |
| 1567 | Lyminge | Lyminge | Lyminge |
| 1569 | Lyminge | Lyminge | Lyminge |
| 1570 | Lyminge | Lyminge | Lyminge |
| 1574 | Lyminge | Lyminge | Lyminge |
| 1575 | Lyminge | Lyminge | Lyminge |
| 1590 | Lyminge | Lyminge | Lyminge |
| 1599 | Lyminge | Lyminge | Lyminge |
| 1611 | Lyminge | Lyminge | Lyminge |
|  |  |  |  |


| DFA classification of PC scores after BGPCA |  |  |  |
| :--- | :--- | :--- | :--- |
| Point | Given group | Classification | Cross-validated |
| 1612 | Lyminge | Lyminge | Lyminge |
| 1620 | Lyminge | Lyminge | Lyminge |
| 1651 | Lyminge | Lyminge | Lyminge |
| 1718 | Lyminge | Lyminge | Lyminge |
| 1783 | Lyminge | Lyminge | Lyminge |
| 1793 | Lyminge | Lyminge | Lyminge |
| 1817 | Lyminge | Lyminge | Lyminge |
| 1858 | Lyminge | Lyminge | Lyminge |
| 1868 | Lyminge | Lyminge | Lyminge |
| 1884 | Lyminge | Pheasant | Pheasant |
| 1891 | Lyminge | Lyminge | Lyminge |
| 1894 | Lyminge | Lyminge | Lyminge |
| 1899 | Lyminge | Lyminge | Lyminge |
| 1904 | Lyminge | Lyminge | Lyminge |
| 1915 | Lyminge | Pheasant | Pheasant |

### 7.5 Permanova summary

| F-value < F-statistic = cannot reject the null hypothesis (same) |  |  |  |  |  |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :---: |
|  | Guinea Fowl | Chicken | Black Grouse | Pheasant |  |  |
| Guinea Fowl |  | cor, hum | hum | cor hum |  |  |
| Chicken | cor, hum |  |  | tbt, tmt |  |  |
| Black Grouse | hum |  |  | hum, tbt |  |  |
| Pheasant | cor, hum | tbt, tmt | hum, tbt |  |  |  |
| F-value > F-statistic = can reject null hypothesis (same) |  |  |  |  |  |  |
|  | Guinea Fowl | Chicken | Black Grouse | Pheasant |  |  |
| Guinea Fowl |  | tbt, tmt | tbt | tbt, tmt |  |  |
| Chicken | tbt, tmt |  | hum, tbt | cor, hum |  |  |
| Black Grouse | tbt | hum, tbt |  |  |  |  |
| Pheasant | tbt, tmt | cor, hum |  |  |  |  |


[^0]:    Table 61: Modern breed chickens excluding creepers and meat breeds - humeri. Eigenvalues in units of Procrustes variance, percentages of variance and cumulative variance for the first six principal components

[^1]:    Table 88: Summary of incorrect classifications following DFA of PC scores from BGPCA.

