IDENTIFYING CHICKEN BREEDS IN THE ARCHAEOLOGICAL RECORD:

A GEOMETRIC AND LINEAR MORPHOMETRIC APPROACH

Thesis submitted for the degree of

Doctor of Philosophy

at the University of Leicester

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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.

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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 mass-produced 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 (1581), Ulisse Aldrovandi (1600, translated by Lind 1963) and Gervase Markham (1614). 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, 1st-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

I

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

2.1 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 1813) (Liu *et al* 2006; Eriksson *et al* 2008; Sawai *et al* 2010). 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 1941 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 3rd millennium BC, 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 1st 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 100 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 2011) 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* 1991; 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 human-chicken 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 (1767-1846) 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-1800s 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 (18th Dynasty 1479-1425 BC) which describe birds that 'give birth' – presumably lay – every day: these are usually understood to be chickens (Coltherd 1966). Pliny (*Historia Naturalis* 10.55), Aristotle (*Historia Animalium* 6.2.3) and Diodorus Siculus (*Bibliotheca Historica* 1.74) 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-13th century, Walter of Henley's treatise on estate management (Lamond 1890) stipulated that each hen could be expected to produce 115 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-20th century non-commercial flocks were typically producing 70 to 80 eggs per annum.

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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 16th-18th century AD and the wild-type allele which governs 'normal', unadapted behaviour persisted in some populations until at least the 18th 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 1982; 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 3rd to early 5th 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 ($11^{th} - 13^{th}$ centuries), interpreted as a move away from meat consumption and towards egg production. It is interesting to note that a 10^{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 1st century BC. Pliny attributes its invention to the inhabitants of the island of Delos although he does not approve of the practice (Historia Naturalis 10.50). 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 1963:137-141) and Heresbach (1577) describe it in the 16th 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 19th and early 20th 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 19th 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 1949:255-61; Spector 1956): in the latter half of the 20th 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 16th century these earlier techniques had been abandoned in favour of surgical removal of the testes. Aldrovandi in 1600 (Lind 1963:408-411) and Gessner in 1555 (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 18th century when it had reportedly waned in other parts of the country: "Few Capons are cut now except about Darking (sic) in Surrey..." (Pegge 1780). 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 (1851) 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 1951; 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 6th-7th 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 4th 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. 1170-1183), 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 12th Earl of Derby (1752-1834), 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 19th century, William Sketchley was able to list twenty varieties of game fowl raised in Britain (Sketchley 1814) 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 18th 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.

2.5.1 **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 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. 1758) has been associated with permanent fluctuating

asymmetry in the tibiotarsus (Ohlsson and Smith 2001) 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 1981; 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- 1450g) being considerably larger than females (485 – 1050g) (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 4mm 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 (1951) 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 20th-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 1868:273). Other variations recorded included the outline of the occipital foramen (circular in a wild 'bankiva' type and almost triangular in a Cochin) (ibid: 261) 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 1868:271-273) 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* 10.21) 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 (1581) and Markham (1614), John Lawrence (writing as Bonington Moubray)'s Treatise on Poultry (1834, first published 1813) 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 19th 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 1961; Serjeantson 2000; Serjeantson 2009; Sykes 2012). In the 1st 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 1991) so perhaps this taboo was not universally observed. It is debatable, however, whether the "pleasure and amusement" did actually refer to cockfighting (Morgan 1975:120 (footnote 1)). By the 18th 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 1849, 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 1st 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 2004:13) 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 1 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 2012). In the large-crested Poland, the condition is associated with abnormal brain growth during gestation resulting in a cerebral hernia and cranial expansion (Tegetmeier 1856; Darwin 1868; 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 (1581) 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 1600 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 14th 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 17th 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 1st century Artemidorus Papyrus (Kinzelbach 2009; Fedi et al 2010) 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 150-250 in Canterbury (Allison 2005), a 4th 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 18th 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 16th century from a cesspit of an inn adjacent to the Salzburger Residenz (Pucher 1991) and five more from 16th-17th 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 2012). 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 2010:1071; 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 1726; 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 19th 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 1963:362-63) 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 1800s, 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 (1886:13), Brown (1906:45) and Scrivener (*ibid.*) all quote a passage from 'A trip to the north of England' by Thomas Sutleif, published in 1702, 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 20th 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 2006:51; 2009:81) 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 1868:247).

Odoric of Pordenone described hens covered with white wool which he saw while travelling in the Chinese province of Fuzhou in the early 14th 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 2006:130). 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 17thcentury 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 20th 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) .





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 1854:160). Meall (1854:161) 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 dw^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* 8.2.14-15): 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); 6th-7th 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). Kyselý'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 Kyselý 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 19th 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 (1651). 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.

2.6.11 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 1798), the grey junglefowl (*G. sonneratii* Temminck 1813) and the Sri Lankan junglefowl (*G. lafayetti* Lesson 1813) (Darwin 1868; Hutt 1949; Crawford 1990), which genetic research has clarified and confirmed (Akishinonomiya *et al* 1994; Hillel *et al* 2003; Liu *et al* 2006; Sawai *et al* 2010). 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-19th 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-1800s 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 1800 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 (1856) 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 1849, 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-1859 '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-19th 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 17th-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 1.1. 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. 1758); common pheasant (*Phasianus colchicus* L. 1758); 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 5th century BC and had spread to Roman Italy by the 1st 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 13th century (Donkin 1991:43; MacDonald 1992), certainly by the 16th century (Poole 2010:163; Gordon 2015) ; contemporary records are confusing, however, as guinea-fowl 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 under-recorded 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 5th century BC. By the 1st century AD they were valued by the Romans as an exotic food and were imported from Colchis in considerable numbers (Jennison 1937:109-110) 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 1992; 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 2011; 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, 30/1/2017).

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 1.2. 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

3.3.1 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 16th-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 4th-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 $7^{th} - 8^{th}$ 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 3.1.

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 1991:201; 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 1993; 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 7th 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 9th 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 2008-2012 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 7th-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 $5^{th} - 7^{th}$ centuries, comprising 15.5% of total NISP, increasing to 37.25% of total NISP for the $8^{th} - 9^{th}$ 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 2011), 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 2006:153). 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 15th-16th century glassware and pottery, mostly apparently from drinking vessels, together with a gold ring and a tin-glazed owl cup, also dated to the 16th century (Wilmott *et al* 2006).

The pit was extensively sampled and much of the fill wet-sieved to 2mm, 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 1508; Maltby 1982; Albarella and Davis 1996 for 1994; Woolgar 2001; 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. 1758),

teal/garganey (Anas crecca/querquedula L. 1758), lapwing (Vanellus vanellus L. 1758), grouse (Tetrao sp.) golden plover (Pluvialis apricaria L. 1758), curlew (Numenius arquata L. 1758), snipe (Gallinago gallinago L. 1758), 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 16th-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 1) 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 2001) – 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 1981 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

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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 1st century AD to the early postmedieval. Most of the vertebrate remains were recovered from deposits associated with four Anglo-Scandinavian tenements dated from mid-9th century to mid-11th centuries (Allison 1985; O'Connor 1989). Extensive sampling and wet-sieving of the Anglo-Scandinavian levels, with residues sorted to 2mm, ensured that smaller taxa including chickens were well-represented.

Chicken bones dominate the bird assemblage (O'Connor 1989:194). 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 10th to late 11th centuries, with a few from early 13th century features post-dating the tenement development. Concentrations of domestic fowl remains were recovered from backfills of the tenements accumulated during Phase 5B (late-10th to mid-11th 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 1995:779; 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 1989 and 1991, 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 7th to the early 11th centuries, with a subsequent phase from the 12th to the 15th 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 1994; Blair 1996), 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 200 000 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 7th to late 10th 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 7th to mid-8th 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 9th 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-7th to 10th 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 4mm were not checked. Forty-four percent of the deposits where eggshell was recorded were from Phases 4-5b (9th century), suggesting that egg-production 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 1st 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 2nd and 3rd 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 (1st century) introduction and emparkment of exotic animals including fallow deer and hare (Sykes 2009; Allen and Sykes 2011; 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 11) consists of three bones, the 2nd, 3rd and 4th 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 2nd, 3rd and 4th digits: a small depression on the distal posterior shaft marks the attachment point for the ligament which connects the accessory metatarsal for the 1st 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 3rd and 4th 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

3.5.1 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 1991; 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. 1758) and starlings (*Sturnus vulgaris* L. 1758) 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 1830) 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 (1868: 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

4.1 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.

4.1.1 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 4.1.3.6. 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 4.3.1 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.

4.1.2 **Past applications and future potential**

Geometric morphometrics, described as "the empirical fusion of biology and geometry" (Bookstein 1982:451), 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 $6^{th} - 7^{th}$ 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.

4.1.3 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 (1991) 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 1); 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 Svkes
i	Dr James Barrett
k	Enid Allison
а	Alison Foster
f	Flixborough
С	Chester
u	Uley
I	Lyminge
e	Heritage England
h	Sheila Hamilton-Dyer
у	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
со	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
lh	Leghorn
ls	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

Table 2: Abbreviations used for breeds and species.

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 100mm 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 2011) and Past 3.14 (Hammer *et al* 2001).

4.1.4 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 4.1.3.7) 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 13) 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, 14 landmarks were chosen. The locations are illustrated in Figure 13 and a full description of each is given in Table 4.



Figure 13: The completed landmark configuration for the coracoid

Coracoid landmarks				
Name	Number	Туре	Description/guide to landmark placement	
Angulus medialis	1	II	Point of maximum curvature of the medial angle	
Angulis lateralis	2	II	Extreme point of the lateral angle: depending on anatomy this can be positioned on the lateral extremity of the sternal articular surface	
Facies articularis sternalis	3	II	Minimum curvature of the sternal articular surface	
Processus lateralis	4	11	Lateral process: extremely variable especially in domestic fowl. Landmark should be positioned on the maximum curvature of the cranial-most projection of the process, regardless of the size and number of other projections.	

Coracoid landmarks			
Name	Number	Туре	Description/guide to landmark placement
Cotyla scapularis, lateral	5	?	Point at which the articular surface of the scapular cotyle meets the lateral margin of the corpus
Mid-corpus, lateral edge	6	III	Mid-point of ventral edge of the corpus, equal to the mid-point of the measured distance between landmarks 4 and 5
Minimum curvature between cotylus scapularis and facies articularis humeralis	7	II	Minimum curvature between the scapular cotyle and the humeral articular surface
Maximum curvature of facies articularis humeralis	8	II	Maximum curvature of the humeral articular surface, at the mid-point
Extreme point of cranial end of coracoid	9	II	Cranial-most point of the coracoid – the point at which callipers would touch when taking a GL measurement
Medial extent of impressio ligamenti acrocoracohumeralis	10	II	Extreme medial point of the impression of the acrocoracohumeralis ligament – the point at which the depression terminates
Medial edge of processus acrocoracoideus	11	II	Medial-most edge of the acrocoracoidal process
Point of processus acrocoracoideus	12	II	Point of the acrocoracoidal process – the extreme tip of the 'hook'
Processus procoracoideus	13	II	Maximum curvature of the procoracoidal process
Mid-corpus, medial edge	14	III	Mid-point of the medial edge of the corpus, equal to the mid-point of the measured distance between landmarks 4 and 5

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				
Name	Number	Туре	Description/guide to landmark placement	
Tuberculum dorsale	1	11	Point of maximum curvature of the dorsal tubercle	
Ventral edge of caput humeri	2	11	Juncture of the articular surface and <i>incisura</i> (groove) of the humeral caput at the proximal/ventral edge	
Mid-point of caput humeri	3	111	Mid-point of measured periphery of articular surface of humeral caput (between landmarks 2 and 21)	
Incisura capitis humeri	4	1	Most distal point of v-shaped groove of the humeral caput	
Tuberculum ventrale I	5	II	Point of maximum curvature of small projection at proximal margin of <i>incisura capitis humeri</i> . N.B. This landmark can be difficult to place in some specimens due to the relative smoothness of the curve	

Humerus landmarks				
Name	Number	Туре	Description/guide to landmark placement	
Crista coracoidea	6	11	Mid-point of proximal edge of the crista coracoidea	
Tuberculum ventrale II	7	11	Proximal edge of small muscle attachment on the ventral tubercle	
Tuberculum ventrale III	8	11	Distal edge of small muscle attachment on the ventral tubercle	
Foramen pneumaticum	9	11	Most distal point of the pneumatic foramen	
Mid-shaft, ventral edge	10	111	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	11	Point of maximum curvature of the ventral supracondylar tubercle	
Margin of epicondylus ventralis	12	11	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	11	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	11	Point of maximum curvature of the ventral condyle	
Minimum curvature of condylus ventralis and condylus dorsalis	16	11	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	11	Point of the extreme edge of the dorsal condyle	
Tuberculum supracondylare dorsalis	19	11	Point of maximum curvature of the dorsal supracondylar tubercle	
Mid-shaft, dorsal edge	20		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	Туре	Description/guide to landmark placement
Dorsal edge of caput humeri	21	11	Minimum curvature of the juncture of the articular surface of the humeral caput and the dorsal tubercle
Musculus pectoralis profundi attachment scar	22	11	Most distal point of the pectoral muscle scar. N.B. In the majority of cases this point occurs central to the edge of the bone and does not define the 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 15) and fully described in Table 6.



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Tibiotarsus landmarks				
Name	Number	Туре	Description/guide to landmark placement	
Proximal articulation: medial margin	I	11	Medial-most point of proximal articulation	
Crista cnemialis cranialis	2	II	Most proximal point of the <i>crista cnemialis cranialis</i>	
Crista cnemialis lateralis	3	II	Most lateral point of the <i>crista cnemialis lateralis</i>	

Tibiotarsus landmarks				
Name	Number	Туре	Description/guide to landmark placement	
Crista fibularis	4	11	Proximal extent of <i>crista fibularis</i> – the prominent edge marking the point of fusion with the fibula	
Condylus lateralis I	5	11	Indentation at proximal extent of the lateral condyle	
Condylus lateralis II	6	11	Maximum curvature of distal end of the lateral condyle	
Incisura intercondylaris	7	11	Minimum curvature of the intercondylar incisura	
Condylus medialis I	8	11	Maximum curvature of distal end of the medial condyle	
Condylus medialis II	9	11	Indentation at proximal extent of the medial condyle	
Pons supratendinus	10	11	Distal extent of margin of the supratendinal bridge	
Canalis extensorius	11	II	Distal opening of <i>canalis extensorius</i> : landmark is placed on the distalmost point	

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	Туре	Description/guide to landmark placement
Proximal tuberculum, medial edge	1	11	Maximum curvature of small tuberculum just distal of the <i>cotyla medialis</i>
Cotyla medialis	2	11	Medial-most point of the cotyla medialis
Eminentia intercondylaris	3	11	Tip of the eminentia intercondylaris
Cotyla lateralis	4	11	Lateral-most point of the cotyla lateralis
Proximal tuberculum, lateral edge	5	11	Maximum curvature of small tuberculum just distal of the <i>cotyla lateralis</i>
Lateral foramen vascularia	6	11	Distal-most extent of the lateral foramen vascularia
Medial foramen vascularia	7	11	Distal-most extent of the medial foramen vascularia
Mid-shaft, lateral edge	8	111	Orthogonal to the mid-point between landmarks 3 and 12, placed on the lateral margin
Trochlea metatarsus IV, edge of articulation	9	11	The most proximal edge of the articulatory surface of the trochlea metatarsus IV. There is often, but not always, an associated depression on the lateral margin at this point
Trochlea metatarsus IV	10	11	Minimum curvature of the central groove of the trochlea metatarsus IV
Incisura intertrochlearis lateralis	11	11	The most proximal extent of the incisura intertrochlearis lateralis

Name	Number	Туре	Description/guide to landmark placement
Trochlea metatarsus III, maximum lateral side	12	11	Maximum curvature of the lateral side of the articular surface
Trochlea metatarsus III, minimum	13	11	Minimum curvature of the central groove of the trochlea metatarsus III
Trochlea metatarsus III, maximum medial side	14	11	Maximum curvature of the medial side of the articular surface
Trochlea metatarsus II, distal point	15	11	Distal-most point of trochlea metatarsus II
Trochlea metatarsus II, medial point	16	11	Medial-most point of trochlea metatarsus II
Foramen vasculare distale	17	11	Exact centre of the foramen vasculare distale
Mid-shaft, medial edge	18	111	Orthogonal to the mid-point between landmarks 3 and 12, placed on the medial margin. If spur is present, ignore spur shield and place landmark on 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 150mm (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)	
Вр	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 (Bp) was consistently taken with the callipers flat against the lateral edge, as illustrated by von den Driesch (1976: 116, 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.* 126-7, 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 3.5.1 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 10mm from the midline of the symphysis on each ramus (Figure 18).



Figure 18: Measuring the internal angle of the furcula from 10mm 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. R159: 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* 1984) 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. Kyselý (2010) 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 Bd/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 1961; 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; >1 means a longer ulna; <1 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); 116.65 (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 (non-parametric 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 2011) has no test for normal distribution but does include a facility to check for outliers which can be excluded or amended as required.

4.3.1 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.

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

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 ρ is the Procrustes Distance.





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 4.3.1), the shape variables of each configuration are plotted onto a 2-D scatterplot (Figure 25/1) 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 (y_1) describing the most variance is the first principal component: a second line orthogonal to it (y_2) 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 2011).

Because of this, CVA can be unsuitable for geometric morphometrics and is in some cases best avoided. As an alternative, Mitteroecker and Bookstein (2011) 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* 2011). 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

5.1 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

5.2.1 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	Sito	Bone element						
renou	Site	Coracoid	Humerus	Ulna	Femur	TBT	TMT	
Poman	Uley	36	24	16	19	4		
Noman	Fishbourne	14				TBT 4 43 43 12 59		
Angle Seven/	Lyminge	67	73	37	69	43	105	
Scandinavian	Flixborough	31			Femur I B I 19 4 69 43 11 12			
Scandinavian	Coppergate	87						
Early-modern	Chester	13	12	13		12	9	
Total		248	109	66	99	59	125	

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 13 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 31) were due to a single particularly short femur (GL 57.63mm). 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 63.19mm and 63.17mm: both of them are significantly shorter than either a modern male Friesian bantam (e008) 77.73mm or a male Spangled Hamburgh bantam (r731) 70.97mm. 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 1 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 5.4.3.1) 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 10:

Breed		Femur	Tmt
Old English	Male (mean)	29.5%	29.5%
Game	Female (mean)	29.8%	28.25%
Warren-Ranger	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 Warren-Ranger 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 6th-7th-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 13 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 11).

Modern elements by breed and sex								
Modern br	eeds	Coracoid	Humerus	Femur	Tibio-	Tarso-		
i iodeini bi		Coracold	T fumer us	T CITICI	tarsus	metatarsus		
Dorking	Male	3	3	3	3	3		
DOIKINg	Female	6	6	6	6	6		
Hamburgh	Male	6	6	6	6	5		
i lambu gri	Female	2	3	3	Tibio- tarsus Tai metal metal 3 3 6 6 6 6 2 3 4 4 6 6 4 4 5 3 1 1 Tibio- tarsus Tai metal 3 3 4 4 32 4 12 9	3		
	Male	4	4	4	4	4		
	Female	3	4	3 2 4 4 4 4 6 6 4 4 3 3 4 4 5 5 1 1	4			
Old English	Male	5	6	6	6	6		
Game	Female	4	4	4	4	4		
Silkio	Male	3	3	3	3	3		
SIIKIE	Female	4	4	4	Tibio- Tarsus metata 3 3 3 6 6 6 2 3 3 4 4 4 4 4 4 6 6 6 4 4 4 5 5 1 1 1 1 7 Tibio- Tarsus 4 8 9 32 48 9 12 9 12	4		
Asian Cama	Male	5	5	5	5	5		
Asian Game	Female	I		I	I	I		
Archaeological el	ements by s	ite						
Site		Companid		Eamun	Tibio-	Tarso-		
Site		Coracold	Humerus	remur	tarsus	metatarsus		
Uley		22	24	17	4	8		
Fishbourne		14						
Lyminge		60	63	39	32	48		
Flixborough		31						
Coppergate		87						
Chester		13	12		12	9		

Table 11: Numbers of specimens used in the measurement ratio study.

Table 11 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 4.1.2. 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 4.1.3. (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 4.1.4, 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 4.1.8 and 4.1.9. 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 4.1.5 and 4.1.6.

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 Lm/GL v Bb/GL, Lm/GL v Bb/Lm (which gave almost identical results) and Bb/GL v Bb/Lm. All of these separated cross-bred Junglefowl and Asian Game from the other groups. The weakest combination was Bf/Bb v Lm/GL.

Coracoid								
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm		
Lm/GL		5	13	13	11	11		
Bf/Bb	5		8	9	7	8		
Bb/GL	13	8		13	9	10		
Bb/Lm	13	9	13		11	11		
Bf/GL	11	7	9	11		7		
Bf/Lm	11	8	10	11	7			

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.

Bf/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 Bf/Bb and Lm/GL while for the heavier breeds, Bb/Lm and Bb/GL are the most significant. Results of a Permanova test of the scores from these two components is included (Table 14).



Figure 40: Modern chicken breeds/types - coracoid. BGPCA. 1st PC = 69.46% of the variance; 2nd 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		0.0031	0.0005	0.0021	0.2038	0.0270
Hamburgh	0.0031		0.0086	0.9550	0.0412	0.0003
X-B JF	0.0005	0.0086		0.0103	0.0004	0.0007
O E Game	0.0021	0.9550	0.0103		0.0611	0.0009
Silkie	0.2038	0.0412	0.0004	0.0611		0.2176
Asian Game	0.0270	0.0003	0.0007	0.0009	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 41) 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 15) (see Appendix D, Section 4.1.5.1 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 Junglefowl	Old English Game	Silkie	Asian 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. 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 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.

<u>Roman</u>

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 Bf/Bb v Bb/GL, illustrated in Figure 42. A Mann-Whitney U-test on the Bb/GL values produced a statistically significant p-value of 0.0001 with a less significant p-value of 0.0186 for the Bf/Bb values. Full test results are given in Appendix D, Section 4.1.7.1.



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 Bf/Bb, and Bf/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 4.1.6.1.

	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 Lm/GL and Bf/Bb plotted against each other. Comparison of the group means (Appendix D, Section 4.1.3.1) for the Bf/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 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 4.1.6.1 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 16th-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 Bb/Lm, shown in Figure 46.





Between-Groups Principal Component Analysis of all of the modern and 16th-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 16th-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 Bp/GL v SC/Bd which distinguished 12 group pairs from a possible 15, while combinations of Bd/GL, Bp/GL and SC/Bp distinguished 11 group pairs. None of the combinations were successful at separating Dorkings, Silkies and Asian Game from each other. The weakest combination was SC/GL with Bd/Bp, which only separated three pairs.

Humerus						
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd
Bd/Bp		3	8	7	8	9
SC/GL	3		9	10	7	9
Bp/GL	8	9		11	11	12
Bd/GL	7	10	11		11	10
SC/Bp	8	7	11	11		9
SC/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 Bp/GL v SC/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; 2nd PC 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		0.0232	0.0001	0.0031	0.1932	0.4613
Hamburgh	0.0232		0.0097	0.0124	0.0651	0.0065
X-B Junglefowl	0.0001	0.0097		0.0080	0.0017	0.0004
O E Game	0.0031	0.0124	0.0080		0.0009	0.0014
Silkie	0.1932	0.0651	0.0017	0.0009		0.4554
Asian Game	0.4613	0.0065	0.0004	0.0014	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





The discriminant function analysis scatterplot (Figure 51) 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 4.1.5.2.

	Dorking	Hamburgh	Cross-bred Junglefowl	Old English Game	Silkie	Asian 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. 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 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 Bp/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 4.1.2.2) 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 Bp/GL ratio plotted against the SC/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.

|--|

	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 4.1.6.2.

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 4.1.4.2. 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.

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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 well-defined 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. 1st PC = 75.30% of the variance; 2nd PC = 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 4.1.8.3) 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 Dd/Bp and Bd/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		0.0274	0.0020	0.0476	0.0542	0.3061
Hamburgh	0.0274		0.1867	0.5815	0.0068	0.0142
X-B JF	0.0020	0.1867		0.0419	0.0046	0.0050
O E Game	0.0476	0.5815	0.0419		0.0153	0.0288
Silkie	0.0542	0.0068	0.0046	0.0153		0.2724
Asian Game	0.3061	0.0142	0.0050	0.0288	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 4.1.5.3.



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 – cross-bred Junglefowl; pink – Silkie.

	Dorking	Hamburgh	Cross-bred Junglefowl	Old English Game	Silkie	Asian 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. 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 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 (Bd/Lm v Dd/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 61) 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 4.1.6.3.

A femur from a 'creeper' chicken

During analysis of the kernel density profiles of log-scaled metrics from Lyminge, femur L661 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 GL to the mean of the combined femora GLs from each site, excluding the creepers (Table 26). Measurement ratios were calculated from diagnostic metrics (Bd/GL and Bp/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 (L661) plots

Dumpy (E005) and can be confidently identified as from a creeper chicken.										
Site/Collection	Bone ID/context/ accession number	Bd	Вр	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				

19.57

17.08

18.60

13.68

15.86

19.37

17.58

19.86

14.00

15.79

79.49

88.59

96.49

71.32

81.13

24.61

19.28

19.28

19.18

19.55

24.36

19.84

20.58

19.63

19.46

closely with the Uley femur from the creeper ABG (U065) and the modern Scots Dumpy (E005) and can be confidently identified as from a creeper chicken.

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

KRM1

R735

R736

L857

U048

Krüper

Hamburgh

Uley mean

Lyminge mean

Old English Game



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 Dip/La, Bd/Dip, Dip/GL, Bd/GL and Bd/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 (Dip/GL v Bd/GL and Dip/La v Bd/La) which both separated 14 pairs from a possible 15. The least successful ratio was SC/Bd: Bd/Dd and SC/Dd were also of limited value.





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 (Bd/La v Dip/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 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,

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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: 1st PC = 73.22% of the variance; 2nd PC = 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 4.1.8.4) 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		0.0020	0.0039	0.2972	0.0044	0.0018				
X-B JF	0.0020		0.1611	0.0039	0.0015	0.0981				
O E Game	0.0039	0.1611		0.0040	0.1833	0.4597				
Silkie	0.2972	0.0039	0.0040		0.0012	0.0025				
Asian Game	0.0044	0.0015	0.1833	0.0012		0.0323				
Hamburgh	0.0018	0.0981	0.4597	0.0025	0.0323					

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 4.1.5.4.



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 71) 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 4.1.5.4



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 4.1.3.4) 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.

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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 4.1.6.4.

	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 Bd/La v Dip/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 4.1.7.2). 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

Tarsometatarsus						
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp
Bd/Bp		9	8	8	8	9
SC/Bd	9		8	9	8	7
SC/GL	8	8		11	10	5
Bp/GL	8	9	11		9	9
Bd/GL	8	8	10	9		6
SC/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 Bp/GL and Bd/GL v SC/GL. The weakest ratio combination was SC/GL v SC/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 egg-types 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 (Bd/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 Bd/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. 1st PC = 85% of the variance; 2nd PC = 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		0.0153	0.2542	0.6864	0.0134	0.0246
Hamburgh	0.0153		0.0089	0.0130	0.0015	0.0019
X-B JF	0.2542	0.0089		0.0563	0.0828	0.0334
O E Game	0.6864	0.0130	0.0563		0.0015	0.0056
Silkie	0.0134	0.0015	0.0828	0.0015		0.1964
Asian Game	0.0246	0.0019	0.0334	0.0056	0.1964	

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 4.1.5.5.



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 Junglefowl	Old English Game	Silkie	Asian 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. 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 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 SC/GL v Bp/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 yaxis, 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 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 Bp/GL and Bd/GL ratios – full results in the Appendix 4.1.7.2), 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.

	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

The classification table is in Appendix D. Section 4.1.6.5

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

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 4.1.7.3), examination of the point distribution in the SC/GL v Bp/GL 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 SC/GL and Bp/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 (z001) is a cross-bred Junglefowl and the hens are of heavier breeds. Two of the hens (h011 and r663) are spurred. These individuals are highlighted in red on the x-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 1/100mm 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 Bf/Bb 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 Bb/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 Bb/GL ratio and high scores for the Bf/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 Lm/GL and Bf/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 shape-variability 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

5.4.1 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 English Game	Hamburgh/ egg-type	Silkie	Cross-bred Junglefowl
Male	3	6	5	3	4
Female	6	4	3/2	4	4
Total	9	10	8/7	7	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 1.5 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/egg-types 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	0.007	0.6158	0.0011
RJF	0.0681		0.0281	0.1861	0.0234
OE Game	0.007	0.0281		0.005	0.1431
Silkie	0.6158	0.1861	0.005		0.001
Hamburgh	0.0011	0.0234	0.1431	0.001	

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 1. 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	0.0227
OE Game	0.1366	0.5967		0.5603	0.0588
Silkie	0.3744	0.324	0.5603		0.183
Hamburgh	0.9115	0.0227	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 1891:19) 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 8th-9th 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 BI 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 10mm 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 1 kg which comprised mostly bantams to over 4 kg which included the large Asian Gamefowl and the male Dorkings (Table 41).

Weight (g)	Category
0 – 1000	0
1001 - 2000	I
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	1	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	Ι	Shamo	I
Japanese bantam	2	Silkie	0
Lakenvelder	3	Spanish	Ι
Leghorn	3	Sussex	Ι
Malay	Ι	Vorwerk	3
Marans			

 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%	0.67924	-0.51211	0.42134	0.31439
50%	0.31693	0.45893	0.52598	-0.64209
100%	0.24509	0.72492	0.005653	0.64373
10mm	0.61491	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 10mm 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 1.5 times the box height from the box.



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

Using the '10mm' 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. 1: 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. 1: 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		0.0427	0.0001	0.0017	0.0007
1	0.0427		0.0051	0.1146	0.0006
2	0.0001	0.0051		0.2649	0.0218
3	0.0017	0.1146	0.2649		0.0071
4	0.0007	0.0006	0.0218	0.0071	

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 (1976:122-124) (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 10) 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 2.6.1. 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 cross-validation.

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	15/11	1/5	16
Male	1/5	21/17	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 = 1.7251

Loadings show the CB measurements make a significant contribution with the AA 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
СВ	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: 0.0001***
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 51).

	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	-0.01051	SB	0.001984
СВ	-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 11-month-old female Vorwerk (r665) a 27-month old Dorking hen (r723) and two Ethiopian unimproved ecotypes d178 (female) and d166 (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.

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6 GMM Results

6.1 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

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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 35mm 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 2011; Webster and Sheets 2010) all based on repetition of procedure and calculating the range of variation. For example, Webster and Sheets (2010) 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 1.1 and 1.2.

Specimen	Sex	ID	GMM no	Hum	Cor
Black grouse	male	bgm	B1759	У	У
Brahma	female	brf	a005	У	У
Crested rumpless Turkish	unknown	crx	t040	У	
Dorking	female	dkf	r724	у	У
Hamburgh bantam	female	hbf	r729	у	У
Hamburgh bantam	male	hbm	r731	у	У
Hamburgh	female	hmf	r742	у	У
Hamburgh	male	hmm	r736	у	У
Indian Game	female	igf	r726	у	У
Japanese bantam	male	jbm	r652	у	У
Lakenvelder	male	lam	r659	у	У
Oxford Game	male	ogm	r732	У	
Poland bantam	male	pbm	a001	У	У
Pheasant	male	phm	a004	У	У
Shamo	male	shm	r658	У	У
Silkie	female	sif	r661	У	У
Silkie	male	sim	r666	У	У

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 4.1.3.8. 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 bgm1_1; bgm1_2; bgm2_1 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 4.1.4.1 and 4.1.4.2) 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 4.3.1). General Procrustes Analysis (GPA) and Principal Components Analysis (PCA) were performed using MorphoJ (Klingenberg 2011) 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.

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Correlation: 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 0.075129 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.





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	<.0001		
Imaging	3.19298	0.19956	16	3.95	0.0005		
Digitising	1.61859	0.05058	32				
Shape Proc	rustes AN	OVA					
Effect	SS	MS	df	F	P (param)		
Specimens	0.05386	9E-05	600	123.74	<.0001		
Imaging	0.00046	7.3E-07	640	13.93	<.0001		
Digitising	6.7E-05	5.2E-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: 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	<.0001		
Imaging	1.43841	0.09589	15	3.55	0.0015		
Digitising	0.80986	0.027	30				
Shape Proc	rustes AN	OVA					
Effect	SS	MS	df	F	P (param)		
Specimens	0.05688	1.69E-04	336	65.99	<.0001		
Imaging	0.00092	2.57E-06	360	4.13	<.0001		
Digitising	0.00045	6.21E-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 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 5.1.1). 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.

РС	Eigenvalues	% Variance	Cumulative %
	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 1 and 2 are illustrated in Figure 101, exaggerated by a scale of -0.1/0.1 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, 10, 11 and 12), a shift of the lateral process towards the basal articulation and a reduction of the medial angle (landmark 1). A slight lateral curvature of the body is also suggested (landmarks 6 and 14).

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Figure 101: All modern chicken breeds - coracoids. Outline graphs showing shape changes for 1^{st} and 2^{nd} principal components. Scale factor = -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 101), 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 5.1.2. Figure 102 plots the scores for the first two components and shows clearly that the shape change associated with PC1 (which is almost identical to that seen in Figure 101) 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 103. 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 2nd 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 PC1, 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 102). PC2 (Figure 103), 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 1) 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 crossvalidation is presented in Table 57: the classifications can be found in Appendix E, Section 5.1.3.



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	I/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 5.1.4. For the first principal component, the most significant loadings relate to the basal area (landmarks 4 and 1) and the breadth of the corpus (landmarks 14 and 13) and for component two they relate to the basal area (landmarks 2 and 1) 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 5.1.8.

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.





Figure 106: Principal component analysis of three Saxon sites – coracoids. 1st PC = 16.84% of the variance; 2nd PC = 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 5.1.5). Examination of the plots of the first five components (of which only PC1 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 102) 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 1st and 2nd principal components. Scale factor = -0.05 (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: 51.67% after cross-validation (Table 58). Classifications are in Appendix E, Section 5.1.6.



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 5.1.8.

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^{st} PC = 18.77% of the variance; 2^{nd} PC = 14.66% of the variance. Colour key: red – Chester; purple – Uley; green – Lyminge.



Figure 111: Uley, Lyminge and Chester – coracoids. Outline graphs showing shape changes for 1st and 2nd principal components. Scale factor = -0.05 (left) and 0.05 (right).

Figure 111 shows the shape-changes associated with Figure 110. 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 11 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 5.1.7.

	Chester	Uley	Lyminge	Total
Chester	10/5	1/2	2/6	13
Uley	0/1	6/	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 cross-validation.



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 112) 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 5.1.8.

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 5.2.1). The remaining 35 components only account for approximately 23% of the variance and were not investigated further.

Principal	Eigenvalues	% Variance	Cumulative %
component	0		
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 113), 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 1st principal component. Scale factor = 0.05 (above) and -0.05 (below)

Scores from the first and second components are plotted in Figure 114. 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 (k164), 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

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

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 115) 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 1) is less pronounced. Shape changes associated 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^{st} and 2^{nd} principal components. Scale factor: PC1 = -0.05 (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 116 to 120) 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 118 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 1 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 119 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 115) 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 121, 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 PC1 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 123 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 PC1 are associated with landmarks 22, 1, 19 and 11, which all relate to expansion of the proximal and distal end and reflect relative robusticity. For PC2, landmarks 1, 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 115 shows that for PC1 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).

РС	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 (landmarks1 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^{st} , 2^{nd} and 3^{rd} principal components. Scale factor = -0.05 (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 1) 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 1 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, 18 and 19).



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

Figures 125 and 126 plot the scores for the first three principal components. The first two components (Figure 125) 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 PC1 v PC3 (Figure 126). 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.





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.



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 cross-validation.



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 128) 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

6.5.1 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.

РС	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^{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 130. 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 114). For the first component, the Japanese Bantam creepers (specimens r652 and r668) again show extreme morphological change and the larger Krüper (k164) 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).

РС	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 131 plots the scores for the first two components and shows clearly that the shape change associated with PC1 (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 134) 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^{st} principal component. Scale factor = 0.05 (above) and -0.05 (below).

Shape changes associated with the first principal component (Figure 133) 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 1) 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 1) 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^{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 3rd 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 1). 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 PC1 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, 71.11% 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	1/1	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 PC1 are 4, 2, 11 and 3 and for PC2 they are 4, 8, 11 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 15 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	0.00001071	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 1st principal component. Scale factor = -0.1 (above) and 0.1 (below)



Figure 139: All archaeological chickens - tibiotarsi. Outline graphs showing shape change associated with the 2^{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 138 and 139. 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 (91 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 5.4.1.

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 PC1 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 (r652, r668, e005), 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 PC1 is illustrated in Figure 144.



Figure 144: All modern chicken breeds - tarsometatarsus. Outline graphs showing shape change associated with the 1^{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^{nd} and 3^{rd} principal components. Scale factor = -0.05 (left) and 0.05 (right).

The associated shape change for PC1 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 17) 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 6.4.1, 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 twoyear-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 116), 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 117), but the tarsometatarsus does not show the same variability and no significant differences can be discerned between these two breeds using PCs 1, 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 118) shows that for this element too, PC2 separates the two types more effectively than PC1.



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 PC1 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 119), 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^{nd} and 3^{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 151.

Principal component I (Figure 152) 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 153) the egg-type 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 PC1 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 cross-validation.

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.

Between-groups PCA



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 PC1 are associated with landmarks 5, 2 and 1 and 16, 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; landmark18 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 61 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^{st} principal component. Scale factor = -0.05 (above) and 0.05 (below)



Figure 157: All archaeological chickens - tarsometatarsi. Outline graphs showing shape change associated with the 2nd 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^{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 PC1 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

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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

6.7.1 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 MorphoJ (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-

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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 6.1 – 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 (61%) 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 31%) 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

6.8.1 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 5.3.3.1; 5.3.4.1; 5.3.6.1; and 5.3.7.1 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			ТВТ			TMT		
Breed	Ν	Class	Breed	Ν	Class	Breed	Ν	Class	Breed	Ν	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
GEOMET	GEOMETRIC MORPHOMETRICS										
Coracoid			Humerus			ТВТ			TMT		
Breed	Ν	Class	Breed	N	Class	Breed	N	Class	Breed	Ν	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	7/6
OEG	9	5/2	OEG	10	8/7	OEG	10	8/7	OEG	9	7/6
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: N = number of specimens; Class = correct classification before/after cross-validation; 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 (100%), 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 5.3.3.1; 5.3.4.1; 5.3.6.1; and 5.3.7.1 respectively), and for the GMM, derived from tables in Appendix E Sections 5.1.8; 5.2.7; 5.3.6; and 5.4.6.

Element	p-value	Number of breed pairs separate	
		Measurement ratios	GMM
Coracoid	<0.05	11	
	<0.001	5	4
Humerus	<0.05		13
	<0.001	3	8
Tibiotarsus	<0.05	10	14
	<0.001	0	7
Tarsometatarsus	<0.05	10	13
	< 0.001	0	8

Table 77: Summary of results from Permanova tests of scores from 1st and 2nd 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 <0.001): 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.

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Measurement ratios								
Breed	Coracoid	Humerus	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	Dk, X-B JF				
			G, H'burg					
Silkie	Dk, Asian G,	Dk, H'burg,	Dk	X-B JF, Asian G				
	OEG	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 1^{st} and 2^{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 (p-values from the BGPCA) for the coracoid are presented in Appendix E, Section 5.1.8. 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	,	Flixboro	ugh	Copperga	ate	Lyming	ge	Ches	ter
Breed	Ν	%	N	%	N	%	N	%	Ν	%
Dorking	5	31	0	0	2	3.5	4	11	I	7.5
Hamburgh	8	50	14	45	20	38	14	38	7	54
X-B JF	0	0	0	0	2	3.5	I	2.5	2	15.5
OEG	3	19	16	52	29	55	18	48.5	2	15.5
Silkie	0	0	I	3	0	0	0	0	0	0
Asian G	0	0	0	0	0	0	0	0	I	7.5
Total	16		31		53		37		13	
DFA using	four r	noder	n groups							
	Uley	,	Flixboro	ugh	Copperga	ate	Lyming	ge	Ches	ter
Breed	Ν	%	N	%	N	%	N	%	Ν	%
Dorking	5	31	I	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	I	3	I	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

7.1 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 1.2. 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 7.1. 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 7.1. 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 11 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.

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 13) 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

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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^{st} principal component. Scale factor = -0.05 (above) and 0.05 (below).



Figure 172: Modern guinea fowl and pheasants with Uley chickens - coracoids. Shape change graphs associated with the 2^{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 7.1.

	Pheasant	Guinea fowl	Chicken
Pheasant	-	0.0001/6.283	0.0001/14.92
Guinea Fowl	0.0001/6.283	-	0.0003/7.286
Chicken	0.0001/14.92	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 cross-validation.

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 11 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.

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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 PC1 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 1) is more prominent. The condyles at the distal articulation (landmarks 12-18) 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 11) is less pronounced.



Figure 176: Modern other Galliformes with Uley chickens. Outline graphs showing shape changes associated with the 1st principal component. Scale factor = 0.05 (above) and -0.05 (below)

Figure 177 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 1) 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^{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		0.0001/37.75	0.0001/15.43	0.0001/33.29
Pheasant	0.0001/37.75		0.0001/10.85	0.0001/17.62
Guinea fowl	0.0001/15.43	0.0001/10.85		0.0001/20.24
Black grouse	0.0001/33.29	0.0001/17.62	0.0001/20.24	

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 178.



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 100% 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 11 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 180) 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 $2 \vee 3$ (Figure 181) 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 182 to 184.



Figure 182: Modern other Galliformes with Uley chickens - tibiotarsi. Outline graph showing shape changes associated with the 1^{st} principal component. Scale factor = 0.05 (above) and -0.05 (below).

Figure 182 shows shape changes associated with PC1 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^{nd} principal component. Scale factor = 0.05 (above) and -0.05 (below).

Second PC shape changes were associated with 18% of the variance (Figure 183). Positive scores exhibit a broad shaft and a relatively larger distal articulation. The proximal end is expanded, with a flared medial edge (landmark 1). 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 1 and 3) are compressed, especially at landmark 1.



Figure 184: Modern other Galliformes with Uley chickens - tibiotarsi. Outline graphs showing shape changes associated with the 3^{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 11) 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 11 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		0.0001/22.26	0.0017/6.788	0.0001/10.77
Guinea fowl	0.0001/22.26		0.0003/26.34	0.0001/16.45
Black grouse	0.0017/6.788	0.0003/26.34		0.0001/18.71
Lyminge	0.0001/10.77	0.0001/16.45	0.0001/18.71	

Table 84: Modern Galliformes and Lyminge chickens - tibiotarsi. Permanova p-values/F-values from pairwise comparisons.

Comparison of the F-statistic (15.51) 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.

				I •	T . I
	Pheasant	Guinea fowi	Black grouse	Lyminge	I otal
Pheasant	21/21	0/0	0/0	0/0	21
	,	0,0	0,0	0,0	
Guinea fowl	1/1	4/4	0/0	1/1	6
	.,.	., .	0,0	.,.	Ţ
Black grouse	0/0	0/0	10/10	0/0	10
	0,0	0,0		0,0	
Lyminge	0/0	0/0	0/0	15/15	15
_/		0,0	0,0		
Total	22/22	4/4	10/10	16/16	52
i o cai		., .			

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 11 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.





A scatterplot of the scores for principal components 1 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 PC1 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 1st principal component. Scale factor = -0.05 (above) and 0.05 (below).



Figure 189: Modern chickens and pheasants with Lyminge chickens - tarsometatarsi. Outline graphs showing shape changes associated with the 2nd principal component. Scale factors = -0.03 (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		0.0001/36.32	0.0001/18.95
Guinea fowl	0.0001/36.32		0.0001/37.85
Lyminge	0.0001/18.95	0.0001/37.85	

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



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 cross-validation 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	1/1	8/8	0/0	9
Lyminge	2/2	0/0	49/49	51
Total	28/27	8/8	51/52	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 Roman-period 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: 71) 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		
e021	coracoid	guinea fowl	chicken		
e016	tarsometatarsus	pheasant	chicken		
	humerus				
e028	tibiotarsus	guinea fowl	pheasant		
	tarsometatarsus				
t079	coracoid	pheasant	chicken		
	tarsometatarsus	•			
t080	tarsometatarsus	pheasant	chicken		
w614	tibiotarsus	guinea fowl	chicken		

Table 88: Summary of incorrect classifications following DFA of PC scores from BGPCA.

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

8.1 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 1963: 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 1800 AD. Many of the newer breeds developed during the 19th 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 pre-1800 texts resembled their 19th-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 Bf/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 Bb/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 101) and separates the breed/type groups in the same way as the measurement ratios (Figure 102). The second component (Figure 103) 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 Bp/GL and Bd/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 (Bp/GL) and a broad distal end relative to the shaft breadth (SC/Bd). The GMM study also identified these changes – Figure 115 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 Bp/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 (Bd/La v Dip/La and Bd/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 133 and 134) 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 (Bd/Bp v Bd/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 2kg. Although the standard for the bantam version of this breed stipulates a small size (the maximum bantam weights are 600g males, 500g 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 16th-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 13 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 1581).

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 100). Similarly, the coracoid from the Uley creeper ABG (U061) 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

9.1 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 1st-2nd 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 16th-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 14th and 17th 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 16th-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 (1581) 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 1st 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 2004:13; Scrivener 2009:61) 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 South-West Britain as early as the 18th 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 mode	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			>10 yrs	935		Kent	none	a001	AF	Pet bantam. Died of old age. "Mr Pompey".		

All mode	rn chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Poland bantam	m	ca. Jul 2013	03/03/2014	8 mths	1205		Lancashire	AF	a002	AF	
Dorking, Red	f		25/10/2014	18 mths	2045		Herefordshire	AF	a003	AF	Surplus stock. Spurred hen. Spurs not fused to tmt
Brahma	f			~3 years	3777		Kent	none	a005	AF	"Sudden Brahma Death Syndrome" - apparently this breed is prone to expiring suddenly and unexpectedly

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
?Houdan	m		25/10/2014	5.5 mths	1954		Herefordshire	none	a006	AF	Surplus stock. Five- toed 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 yrs 2 mths	1800		Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WR I I 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 mode	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 End Poultry Farm, Allington Lane, Southampton, Hampshire 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 mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Old English Pheasant Fowl	f	Apr-89	Aug-91	2 yrs 4 mths	2300		Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WR11 5QJ	2812	e004	EH	Dev sternum. Spongy growths infilling ribs/verts in pelvis. Perforations around partes glutaeae and acet (both sides). 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	3 yrs 4 mths	2100		Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WR I I 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 mode	ll modern chickens											
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes	
Poland bantam, Gold	m	1991	04/02/1992	8-10 mths	1345		Sussex	2783	e006	EH	Perforated sternum. Surplus stock, culled	
Sussex, Speckled	f	March '88	May-91	3 yrs 2 mths	3100		Domestic Fowl Trust, Honeybourne, Evesham, Worcs. WR11 5QJ	2813	e007	EH	Very fat, with fat deposits around internal organs. Very deviated sternum. Enthysophyte to distal tbt	
Friesian bantam	m	1990	04/02/1992	l yr 10 mths	1500		Old Spot Sussex	2785	e008	EH	Convex pelvis, slightly deviated sternum. Surplus stock, culled.	
Araucana bantam, Lavender	m	1991	04/02/1992	8-10 mths	1610		Sussex	2779	e009	EH	Surplus stock, culled. Pelvis poorly ossified, thin and fragile. "Testes much enlarged"	

All mode	rn chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Red Jungle Fowl	f		10/08/2006	adult	1020 (withou t head)	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 1050g), this specimen weighed without the head.
Poland bantam, White Crested Black	m	1989	04/02/1992	2 yrs 10 mths	1790		Sussex	2780	e011	EH	Surplus stock, culled
Poland bantam, Chamois	m	1991	04/02/1992	8-10 mths	1455		Sussex	2781	e012	EH	Surplus stock, culled
Old English Game	m	11/05/199 3	02/11/1995	6 mths	2356g		Environmental Archaeology Unit, York	47	e013	EH	Poss from Walled Garden flock. Prev acc no EAU 613.

All mode	ern chic	kens									
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. Pelvis fused - adult. Very small, probably 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 mode	modern chickens											
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes	
											(where crest would be)	
Sussex, Light	m	1991	1997	6 yrs				1163	h004	SHD	Utility strain. Cranium not present. Furculum robust but very narrow	
Poland	?m		1986				Poland	3035	h005	SHD	Sex not recorded. No spur/scar but this skeleton considerably larger than female Poland from same breeder (3061)	
Poland	f		1986				Poland	3061	h006	SHD	Cranium slightly domed and perforated. Projection on synsacrum. Tbts slightly bowed	
Maran	m		01/12/1991	7 yrs		Sheila H-D	Southampton	556	h007	SHD	Died suddenly. One spur broken off when ~18 months	
Sussex, Light	f		09/05/1993	~2 yrs		Sheila H-D	Southampton	914	h008	SHD	Curly' because of slight ?frizzle to a few feathers	

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Rose- comb bantam, brown	m		21/03/1994	2 yrs 8 mths		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	10 mths		Sheila H-D	Southampton	4470	h010	SHD	Perforated sternum. Culled due to aggressive nature
Dorking, Red	f		15/08/2014	16 mths	2062		Herefordshire.	unkno wn	h011	SHD	Surplus stock. Very small bumps on tmts would probably develop into spurs
Poland bantam	m	ca. Jul 2013	03/03/2014	8 mths	1125		Lancashire	none	j005	JM	Donated to James Morris

All mode	l modern chickens											
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes	
Poland bantam	m	ca. Jul 2013	03/03/2014	8 mths	1210		Lancashire	none	j006	JM	Donated to James Morris	
Kruper	m			6.5 mths		Enid Allison	Canterbury Archaeological Trust, 92a Broad Street, Canterbury, Kent, CT I 2LU	unkno wn	k164	EA	From Germany?	
Old English Game Fowl	f				1262		University of York	KDI	n001	PRS		
Hamburg h Bantam, Silver Spangled	m	ca. May 2013	22/02/2014	9-12 mths	1585		Aberdeenshire	R651	r651	UoL		
Japanese bantam, Black- tailed White	m	ca. Feb 2009	22/02/2014	5 yrs	766		Aberdeenshire	R652	r652	UoL		

All mode	II modern chickens											
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes	
Poland bantam	m	ca. Jul 2013	03/03/2014	8 mths	1080		Lancashire	R653	r653	UoL		
Poland bantam	m	ca. Jul 2010	03/03/2014	4 yrs	1115		Lancashire	R655	r655	UoL		
Poland bantam	m	ca. Jul 2013	03/03/2014	8 mths	1370		Lancashire	R656	r656	UoL		
Shamo "Haji" Ring no. G165	m	25/03/201 2	26/03/2014	2 yrs	3860		Isle of Man	R657	r657	UoL	Confined before culling due to aggressive nature	

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Shamo "Shobu" Ring no. G175	m	15/04/201 2	26/03/2014	23 mths	4320		Isle of Man	R658	r658	UoL	Free range, larger, more muscular bird
Laken- velder	m	ca. Jun 2013	30/03/2014	9-12 mths	2220		Herefordshire	R659	r659	UoL	
Silkie, Lavender	f	ca. Mar 2008	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	2	30/03/2014	16 mths	710		Herefordshire	R661	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 mode	ern chio	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Asil (Reza)	f	ca. Apr 2012	15/04/2014	2 yrs	1705		Oxfordshire	R662	r662	UoL	Excess stock, healthy bird in lay
Oxford Game	f	ca. Apr 2012	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	ca. May 2010	17/05/2014	~4 yrs	4480		West Berkshire	R664	r664	UoL	Surplus stock
Vorwerk	f	04/05/201	27/03/2014	 mths	1900	Gabrielle	Herefordshire	R665	r665	UoL	Last known egg laid ~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 mode	rn chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
											recovered during preparation
Silkie, Lavender	m	ca. 2009	30/03/2014	4-5 yrs	1625		Herefordshire	R666	r666	UoL	Culled due to age and ill health (?cold). Probably infertile
Oxford Game	f	ca. Apr 2013	15/04/2014	12 mths	1500		Oxfordshire	R667	r667	UoL	Excess stock, healthy bird, black-red (partridge). No spurs
Japanese bantam, Black- tailed White	m	ca. Jan 2013	17/05/2014	14 mths	770		Oxfordshire	R668	r668	UoL	Surplus stock, good example of breed but damaged comb

All mode	rn chic	kens									
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	14 mths	2410		County Durham	R670	r670	UoL	Wrong plumage
Dorking, Red	f		06/07/2014	27 mths	2155		Herefordshire	R723	r723	UoL	Bumble foot

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Dorking, Red	f		07/07/2014	16 mths	2365		Herefordshire	R724	r724	UoL	Found dead; no visible symptoms
Indian Game	f		09/10/2014	5 yrs	2610		Dorset	R725	r725	UoL	Died of natural causes, looks like a blocked gut. In lay
Indian Game	m		11/11/2014	5.5 mths	2935		Herefordshire	R726	r726	UoL	Surplus stock

All mode	rn chic	kens									
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, Silver- spangled	f			2-3 yrs	885			R728	r728	UoL	Surplus stock. This hen has spurs
Hamburg h Bantam, Silver- spangled	f			2-3 yrs	755			R729	r729	UoL	Surplus stock
Hamburg h Bantam, Silver- spangled	f			2-3 yrs	615			R730	r730	UoL	Surplus stock
Hamburg h Bantam, Silver- spangled	m			2-3 yrs	1020			R731	r731	UoL	Surplus stock. Perforation in sternum

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Oxford Game	m	ca. Apr 2012	15/04/2014	2 yrs	2565		Oxfordshire	R732	r732	UoL	Excess stock, healthy bird, sawn spurs (in case of fighting within flock - sawn off half- way, 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		11/11/2014	7 mths	4050		Herefordshire	R734	r734	UoL	Surplus stock.

All mode	rn chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Oxford Game	m	ca. Apr 2013	15/04/2014	12 mths	1605		Oxfordshire	R735	r735	UoL	Excess stock, healthy bird, small spurs
Hamburg h, Silver- spangled	m		23/10/2014	2 yrs	2690		Essex	R736	r736	UoL	Full-size bird. Surplus breeding stock. Non- metric trait - hole in sternum
Hamburg h, Silver- spangled	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, Silver- spangled	m		09/09/2014	5 mths	2335		Essex	R741	r741	UoL	Full-size bird, surplus stock. Wavy sternum crest and perforation in sternum

All mode	rn chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Hamburg h, Silver- spangled	f		13/01/2014	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			l yr		Naomi Sykes		unkno wn	s003	NS	"Redwick". Never laid any eggs
Silkie	m							S/2007. 93.10	t007	NHM	
Rhode Island	m							S/1999. 43.53	t019	NHM	
Leghorn	m							S/1999. 43.56	t022	NHM	
Kulm	m							S/1952. 3.51	t023	NHM	
Kulm	m							S/1952. 3.52	t024	NHM	
Sussex, Light	f							S/1999. 43.57	t026	NHM	
Sussex, Light	f							S/2009. 1.52	t027	NHM	

All mode	nodern chickens											
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes	
Sussex, Light	f							S/1999. 43.44	t028	NHM		
Silkie	f							S/1999. 43.41	t032	NHM		
Silkie	m							S/1999. 43.47	t034	NHM		
Crested Rump- less Turkish, White	x							S/1952. 2.104	t040	NHM	Cannot find info on sex of this bird, despite lengthy search of Darwin's publications and correspondence.	
Game	m							1868.2. 19.75	t041	NHM		
Sultan	f							1868.2. 19.88	t042	NHM		
Cochin	m							1868.2. 19.70	t046	NHM		
Sultan	m							1868.2. 19.72	t048	NHM		
Spanish	m							1868.2. 19.71	t049	NHM		
"wild" RJF	m							1868.2. 19.59	t059	NHM		
Hamburg h, Gold-	m							1868.2. 19.56	t060	NHM		

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
pencilled											
Dorking	m							1868.2. 19.54	t065	NHM	
Red Jungle Fowl	f			31 wks	734			S/2009. 1.42	t143	NHM	Assessed as skeletally mature by Thomas 2014
Red Jungle Fowl	m			32 wks	992			S/2009. 1.43	t 44	NHM	
Red Jungle Fowl	f							S/2009. 1.51	t145	NHM	
Red Jungle Fowl	m							S/1999. 43.58	t146	NHM	
Leghorn	f							S/1999. 43.36	t 47	NHM	
Old English Game Fowl	f		d. 23 Jul 1992			From the Walled Garden, EAU	University of York	EAU51 8	w518	UoY	
Red Jungle Fowl	f							EAU51 9	w519	UoY	
Dorking, Dark	m	Mar-85				Domestic Fowl Trust		EAU52 8	w528	UoY	Prepped May 1992

All mode	ern chic	kens									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Dorking, Silver- grev	f							EAU53 7	w537	UoY	
Sussex, Light	f	Apr-89				Domestic Fowl Trust		EAU53 8	w538	UoY	Prepped May 1992. No date of death
Old English Game Fowl	m					From the Walled Garden, EAU	University of York	EAU61 I	w611	UoY	"Jack Cock" 021193 (cull/prep date?)
Old English Game Fowl	m					From the Walled Garden, EAU	University of York	EAU61 2	w612	UoY	Bill the Chicken
Rhode Island Red	?f							1401	z002	UoS	No spurs or spur scars, pelvis fused, smaller than Tring RIR
Modern broiler	m	15/01/201 4	19/02/2014	35 days			North Linconshire	R650		UoL	

All modern chickons											
Aii mode		кепз									
Breed/ colour	Sex	Hatched	Culled/ died	Age	Wt (g)	Donor	Address	Acc no	ID	Collection	Notes
Red Jungle Fowl	m		1978			Whip- snade 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							S/1999. 43.36		NHM	
Sultan	f							1868.2. 19.88		NHM	
Malay	m			2 yrs					k001	KvG	Part-assembled skeleton - could not measure/photograph all elements

I.2 Non-chicken Galliformes

All modern non-chicken Galliformes								
S pecies	Sex	Weight (g)	Collection	Acc no	GMM ID	Notes		
Common pheasant	m		EH	4292	e015	Collected from Nottingham area. Coracoids not present, TBTs damaged, distal ends		
Common pheasant	f		EH	4294	e016	Collected Bridge of Allan, Stirlingshire. Left coracoid damaged, right used. L femur, prox sl damaged. TBTs broken, not photographed		
Common pheasant	m		EH	4295	e017	Collected Longformacus, Berwickshire, 1986. L femur broken, right used		
Common pheasant	m	1250	EH	2139	e018	Road casualty (M11, just north of M25 junction), Epping, Essex. 15/12/1988. Right coracoid missing, left is damaged and has slight lipping to cotyla scapularis		
Common pheasant	f		EH	2531	e019	Cambridgeshire 'No details taken at time of recording'		
Common pheasant	m	1500	EH	2742	e020	Collected Audley End, Essex. 5/10/91. Road casualty?		
Common pheasant	f		EH	2530	e026	Cambridgeshire		
Common pheasant	m		NHM	1904.2.2.1	t066			

All modern non-chicken Galliformes								
Species	Sex	Weight (g)	Collection	Acc no	GMM ID	Notes		
Common pheasant	m		NHM	S/1952.1.196	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/1979.29.1	t079			
Common pheasant	f		NHM	S/1994.54.1	t080			
Common pheasant	f		NHM	S/2011/18.1	t081			
Common pheasant	m		NHM	S/1997.77.1	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 (g)	Collection	Acc no	GMM ID	Notes		
Common pheasant	f		NHM	S/1977.107.1	t089			
Common pheasant	f		NHM	S/1999.43.210	t090			
Common pheasant	f		NHM	S/1985.30.1	t092			
Common pheasant	?f*	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 C1239		
Common pheasant	f		UoS	1496	z006	Partial skeleton. Tony Legge collection P1.2		
Common pheasant	m		UoS	1498	z007	Partial skeleton. Tony Legge collection P1.2		
Common pheasant	f		UoS	1562	z008			
Common pheasant	m		AF	AF	a004	Road casualty, A15 near Aswarby Park, Sleaford. NG34 8SA		
Guinea fowl	f		EH	1512	e021	Coracoid basal facet very broad and deep		

All modern non-chicken Galliformes

Species	Sex	Weight (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	All modern non-chicken Galmormes									
<u> </u>										
Species	Sex	(g)	Collection	Acc no	GMM ID	Notes				
Black grouse	m		NHM	S/1984.54.1	t126					
Black grouse	f		NHM	S/1952.2.20	t128					
Black grouse	f		NHM	1905.10.20.1	t136					
Black grouse	m		UoY	EAU614	w614					
Black grouse	f		UoY	EAU615	w615					
Black grouse	m		UoY	EAU797	w797					
Black grouse	f		UoS	1729	z009	Partial skeleton.				
Black grouse	m		UoS	266	z010					
Appendix B: Biometrical data – modern chickens

2.1 Coracoid

2.1.1 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	metri	cs				
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	h011	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	metri	cs				
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	metri	cs				
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	x	t040	11.87	9.90	47.42	44.50

Modern breed coracoi	d metri	cs				
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

2.1.2 Measurement ratios

Mode	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			

Mode	rn coracoid m	neasui	rement ra	tios				
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
r741	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	28.01	28.64	22.47	22.98
t143	RJF	f	94.86	80.50	27.04	28.50	21.77	22.95
t 44	RJF	m	95.85	81.57	25.61	26.72	20.89	21.79
t 46	RJF	m	94.92	85.83	26.36	27.77	22.63	23.84
w518	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		
w519	RJF	f	94.99	77.81	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		
w611	O E Game	m	95.53	87.97	25.78	26.98	22.67	23.73		
w612	O E Game	m	95.20	84.23	28.16	29.58	23.72	24.91		
z001	RJF	m	94.12	80.09	27.25	28.95	21.82	23.19		

2.2 Humerus

2.2.1 Standard metrics

Modern breed humerus metrics									
GMM ID	Breed	Sex	Bd	Вр	GL	SC			
a001	Poland bantam	m	16.15	19.84	76.98	7.20			
a002	Poland bantam	m	14.94	18.39	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	Вр	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				
h010	Maran	m	23.17	29.72	105.77	10.17				

Modern b	Modern breed humerus metrics									
GMM ID	Breed	Sex	Bd	Вр	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	Вр	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	Вр	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					
t 44	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	Вр	GL	SC					
t146	Red Jungle Fowl	m	13.73	17.67	69.78	5.99					
t 47	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					
k164	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	28.51	23.17	34.85	42.88			
e001	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			

Mode	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				
t 44	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				
t 46	RJF	m	77.7	8.58	25.32	19.68	33.9	43.63				
t 47	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			
w611	O E Game	m	77.58	9.59	26.05	20.21	36.8	47.44			
w612	O E Game	m	79.94	9.62	26.49	21.18	36.3	45.41			
z001	RJF	m	79.95	9.46	25.68	20.53	36.82	46.05			

2.3 Femur

2.3.1 Standard metrics

Modern b	Modern breed femur metrics										
GMM ID	Breed	Sex	Bd	Вр	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 b	Modern breed femur metrics											
GMM ID	Breed	Sex	Bd	Вр	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			
h011	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 b	Modern breed femur metrics											
GMM ID	Breed	Sex	Bd	Вр	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			
r 667	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 b	reed femur metrics								
GMM ID	Breed	Sex	Bd	Вр	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
r 7 28	Hamburgh bantam	f	12.19	12.54	9.79	7.89	65.83	60.95	5.76
r 729	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
r 74 0	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 b	Modern breed femur metrics										
GMM ID	Breed	Sex	Bd	Вр	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	x	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	.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 b	Modern breed femur metrics										
GMM ID	Breed	Sex	Bd	Вр	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	81.65	8.77		
w611	Game Fowl	m	17.58	18.01	14.48	11.97	89.57	83.61	8.06		
w612	Game Fowl	m	18.28	19.04	15.68	13.42	93.11	86.90	8.42		
z001	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		
k164	Krüper	m	19.57	19.37	16.57	14.20	79.49	73.69	7.85		

2.3.2 Measurement ratios

Mode	rn femora me	easure	ement ra	tios												
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
h011	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

Mode	rn femora me	easure	ement ra	tios												
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

Mode	rn femora me	easure	ement ra	tios												
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	86.5 I	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	40.5 I	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

2.4.1 Standard metrics

Modern b	reed tibiotarsus metr	rics						
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
e011	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 b	reed tibiotarsus metric	S						
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
h 009	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
h011	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
r651	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 b	reed tibiotarsus metri	cs						
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 b	reed tibiotarsus metrics	5						
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	х	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 b	reed tibiotarsus metri	cs						
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
t 43	Red Jungle Fowl	f	9.09	9.44	15.99	88.57	85.26	5.12
t 44	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
t 46	Red Jungle Fowl	m	10.56	11.23	19.71	108.46	103.78	6.12
t 47	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

Mode	rn tibiotarsi ı	neası	iremen	t ratios													
	breed/		Bd/	Bd/	Dd/	SC/	SC/	Bd/	Dd/	SC/	Bd/	Dd/	Dip/	SC/	Dip/	La/	SC/
ID	type	sex	Dip	GL	GL	Bd	GL	La	La	La	Dd	Dip	GL	Dip	La	GL	Dd
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	65.3 I	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

Mode	rn tibiotarsi r	neası	iremen	t ratios													
	breed/		Bd/	Bd/	Dd/	SC/	SC/	Bd/	Dd/	SC/	Bd/	Dd/	Dip/	SC/	Dip/	La/	SC/
ID	type	sex	Dip	GL	GL	Bd	GL	La	La	La	Dd	Dip	GL	Dip	La	GL	Dd
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
t 44	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
t 46	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
t 47	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

Mode	rn tibiotarsi r	neasu	iremen	t ratios													
	breed/		Bd/	Bd/	Dd/	SC/	SC/	Bd/	Dd/	SC/	Bd/	Dd/	Dip/	SC/	Dip/	La/	SC/
ID	type	sex	Dip	GL	GL	Bd	GL	La	La	La	Dd	Dip	GL	Dip	La	GL	Dd
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

2.5.1 Standard metrics

Modern b	reed tarsometatarsus me	etrics					
GMM ID	Breed	Sex	Bd	Вр	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	١7.89
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	Вр	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				
h00 l	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	4.4	10.62	12.83			
h011	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				
k001	Malay	m	25.97	26.05	146.74	14.13				

Modern breed tarsometatarsus metrics										
GMM ID	Breed	Sex	Bd	Вр	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	Вр	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			
r 729	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	77.41	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	Вр	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	x	11.99	11.93	63.16	6.54				
t041	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			
t 47	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	Вр	GL	SC	Spur Length		
z001	Red Jungle Fowl	m	13.09	14.65	73.51	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												
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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	7.9	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				
t041	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	
t143	RJF	f	105.42	46.45	8.26	16.86	17.77	48.97	
t 44	RJF	m	102.63	50.60	8.62	16.60	17.04	51.93	
t145	RJF	f	94.22	51.33	8.98	18.57	17.50	48.36	
t 46	RJF	m	100.98	50.68	8.67	16.94	17.11	51.18	
t 47	Hamburgh	f	97.11	49.74	8.57	17.75	17.23	48.30	
w518	O E Game	f	101.75	48.78	9.13	18.40	18.73	49.63	
w519	RJF	f	92.80	44.78	7.68	18.49	17.15	41.55	
w528	Dorking	m	100.50	47.17	9.49	20.02	20.13	47.41	
w537	Dorking	f	105.71	48.25	9.85	19.31	20.41	51.00	
w611	O E Game	m	104.82	47.73	7.84	15.66	16.41	50.03	
w612	O E Game	m	98.58	51.98	8.45	16.50	16.26	51.24	
z001	RJF	m	89.35	54.24	9.66	19.93	17.81	48.46	

2.6 Pelvis metrics

Modern breed pelvis measurements												
Breed	Sex	GMM ID	AA	BA	СВ	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	СВ	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	d150	45.02	59.45	38.60	9.01	110.43	99.21	75.84	29.75	25.23	38.47
Tigray ecotype	m	d148	43.76	57.49	36.53	9.86	108.10	97.47	73.85	28.58	24.00	35.17
Tigray ecotype	m	d175	41.10	54.08	36.54	9.41	99.45	93.81	80.64	28.26	22.14	37.25
Tigray ecotype	m	d 3	51.75	63.50	43.72	9.39	119.46	112.97	84.43	34.49	29.80	38.41
Tigray ecotype	m	d156	42.35	54.81	54.81	9.79	105.56	100.96	75.26	28.21	28.91	44.32
Tigray ecotype	m	d172	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	d178	45.82	58.93	37.58	8.71	104.97	95.49	74.47	29.44	25.33	43.31
Tigray ecotype	m	d180	42.29	53.22	37.91	9.28	103.43	98.95	74.90	28.85	22.76	37.55
Tigray ecotype	f	d105	42.62	52.73	33.81	7.28	92.78	88.32	71.66	30.25	25.76	38.95
Tigray ecotype	f	d145	43.46	55.66	31.04	8.44	97.49	90.07	69.8	26.47	34.11	44.66
Tigray ecotype	f	d163	42.99	53.90	32.34	8.42	101.06	90.23	73.11	28.53	31.20	42.08
Tigray ecotype	m	d135	44.46	56.26	35.61	9.11	106.97	100.66	84.26	28.10	28.19	36.92
Tigray ecotype	f	d177	39.34	48.35	33.34	7.88	91.06	85.71	64.97	27.23	28.01	41.97
Tigray ecotype	m	d146	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

2.6.1 MANOVA test results

MANOVA test results of three pelvic metric analyses									
	Metrics Group A	Metrics Group B	Metric Group C						
Wilks' lambda:	0.5941	0.367	0.2794						
dfl:	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):	0.00381**	0.0001031***	0.00003***						

2.7 Furcula

Modern breed furcula	Modern breed furcula measurements											
Breed	ID	Туре	Sex	Wt (g)	Wt cat.	Flying ability	10%	50%	100%	10mm	Length	Width
Silkie	t032	Silkie	f		0	0	107.56	48.78	30.89	73.72	37.83	24.85
Silkie	t034	Silkie	m		0	0	89.10	48.23	32.56	72.59	47.82	31.88
Silkie	t007	Silkie	m		0	0	97.66	50.85	33.82	76.36	45.32	31.50
Hamburg bantam	r729	Bantam	f	755	0	3	102.08	61.78	39.11	80.23	33.64	26.69
Poland	a001	Crested	m	935	0	1	81.47	48.58	32.81	67.81	46.58	31.90
Japanese bantam	r668	Bantam	m	770	0	2	103.50	53.78	34.86	72.76	34.35	23.51
Silkie	r661	Silkie	f	710	0	0	97.10	50.94	28.79	72.69	37.78	23.37
Hamburg bantam	r730	Bantam	f	615	0	3	104.50	60.91	39.46	76.71	32.44	26.09
Japanese bantam	r652	Bantam	m	766	0	2	105.76	51.73	32.50	72.14	36.21	23.01
Hamburg bantam	r728	Bantam	f	885	0	3	96.82	53.71	37.53	71.68	36.90	27.50
Rosecomb	h009	Bantam	m		0	2	78.48	46.78	33.43	65.16	46.95	31.70
Silkie	h003	Silkie	f		0	0	90.15	45.96	34.24	65.96	40.33	27.77
Poland	h002	Crested	m	794	0	1	88.33	46.83	31.75	69.60	46.32	29.73
Red Junglefowl	t059	Bantam	m		I	3	95.03	46.87	27.72	72.71	45.77	27.12
Dorking	e001	DPH	f	1800	I	2	92.51	43.61	30.51	76.25	54.19	34.42
Araucana bantam	e009	Bantam	m	1610	I	3	95.53	41.97	25.04	72.19	49.23	28.16
Freisian bantam	e008	Bantam	m	1500	I	3	114.92	57.79	33.70	93.34	47.08	31.72
Poland	e011	Crested	m	1790	I	1	89.85	47.31	30.08	73.54	48.94	32.08

Modern breed furcula measurements												
Breed	ID	Туре	Sex	Wt (g)	Wt cat.	Flying	10%	50%	100%	10mm	Length	Width
						ability						
Poland	e012	Crested	m	1455	I	I	108.22	49.75	31.33	82.84	51.26	33.04
Dorking	r727	DPH	m	1678	I	2	88.54	49.89	31.68	72.04	45.04	31.29
OE Game	r667	OE Game	f	1500	I	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	I	2	81.54	46.21	28.75	68.97	48.81	30.35
Silver-Spangled Hamburgh	r651	Egg-type	m	1585	I	3	91.87	51.01	40.38	73.90	45.35	37.48
Silver-Spangled Hamburgh	r742	Egg-type	f	1425	I	3	90.16	48.40	33.44	72.94	47.47	32.62
Poland	r655	Crested	m	1115	I	I	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	I	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	I	I	87.67	50.39	33.57	71.96	41.89	30.14
Poland	j005	Crested	m	1125	I	I	94.95	51.21	32.18	74.77	42.07	28.23
Silkie	r660	Silkie	f	1455	I	0	93.20	47.96	29.94	71.71	41.20	26.15
Poland	j006	Crested	m	1210	I	I	102.00	56.29	32.62	83.33	43.52	28.93
Hamburg bantam	r731	Bantam	m	1020	I	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		I	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		I	I	93.96	50.77	36.19	73.86	45.44	33.04

Modern breed furcula measurements												
Breed	ID	Туре	Sex	Wt (g)	Wt cat.	Flying	10%	50%	100%	10mm	Length	Width
						ability						
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	r741	Egg-type	m	2335	2	3	96.28	45.18	34.89	75.69	54.44	37.23
Lakenvelder	r 659	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	I	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	w611	OE Game	m		2	2	104.45	50.17	35.56	84.07	49.30	37.63

Modern breed furcula measurements												
Breed	ID	Туре	Sex	Wt (g)	Wt cat.	Flying	10%	50%	100%	10mm	Length	Width
						ability						
Spanish	t049	Egg-type	m		3	I	100.71	53.34	38.31	82.40	57.56	44.39
Sussex	t028	DPH	f		3	I	103.06	48.32	32.62	75.95	45.72	31.30
Kulm	t023	Asian G	m		4	I	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	I	83.07	42.59	30.65	71.56	58.37	39.42
Shamo	r658	Asian G	m	4320	4	I	106.71	59.71	48.34	96.26	66.21	64.46
Shamo	r657	Asian G	m	3860	4		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	I	98.15	46.89	27.46	75.91	49.68	29.57

Modern breed furcula measurements												
Breed	ID	Туре	Sex	Wt (g)	Wt cat.	Flying	10%	50%	100%	10mm	Length	Width
						ability						
Marans	h007	DPH	m		3	I	94.36	52.92	41.44	78.63	51.91	46.03
Marans	h010	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. R159)									
Element	GL	Log10							
humerus	74.00	1.8692							
coracoid	57.30	I.7582							
ulna	75.00	1.8751							
femur	85.20	1.9304							
tibiotarsus	116.40	2.0660							
tarsometatarsus	76.90	1.8859							

Appendix C: Biometrical data – archaeological chickens

3.1 Uley

3.1.1 Uley coracoid

3.1.1.1 Standard metrics - coracoid

Uley - cora	coids									
Site code/ area	Context	Phase	ID	Meas. ratio	GMM	Side	Bb	Bf	GL	Lm
WH77 B2	12	6b	U004	у	у	r	15.52	12.67	52.73	50.03
WH77	22	5e	U023	У	У	r	15.76	12.31	55.28	52.32
WH77	37	5e	U025	у	у	I	14.44	12.18	52.68	49.87
WH77	47	?	U031	у		r	15.36	12.9	57.8	55.42
WH77	72	5e	U040	У	У	r	15.59	12.73	59.38	56.86
WH77	126	5a-d	U043	у	у	r	15.94	12.71	58.86	56.24
WH77	136	5e	U050	у	у	I	15.78	12.07	54.91	52.36
WH77	136	5e	U051			r	15.14	12.23	56.38	53.66
WH77	155	5e	U057	У	У	r	14.8	12.12	57.85	55.21
WH77	164	5e	U061	у	у	I	15.43	12.34	52.03	49.52
WH77	164	5e	U062			r	15.57	12.73	51.75	49.14
WH77	187	5e	U075	У	У	I	15.02	12.51	56.54	52.93
WH77	320	4 a	U091	у		r	15.91	12.77	53.22	50.54

Uley - cora	coids									
Site code/ area	Context	Phase	ID	Meas. ratio	GMM	Side	Bb	Bf	GL	Lm
WH77	331	6b	U096	у		r	15.39	12.69	54.25	51.92
WH77	348	4b	U110	у	у	r	14.83	11.66	58.71	56.33
WH77	369	4b	UII7	у	У	r	15.36	13.69	57	54.46
WH78	681	5b	UI2I	у		I	14.17	11.88	53.2	51.03
WH78	820a	4b	UI27	у	У	I	11.54	9.79	46.86	44.69
WH78	616	?	UI 39	у	у	I	13.99	11.01	52.19	49.38
WH78	634	5a-c	UI51	у	у	I	14.94	12.35	54.79	52.22
WH79	02 layer	?	U163	у		r	13.22	10.99	50.9	47.91
WH79	9	5d-6b	U180	у	у	I	15.09	12.68	57.47	55.22
WH79	9	5d-6b	U186	у	у	I	14.63	12.31	58.79	55.98
WH78	820a	4b	U198	у		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	78.11	28.51	30.12	22.27	23.53						
U25	94.67	84.35	27.41	28.96	23.12	24.42						
U31	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	26.81	20.95	21.95							
U61	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							
U91	94.96	80.26	29.89	31.48	23.99	25.27							
U96	95.71	82.46	28.37	29.64	23.39	24.44							
U110	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							
UI 39	94.62	78.70	26.81	28.33	21.10	22.30							
UI5I	95.31	82.66	27.27	28.61	22.54	23.65							
U163	94.13	83.13	25.97	27.59	21.59	22.94							
U180	96.08	84.03	26.26	27.33	22.06	22.96							
U186	95.22	84.14	24.89	26.13	20.94	21.99							
U198	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 - hum	eri									
Site code/ area	Context	Phase	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc
WH77 B2	12	6 b	U003	r	у	у	14.28	18.85	69.99	6.34
WH77 B2	148	5c-d	U007	r	у		15.77	19.65	73.51	7.39
WH77 B2	148	5c-d	U010	1	у	у	16.66	20.45	76.47	7.07
WH77	22	5e	U021	I	у		14.60	18.57	71.77	7.32
WH77 BI	69	5e	U034	Ι	у	у	13.60	17.48	68.03	6.89
WH77 BI	69	5e	U035	r	у	у	14.78	19.01	72.43	6.82
WH77	155	5e	U055	I	у	у	16.64	20.07	73.42	8.08
WH77	164	5e	U063	I			14.95	19.26	58.74	6.80
WH77	164	5e	U064	r			14.93	20.79	58.64	6.86
WH77	165	5a-b	U071	r	у	у	15.66	19.78	69.77	7.09
WH77	165	5a-b	U072	r	у	у	16.97	21.31	78.48	7.38
WH77	187	5e	U076	I			15.26	18.68	60.63	7.01
WH77	300	6b	U077	r	у	у	16.32	19.92	74.84	7.08
WH77	302	4 a	U081	I	у	у	16.39	20.19	75.83	7.83
WH77	331	6b	U097	r	у	у	16.12	20.36	73.60	6.91
WH77	348	4b	U109	r	у	у	15.51	19.43	73.32	7.20
WH78	878	?	UI24	I	у	у	14.94	18.80	69.58	6.83

	1	1	1	1		1	1	1	1	r —
Site code/ area	Context	Phase	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc
WH78	820a	4b	UI28	I	у	у	15.32	18.78	70.30	6.70
WH78	820a	4b	UI29	I	у	у	14.44	17.44	66.73	6.23
WH78	634	5а-с	UI48	r	у	у	16.72	21.29	76.45	7.71
WH78	634	5а-с	UI49	I	у	у	15.48	18.88	72.54	6.77
WH78	726	3	UI55	I	у	у	13.48	17.24	63.29	5.97
WH78	813	4b	UI58	I	у	у	13.27	16.78	63.20	6.01
WH79	406	7	UI67	r	у	у	15.13	19.77	71.82	7.16
WH79	1228	5a-b	UI75	r	у		14.71	18.52	72.35	6.89
WH79	1224	4b	U178	r	у		15.90	19.63	75.49	7.14
WH79	1191	5d-6b	UI87	I	у		14.70	18.81	72.75	7.16

3.1.2.2 Measurement ratios – humerus

Uley hu	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							
U21	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	20.41	35.88	46.14						
U55	82.91	11.01	27.34	22.66	40.26	48.56						
U71	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						
U81	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						
U109	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						
U187	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. Ratio	Bd	Вр	Dd	Dp	GL	Lm	sc		
WH77 B2	148	5c-d	U013	I	у	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	5e	U022	r	у	16.37	16.50	13.15	11.30	80.20	76.07	7.19		
WH77	136	5e	U048	r	у	15.86	15.79	12.79	9.92	81.13	76.60	6.93		
WH77	136	5e	U049	I	у	15.51	15.37	12.73	10.43	79.72	74.56	7.30		
WH77	164	5e	U065	I		15.14	14.47	12.33	10.65	65.32	60.48	5.95		
WH77	164	5e	U066	r		15.09	14.55	12.61	10.63	65.92	60.84	6.15		
WH77	302	4 a	U082	r	у	16.30	16.66	13.68	11.34	84.59	78.53	7.70		
WH77	348	4b	U089	r	у	16.51	16.38	12.72	11.23	84.07	79.25	7.24		
WH77	325	4b	U094	r	у	14.78	15.27	11.73	10.27	77.72	73.28	6.65		
WH77	341	6 to 7	UI04	r	у	15.26	15.95	13.48	10.34	82.75	77.77	7.25		
WH77	348	4b	UIII	r	у	14.97	15.50	11.96	10.51	79.79	74.95	7.02		
WH77	354	4b	UII3	r	у	15.97	15.94	12.49	10.82	81.08	75.22	7.28		
WH77	368	6b	UII6	r	У	15.64	14.94	12.23	10.33	77.17	71.89	6.66		
WH78	682	4a	UI23	I	У	14.76	15.67	12.27	10.54	81.75	76.44	6.55		
WH78	823	4a	UI45	I	У	16.70	16.25	13.71	11.30	81.65	76.47	7.61		
WH79	9	5d-6b	U165	r	У	15.86	15.61	12.65	10.74	79.43	74.47	7.24		

Uley - femora												
Site code/ area	Context	Phase	ID	Side	Meas. Ratio	Bd	Вр	Dd	Dp	GL	Lm	sc
WH79	180	3b	UI73	r	у	14.65	15.53	12.79	10.06	77.86	72.10	7.05
WH79	9	5d-6b	U190	r	у	14.94	15.76	12.22	10.23	79.93	75.22	7.03
WH77	386	?	UI94	r	у	14.85	14.45	12.35	10.22	76.87	72.09	6.57

3.1.3.2 Measurement ratios – femur

Uley fe	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	15.35	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	15.76	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	15.97	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	15.09	16.01	56.69
U104	88.34	47.51	8.76	18.44	19.27	19.62	20.51	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	17.01	54.46
UI23	83.13	44.38	8.01	18.06	19.17	19.31	20.50	8.57	41.80	78.30	85.90	15.01	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
U165	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
U173	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

3.1.4 Uley tibiotarsus

3.1.4.1 Standard metrics - tibiotarsus

Uley - tibio	Uley - tibiotarsi													
Site code/ area	Context	Phase	ID	Side	Meas. Ratio	GMM	Bd	Dd	Dip	GL	La	sc		
WH77 B2	148	5c-d	U009	I			11.79	12.34						
WH77 B2	148	5c-d	U011	r	У	У	10.62	11.84	20.12	115.02	110.98	6.12		
WH77	47	?	U028	I	У		11.95	12.33	22.13	116.51	112.24	6.73		
WH77	47	?	U029	I	У	У	11.41	11.47	20.5	109.78	106.45	6.16		
WH77	332	4b	U102	r	У		12.36	12.81	22.65	117.86	113.98	6.64		
WH79	9	5d-6b	U189	r				12.89				5.84		

3.1.4.2 Measurement ratios – tibiotarsus

Uley tit	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
U102	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

Site code/ area	Context	Phase	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length
WH77 B2	148	5c-d	U012	r				14.23	80.25	6.83	19.32
WH77	20	5e	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	5e	U067	I			13.01	12.19	52.82	7.49	18.10
WH77	302	4 a	U079		у	у	13.39	13.62	80.78	6.68	22.51
WH77	302	4 a	U080	I	у	у	13.31	13.58	81.80	6.72	

Uley - tarsor	netatarsi										
Site code/ area	Context	Phase	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length
WH77	341	6 to 7	U105	r	у	у	12.80	14.71	82.70	6.74	20.62
WH77	354	4b	UII2	I	у	у	13.99	13.45	80.00	7.33	
WH78	634	5а-с	UI54	I	у		14.04	14.23	79.32	7.12	19.92
WH78	868	?	U156	I	у		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	U171	r	у	у	13.15	12.89	79.58	7.19	
WH79	1228	5a-b	UI77	I	у		13.71	13.66	84.47	7.15	19.92
WH79	9	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	98.31	49.89	8.27	16.86	16.58	49.05				
U80	m	98.01	50.49	8.22	16.60	16.27	49.48				
U105	m	87.02	52.66	8.15	17.79	15.48	45.82				
UII2	m	104.01	52.39	9.16	16.81	17.49	54.50				
UI54	m	98.66	50.71	8.98	17.94	17.70	50.04				
U156	m	92.97	49.96	8.39	18.07	16.80	46.45				
U171	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

3.2.1 Fishbourne coracoid

3.2.1.1 Standard metrics - coracoid

Fishbourne cor	acoids								
Site code/area	Context	ID	Ch. project ID	Meas. ratio	Side	Bb	Bf	GL	Lm
FB62	82	FBI	469	у	I	11.92	11.26	51.84	49.06
FB64	169	FB2	472	у	r	11.84	9.03	44.83	42.65
FB64	178	FB3	474	у	r	12.77	10.65	50.66	48.81
FB64	225	FB4	478	у	r	14.5	13.26	56.82	53.78
FB65	257	FB5	479	у	r	13.53	11.1	51.12	48.32
FB66	337	FB6	485	у	r	13.41	11.91	58.26	55.91
FB67	347	FB7	495	у	I	11.07	9.45	46.14	44.03
FB67	367	FB8	496	у	I	13.9	12.12	56.55	53.26
FB67	367	FB9	497	у	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	FB10	501	у	I	15.12	12.51	58.82	56.03			
FBE02	1030	FBII	517	у	r	11.76	11.25	48.13	45.46			
FBE02	1098.3	FB12	519	У	I	13.03	10.63	57.17	53.65			
FBE02	1098.3	FB13	520	У	r	12.62	10.29	48.33	46.24			
FBE99	907	FB14	525	У	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					
FB10	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					
FB12	93.84	81.58	22.79	24.29	18.59	19.81					
FB13	95.68	81.54	26.11	27.29	21.29	22.25					
FB14	96.20	92.87	23.49	24.42	21.82	22.68					

3.3 Lyminge

3.3.1 Lyminge coracoid

3.3.1.1 Standard metrics – coracoid

Lyminge -	Lyminge - coracoid												
Site code	Context	ID	GMM ID	Side	Meas. ratio	GMM	Bb	Bf	GL	Lm	GMM	ABG?	
/season													
LYM08	10	L005		r	у	у	13.33	10.89	48.02	46.33	у		
LYM08	106	L022		r			11.53	9.76	48.24	45.04	у		
LYM08	247	L054	l054ggxxxlcor	I	у	у	13.74	11.62	50.18	47.59	у		
LYM08	247	L055		I			13.78	11.68	50.92	48.69	у		
LYM08	247	L056		r	у		12.13	9.72	47.80	46.01	у		
LYM08	247	L057		r	у	у	12.75	10.77	48.62	46.22	у		
LYM08	273	LIOI		Ι	у		13.70	11.82	49.47	46.54	у		
LYM08	509	LII5		1	у		12.05	10.50	47.92	45.53	у		

Lyminge -	coracoid											
Site code	Context	ID	GMM ID	Side	Meas. ratio	GMM	Bb	Bf	GL	Lm	GMM	ABG?
/season												
LYM08	525	L127	1127ggxxxlcor	Ι	у	у	13.79	11.64	50.11	47.61	у	
LYM08	544	L134	1134ggxxxlcor	I	у	у	12.13	10.25	50.08	47.26	у	
LYM08	592	LI47	1147ggxxxrcor	r	у	у	14.95	13.24	55.25	52.63	у	
LYM08	616	L149		r	у		14.22	12.01	58.37	56.02	у	
LYM08	620	L152	1152ggxxxlcor	I	у	у	13.21	12.04	56.55	54.15	у	
LYM08	637	L162		I	у		14.29	11.48	53.60	50.91	у	
LYM08	642	L169	1169ggxxxlcor	I	у	у	14.09	11.33	49.03	46.11	у	
LYM08	684	L222	l222ggxxxlcor	I	у	у	12.54	10.91	47.74	45.37	у	
LYM08	684	L223		r			12.61	10.66	47.48	45.03	у	
LYM08	684	L224		I	у		11.62	9.97	49.61	46.88	у	
LYM08	684	L225		r			12.61	10.73	49.44	46.51	у	
LYM08	684	L226	l226ggxxxlcor	I	у	у	13.17	10.75	49.50	46.88	у	
LYM08	744	L273		r	у		14.43	11.30	55.57	53.51	у	
LYM09	1095	L340	l340ggxxxlcor	I	у	у	12.39	10.96	46.17	44.60	у	
LYM09	1095	L341	1341ggxxxlcor	I	у		12.34	9.77	47.40	45.60	у	
LYM09	1099	L346	l346ggxxxlcor	I	у	у	12.06	10.29	46.59	44.92	у	
LYM09	1228	L385		r	у		11.56	9.99	48.75	46.51	у	
LYM09	1296	L408	l408ggxxxrcor	r	У	у	13.83	10.97	49.35	46.87	у	
LYM09	1310	L421		I			13.20	11.05	50.75	48.13		
LYM09	1330	L477	l477ggxxxlcor	I	У	у	14.77	12.01	55.95	53.35	у	

Lyminge -	coracoid											
Site code	Context	ID	GMM ID	Side	Meas. ratio	GMM	Bb	Bf	GL	Lm	GMM	ABG?
/season												
LYM09	1332	L489		I			13.73	12.78	54.10	53.37		
LYM09	1332	L507		r	у		13.10	10.73	49.17	47.14	у	
LYM09	1332	L508		r	у		13.18	10.80	54.23	52.52	у	
LYM09	1332	L509	1509ggxxxlcor	I	у	у	12.76	9.52	48.57	46.91	у	
LYM09	1333	L519	1519ggxxxlcor	I	У	у	13.72	11.40	50.51	47.64	у	
LYM09	1333	L520		r			13.25	11.11	50.53	47.56	у	
LYM09	1399	L530	l530ggxxxlcor	I	У	у	15.23	12.17	56.19	53.19	у	
LYM09	1446	L537		I	У		14.60	12.58	56.10	53.73	у	
LYM09	1464	L560	1560ggxxxrcor	r	У	у	12.83	10.24	48.34	46.26	у	
LYM09	1514	L601		r			12.86	11.26	47.38	44.96		
LYM09	1544	L614		I	У		12.13	11.21	51.78	50.41	у	
LYM09	1564	L617	l617ggxxxrcor	r	У	у	13.90	12.33	56.22	53.14	у	
LYM09	1672	L702	l702ggxxxlcor	I	у	у	15.88	13.07	56.76	53.81	у	
LYM09	1672	L703	l703ggxxxlcor	I			11.45	9.16	47.21	47.19	у	
LYM09	1672	L708		r	у		12.70	9.99	48.54	45.90	у	
LYM09	1672	L710	1710ggxxxlcor	I	у	у	13.21	10.67	49.85	47.63	у	
LYM09	1672	L711		r	у		11.43	8.89	45.71	43.24	у	
LYM09	1672	L716		r	у		14.75	12.24	54.93	52.04	у	
LYM09	1705	L741	1741ggxxxlcor	Ι	у	у	15.15	13.97	53.86	50.82	у	
LYM09	1725	L759		Ι	у		15.52	13.32	60.72	58.17	у	

Lyminge -	coracoid											
Site code	Context	ID	GMM ID	Side	Meas. ratio	GMM	Bb	Bf	GL	Lm	GMM	ABG?
/season												
LYM09	1730	L781	1781ggxxxrcor	r	у	у	15.64	11.81	56.78	53.67	у	
LYM09	1730	L787		r	у		13.19	10.84	48.24	45.17	у	
LYM09	1730	L791	1791ggxxxlcor	1	у	у	13.23	10.45	48.40	45.88	у	
LYM09	1730	L797	1797ggxxxlcor	1	у	у	12.68	10.56	48.82	46.28	у	
LYM09	1817	L816	1816ggxxxrcor	r	У	у	15.92	13.53	57.07	54.54	у	
LYM09	1828	L823	l823ggxxxlcor	1	У	у	14.25	12.00	48.36	45.71	у	
LYM12	3226	L871		1			14.73	12.45	54.41	52.17		
LYM12	3242	L881	1881 ggxxxlcor	1	У	у	13.06	10.04	50.20	47.86	у	
LYMI2	3371	L893		r	У		15.02	12.99	58.42	54.34	у	
LYM12	3678	L901	1901 ggxxxlcor	1	У	у	15.24	12.93	55.21	52.41	у	
LYMI3	6256	L916	1916ggxxxrcor	r	У	у	13.56	11.90	56.93	54.18	у	
LYMI3	6256	L917	1917ggxxxrcor	r	У	у	12.71	10.05	49.54	47.01	у	
Lym08	680	ABGI	l255ggxxxlcor	1	У	у	13.42	10.58	49.01	46.28		ABGI
Lym08	680	ABGI		r			13.64	10.41	48.81	45.66		ABGI
Lym12	3695	ABG2	l249ggxxxlcor	I	У	у	15.44	11.79	57.78	55.08		ABG2
Lym12	3695	ABG2		r			15.63	12.33	57.56	55.22		ABG2
Lym09	1409	ABG3		r					44.45			ABG3
Lym08	582	ABG5P		1								ABG5P
Lym09	1482	ABG6		1								ABG6
Lym09	1600	ABG7	l228ggxxxlcor	1	у	У	13.40	10.80	49.40	46.70		ABG7

Lyminge -	coracoid											
Site code	Context	ID	GMM ID	Side	Meas. ratio	GMM	Bb	Bf	GL	Lm	GMM	ABG?
/season												
Lym09	1333	ABG8	l236ggxxxrcor	r	у	у	14.30	10.70	50.60	49.00		ABG8
Lym09	1312	ABG9		r	у		12.50	10.20	49.60	46.80		ABG9
Lym08	150	ABG10	1261ggxxxrcor	r	у	у	12.40	9.60	48.90	46.80		ABGI0
Lym09	1091	ABGII		r								ABGII

3.3.1.2 Measurement ratios - coracoid

Lyminge	coracoid	measu	rement r	atios		
ID	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
L5	96.48	81.70	27.76	28.77	22.68	23.51
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	95.01	87.14	25.15	26.47	21.91	23.06
L127	95.01	84.41	27.52	28.96	23.23	24.45
L134	94.37	84.50	24.22	25.67	20.47	21.69
L147	95.26	88.56	27.06	28.41	23.96	25.16

Lyminge	coracoid	measur	rement r	atios		
ID	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
L149	95.97	84.46	24.36	25.38	20.58	21.44
L152	95.76	91.14	23.36	24.40	21.29	22.23
L162	94.98	80.34	26.66	28.07	21.42	22.55
L169	94.04	80.41	28.74	30.56	23.11	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	94.71	81.62	26.61	28.09	21.72	22.93
L273	96.29	78.31	25.97	26.97	20.33	21.12
L340	96.60	88.46	26.84	27.78	23.74	24.57
L341	96.20	79.17	26.03	27.06	20.61	21.43
L346	96.42	85.32	25.89	26.85	22.09	22.91
L385	95.41	86.42	23.71	24.85	20.49	21.48
L408	94.97	79.32	28.02	29.51	22.23	23.41
Liii	94.84	83.71	26.01	27.43	21.77	22.96
L477	95.35	81.31	26.40	27.69	21.47	22.51
L507	95.87	81.91	26.64	27.79	21.82	22.76
L508	96.85	81.94	24.30	25.10	19.92	20.56
L509	96.58	74.61	26.27	27.20	19.60	20.29
L519	94.32	83.09	27.16	28.80	22.57	23.93
L530	94.66	79.91	27.10	28.63	21.66	22.88
L537	95.78	86.16	26.02	27.17	22.42	23.41

Lyminge	coracoid	measur	rement r	atios		
ID	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
L560	95.70	79.81	26.54	27.73	21.18	22.14
L614	97.35	92.42	23.43	24.06	21.65	22.24
L617	94.52	88.71	24.72	26.16	21.93	23.20
L702	94.80	82.30	27.98	29.51	23.03	24.29
L708	94.56	78.66	26.16	27.67	20.58	21.76
L710	95.55	80.77	26.50	27.73	21.40	22.40
L711	94.60	77.78	25.01	26.43	19.45	20.56
L716	94.74	82.98	26.85	28.34	22.28	23.52
L741	94.36	92.21	28.13	29.81	25.94	27.49
L759	95.80	85.82	25.56	26.68	21.94	22.90
L781	94.52	75.51	27.54	29.14	20.80	22.00
L787	93.64	82.18	27.34	29.20	22.47	24.00
L791	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
L816	95.57	84.99	27.90	29.19	23.71	24.81
L823	94.52	84.21	29.47	31.17	24.81	26.25
Lvi	95.88	84.52	27.07	28.23	22.88	23.86
L881	95.34	76.88	26.02	27.29	20.00	20.98
L893	93.02	86.48	25.71	27.64	22.24	23.91
L901	94.93	84.84	27.60	29.08	23.42	24.67
L916	95.17	87.76	23.82	25.03	20.90	21.96

Lyminge	coracoid	measu	rement r	atios		
ID	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
L917	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
LABG10	95.71	77.42	25.36	26.50	19.63	20.51

3.3.2 Lyminge humerus

3.3.2.1 Standard metrics - humerus

Site code/	Context	GMM	Side	Meas.	GMM	Bd	Вр	GL	SC
season		ID		Ratio					
LYM08	169	31	1	у	у	13.46	18.13	63.85	6.57
LYM08	215	37	I	у		13.91	17.83	63.29	6.6
LYM08	247	43	1	у	у	15.85	19.65	74.84	7.03
LYM08	247	44	I	у		12.89	16.02	59.94	5.72
LYM08	247	45	1	у	у	14.40	17.82	66.75	6.74
LYM08	247	46	r	у		14.26	18.03	66.60	6.7

Site code/ season Context GMM ID Side ID Meas. Ratio GMM Bd Bd Bp GL SC LYM08 247 47 r r y 13.74 17.27 64.11 LYM08 247 48 r y 15.82 19.55 74.96 LYM08 273 99 r y 13.60 16.46 61.50 LYM08 273 100 1 y y 13.44 18.62 66.15 LYM08 502 113 1 y 16.34 20.07 72.34 LYM08 509 116 r y 13.81 17.07 63.78 LYM08 642 168 1 y y 13.51 17.50 64.19 LYM08 661 199 1 y y 13.92 18.03 64.71 LYM08 684 227 r 13.92 17.90 64.88 9	Lyminge - hu	imerus								
season ID Ratio III Ratio LYM08 247 47 r y 13.74 17.27 64.11 LYM08 247 48 r y 15.82 19.55 74.96 LYM08 273 99 r y 13.60 16.46 61.50 LYM08 273 100 1 y y 13.94 18.62 66.15 LYM08 502 113 1 y 15.34 20.07 72.34 LYM08 509 116 r y 13.81 17.07 63.78 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 641 199 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 64.19 LYM08 684 228 1 13.92 17.90 64.88	Site code/	Context	GMM	Side	Meas.	GMM	Bd	Вр	GL	SC
LYM08 247 47 r y 13.74 17.27 64.11 LYM08 247 48 r y 15.82 19.55 74.96 LYM08 273 99 r y 13.60 16.46 61.50 LYM08 273 100 1 y y 13.94 18.62 66.15 LYM08 502 113 1 y y 15.34 20.07 72.34 LYM08 509 116 r y 16.34 20.15 74.89 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 1 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 1 y	season		ID		Ratio					
LYM08 247 48 r y 15.82 19.55 74.96 LYM08 273 99 r y 13.60 16.46 61.50 LYM08 273 100 1 y y 13.94 18.62 66.15 LYM08 502 113 1 y 15.34 20.07 72.34 LYM08 509 116 r y 13.81 17.07 63.78 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 1 y y 13.24 16.70 62.35 LYM08 661 199 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 17.90 64.88 64.71 LYM08 684 228 1 13.92 17.90 64.88 64.71 LYM08 684 230 1 y y 13.20 17.21 65.39 65.90	LYM08	247	47	r	у		13.74	17.27	64.11	6.50
LYM08 273 99 r y 13.60 16.46 61.50 LYM08 273 100 I y y 13.94 18.62 66.15 LYM08 502 113 I y I5.34 20.07 72.34 LYM08 509 116 r y 16.34 20.15 74.89 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 I y y 13.24 16.70 62.35 LYM08 661 199 I y y 13.92 18.03 64.71 LYM08 684 227 r 13.92 17.90 64.88 1 LYM08 684 229 r 13.12 17.31 65.13 1 LYM08 684 230 I y y 13.20 17.21 65.39 LYM08 684 230 I y y 13.65 17.41 65.90 1	LYM08	247	48	r	у		15.82	19.55	74.96	7.12
LYM08 273 100 I y y 13.94 18.62 66.15 LYM08 502 113 I y 15.34 20.07 72.34 LYM08 509 116 r y 16.34 20.15 74.89 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 I y y 13.51 17.50 64.19 LYM08 661 199 I y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 I 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 0 LYM08 684 230 I y y 13.20 17.21 65.39 0 LYM08 744 276 I y y 13.47 17.71 63.14 0 LYM08	LYM08	273	99	r	у		13.60	16.46	61.50	6.03
LYM08 502 113 I y 15.34 20.07 72.34 LYM08 509 116 r y 16.34 20.15 74.89 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 I y y 13.51 17.50 64.19 LYM08 661 199 I y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 I 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 I y y 13.65 17.41 65.90 LYM08 684 230 I y y 13.65 17.41 65.90 0 LYM08 744 276 I y y 13.27 17.67 68.31 0 LYM08 7	LYM08	273	100	1	у	у	13.94	18.62	66.15	6.33
LYM08 509 116 r y 16.34 20.15 74.89 LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 1 y y 13.51 17.50 64.19 LYM08 661 199 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 1 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 1 y y 13.65 17.41 65.90 LYM08 727 261 r y 13.65 17.41 65.90 66.31 LYM08 744 276 1 y y 13.27 17.67 68.31 68.31 LYM08 744 277 r 13.47 17.71 63.14 63.63 LYM09 1026 </td <td>LYM08</td> <td>502</td> <td>113</td> <td>1</td> <td>у</td> <td></td> <td>15.34</td> <td>20.07</td> <td>72.34</td> <td>7.16</td>	LYM08	502	113	1	у		15.34	20.07	72.34	7.16
LYM08 546 135 r y 13.81 17.07 63.78 LYM08 642 168 1 y y 13.51 17.50 64.19 LYM08 661 199 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 1 13.92 18.03 64.71 LYM08 684 228 1 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 1 y y 13.20 17.21 65.39 LYM08 727 261 r y 13.65 17.41 65.90 6 LYM08 744 276 1 y y 13.78 17.71 63.14 6 LYM08 744 277 r 13.47 17.67 68.31 6 LYM09 1026 306	LYM08	509	116	r	у		16.34	20.15	74.89	7.18
LYM08 642 168 1 y y 13.51 17.50 64.19 LYM08 661 199 1 y y 13.24 16.70 62.35 LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 1 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 229 r 13.20 17.21 65.39 LYM08 684 230 1 y y 13.65 17.41 65.90 LYM08 684 230 1 y y 13.65 17.41 65.90 66.90 LYM08 744 276 1 y y 13.47 17.71 63.14 63.14 LYM08 744 277 r 13.47 17.71 63.24 64.40 LYM09 1026 306 r y y 13.43 17.67 68.31 64.40 <tr< td=""><td>LYM08</td><td>546</td><td>135</td><td>r</td><td>у</td><td></td><td>13.81</td><td>17.07</td><td>63.78</td><td>6.00</td></tr<>	LYM08	546	135	r	у		13.81	17.07	63.78	6.00
LYM086611991yy13.2416.7062.35LYM08684227r13.9218.0364.71LYM08684228113.9217.9064.88LYM08684229r13.1217.3165.13LYM086842301yy13.2017.21LYM086842301yy13.6517.41LYM086842301yy13.6517.41LYM08727261ryy13.6517.41LYM087442761yy13.7817.71LYM08744277r13.4717.7163.24LYM091026306ryy13.4317.66LYM0911013661yy13.4317.8663.63LYM0911243691y12.9616.5658.091	LYM08	642	168	1	у	у	13.51	17.50	64.19	6.52
LYM08 684 227 r 13.92 18.03 64.71 LYM08 684 228 1 13.92 17.90 64.88 LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 1 y y 13.20 17.21 65.39 LYM08 684 230 1 y y 13.65 17.41 65.90 LYM08 727 261 r y y 13.65 17.41 65.90 LYM08 744 276 1 y y 13.78 17.71 63.14 LYM08 744 277 r 13.47 17.71 63.24 0 LYM09 1026 306 r y y 13.27 17.67 68.31 0 LYM09 1026 307 1 y y 13.43 17.86 63.63 0 LYM09 1101 366 1 y y 13.43 17.86 63.63 0 <td>LYM08</td> <td>661</td> <td>199</td> <td>1</td> <td>у</td> <td>у</td> <td>13.24</td> <td>16.70</td> <td>62.35</td> <td>6.40</td>	LYM08	661	199	1	у	у	13.24	16.70	62.35	6.40
LYM08 684 228 I I I I3.92 I7.90 64.88 LYM08 684 229 r I3.12 I7.31 65.13 LYM08 684 230 I y y I3.20 I7.21 65.39 LYM08 684 230 I y y I3.65 I7.41 65.90 LYM08 727 261 r y y I3.65 I7.41 65.90 LYM08 744 276 I y y I3.47 I7.71 63.14 LYM08 744 277 r I I3.47 I7.71 63.24 I LYM09 1026 306 r y y I3.47 I7.67 68.31 I LYM09 1026 307 I y y I3.43 I7.86 63.63 I LYM09 1101 366 I y Y I3.43 I7.86 63.63 I LYM09 1124 369 I <t< td=""><td>LYM08</td><td>684</td><td>227</td><td>r</td><td></td><td></td><td>13.92</td><td>18.03</td><td>64.71</td><td>6.59</td></t<>	LYM08	684	227	r			13.92	18.03	64.71	6.59
LYM08 684 229 r 13.12 17.31 65.13 LYM08 684 230 I y y 13.20 17.21 65.39 LYM08 727 261 r y y 13.65 17.41 65.90 LYM08 727 261 r y y 13.65 17.41 65.90 LYM08 744 276 I y y 13.78 17.71 63.14 LYM08 744 277 r 13.47 17.71 63.24 0 LYM09 1026 306 r y y 13.27 17.67 68.31 0 LYM09 1026 307 I y y 14.41 17.69 64.40 0 LYM09 1101 366 I y y 13.43 17.86 63.63 0 LYM09 1124 369 I y y 12.96 16.56 58.09 0	LYM08	684	228	1			13.92	17.90	64.88	6.79
LYM08 684 230 I y y I3.20 I7.21 65.39 LYM08 727 261 r y I3.65 I7.41 65.90 LYM08 744 276 I y y I3.78 I7.71 63.14 LYM08 744 277 r I y y I3.47 I7.71 63.24 LYM08 744 277 r I 13.47 I7.71 63.24 1 LYM09 1026 306 r y y I3.27 I7.67 68.31 0 LYM09 1026 307 I y y I4.41 I7.69 64.40 0 LYM09 1101 366 I y y I3.43 I7.86 63.63 0 LYM09 1124 369 I y y I2.96 I6.56 58.09 0	LYM08	684	229	r			13.12	17.31	65.13	6.23
LYM08 727 261 r y 13.65 17.41 65.90 LYM08 744 276 I y y 13.78 17.71 63.14 LYM08 744 277 r 13.47 17.71 63.24 1 LYM09 1026 306 r y y 13.27 17.67 68.31 LYM09 1026 307 I y y 14.41 17.69 64.40 1 LYM09 1101 366 I y y 13.43 17.86 63.63 1 LYM09 1124 369 I y y 12.96 16.56 58.09 1	LYM08	684	230	1	у	у	13.20	17.21	65.39	6.23
LYM08 744 276 I y y I3.78 I7.71 63.14 LYM08 744 277 r I3.47 I7.71 63.24 I LYM09 1026 306 r y y I3.27 I7.67 68.31 LYM09 1026 307 I y y I4.41 I7.69 64.40 LYM09 1101 366 I y y I3.43 I7.86 63.63 I LYM09 1124 369 I y y I2.96 I6.56 58.09 I	LYM08	727	261	r	у		13.65	17.41	65.90	6.15
LYM08 744 277 r I3.47 I7.71 63.24 LYM09 1026 306 r y I3.27 I7.67 68.31 LYM09 1026 307 I y y I4.41 I7.69 64.40 LYM09 1101 366 I y y I3.43 I7.86 63.63 LYM09 1124 369 I y y I2.96 I6.56 58.09 6	LYM08	744	276	1	у	у	13.78	17.71	63.14	6.50
LYM09 1026 306 r y 13.27 17.67 68.31 LYM09 1026 307 I y y 14.41 17.69 64.40 LYM09 1101 366 I y y 13.43 17.86 63.63 LYM09 1124 369 I y 12.96 16.56 58.09 64.40	LYM08	744	277	r			13.47	17.71	63.24	6.51
LYM09 I026 307 I y y I4.41 I7.69 64.40 LYM09 I101 366 I y y I3.43 I7.86 63.63 LYM09 I124 369 I y I2.96 I6.56 58.09	LYM09	1026	306	r	у		13.27	17.67	68.31	6.33
LYM09 I 101 366 I y y I 3.43 I7.86 63.63 LYM09 I 124 369 I y I 2.96 I 6.56 58.09 I	LYM09	1026	307	1	у	у	14.41	17.69	64.40	6.52
LYM09 1124 369 I y 12.96 16.56 58.09	LYM09	1101	366	1	у	У	13.43	17.86	63.63	6.29
	LYM09	1124	369	1	у		12.96	16.56	58.09	6.01

Site code/ season Context GMM ID Side ID Meas. Ratio GMM GM Bd Bp GL LYM09 1148 371 r y 13.37 17.79 63.85 LYM09 1284 400 r y 13.54 16.70 64.40 LYM09 1297 412 r y 13.31 17.18 62.51 LYM09 1310 441 1 y y 13.60 17.92 61.53 LYM09 1312 453 r y 13.60 17.93 66.16 LYM09 1332 478 r y 13.89 17.69 61.60 LYM09 1332 479 1 y 13.38 16.75 62.94 LYM09 1332 486 1 y 13.38 16.75 62.94 LYM09 1592 645 r y 13.39 16.57 59.36 LYM09 1592	Lyminge - hu	imerus								
season ID Ratio III III Press Press IIII IIIII IIIIII IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII	Site code/	Context	GMM	Side	Meas.	GMM	Bd	Вр	GL	SC
LYM091148371ry13.3717.7963.85LYM091284400ry13.5416.7064.40LYM091297412ry13.3117.1862.51LYM0913104411yy13.1217.2261.53LYM091312453ry13.6017.9366.16LYM091330478ry13.6017.9366.16LYM0913324791y13.8917.6961.60LYM0913324861y13.1317.8364.36LYM0913324861y13.1317.6961.60LYM091592645ry13.3816.7562.94LYM0915926461yy13.3916.5759.36LYM0915926471yy13.6217.6462.90LYM0916727001yy13.5517.2362.34LYM091672704ry15.2819.9472.57LYM0916727121yy13.4817.7864.36LYM0916727131yy13.4817.7864.23LYM0916727141yy13.4817.8664.23LYM091672715ry13.6216.2861.	season		ID		Ratio					
LYM091284400ry13.5416.7064.40LYM091297412ry13.3117.1862.51LYM0913104411yy13.1217.2261.53LYM091312453ry13.6017.9366.16LYM091330478ry13.6917.4163.22LYM0913324791y13.8917.6961.60LYM0913324861y13.1317.8364.36LYM0913324861y13.1317.6961.60LYM091592645ry13.3816.7562.94LYM0915926461yy13.2916.5759.36LYM0915926471yy13.5517.2362.34LYM0916727001yy13.5517.2362.34LYM0916727011yy13.5517.2362.34LYM0916727121yy13.9718.2764.96LYM0916727131yy13.4817.7864.23LYM0916727141yy13.4817.7864.23LYM091672715ry15.2019.6572.32	LYM09	1148	371	r	у		13.37	17.79	63.85	6.19
LYM091297412ry13.3117.1862.51LYM0913104411yy13.1217.2261.53LYM091312453ry13.6017.9366.16LYM091330478ry13.6917.4163.22LYM0913324791y13.8917.6961.60LYM0913324861y13.1317.8364.36LYM0913324861y13.3816.7562.94LYM091592645ry13.3916.5759.36LYM0915926461yy13.6217.6462.90LYM0915926471yy13.6217.6462.90LYM0916727001yy13.5517.2362.34LYM0916727011y13.9718.2764.96LYM0916727121yy13.9718.2764.96LYM0916727131yy13.9718.2764.96LYM0916727131yy13.9817.7864.23LYM0916727131y12.9616.2861.44LYM0916727141y15.2019.6572.32	LYM09	1284	400	r	у		13.54	16.70	64.40	6.39
LYM091310441Iyy13.1217.2261.53LYM091312453ry13.6017.9366.16LYM091330478ry13.6917.4163.22LYM091332479Iy13.8917.6961.60LYM091332486Iy13.1317.8364.36LYM091332486Iy13.3816.7562.94LYM091592645ry15.2119.4769.03LYM091592646Iyy13.6217.6462.90LYM091592647Iyy13.5517.2362.34LYM091672700Iyy13.5517.2362.34LYM091672704ryy13.9718.2764.96LYM091672713Iyy13.4817.7864.23LYM091672713Iyy13.4817.7864.23LYM091672714Iyy13.4817.7864.23LYM091672714Iyy13.4816.2861.44LYM091672715ry15.2019.6572.32	LYM09	1297	412	r	у		3.3	17.18	62.51	6.45
LYM091312453ry13.6017.9366.16LYM091330478ry13.6917.4163.22LYM0913324791y13.8917.6961.60LYM0913324861y13.1317.8364.36LYM091445531ry13.3816.7562.94LYM091592645ry15.2119.4769.03LYM0915926461yy13.6217.6462.90LYM0915926471yy13.5517.2362.34LYM0916727001yy13.5517.2362.34LYM0916727011yy13.9718.2764.96LYM0916727121yy13.4817.7864.23LYM0916727131yy13.4817.7864.23LYM0916727131yy13.4817.7864.23LYM0916727131yy13.4817.7864.23LYM0916727141yy13.4817.7864.23LYM091672715ry15.2019.6572.32	LYM09	1310	441	1	у	у	13.12	17.22	61.53	6.50
LYM091330478ry113.6917.4163.22LYM0913324791y113.8917.6961.60LYM0913324861y13.1317.8364.36LYM091445531ry13.3816.7562.94LYM091592645ry13.3916.5759.36LYM0915926461yy13.3916.5759.36LYM0915926471yy13.6217.6462.90LYM0916727001yy13.5517.2362.34LYM0916727011yy15.2819.9472.57LYM0916727131yy13.4817.7864.23LYM0916727131yy13.4817.7864.23LYM0916727141yy13.4817.7864.23LYM091672715ry15.2019.6572.32	LYM09	1312	453	r	у		13.60	17.93	66.16	6.47
LYM091332479Iy13.8917.6961.60LYM091332486Iy13.1317.8364.36LYM091445531ry13.3816.7562.94LYM091592645ry15.2119.4769.03LYM091592646Iyy13.3916.5759.36LYM091592646Iyy13.6217.6462.90LYM091672700Iyy13.5517.2362.34LYM091672701Iyy15.2819.9472.57LYM091672712Iyy13.4817.7864.23LYM091672713Iyy13.4817.7864.23LYM091672714Iyy13.4817.7864.23LYM091672715ry15.2019.6572.32	LYM09	1330	478	r	у		13.69	17.41	63.22	6.08
LYM091332486Iy13.1317.8364.36LYM091445531ry13.3816.7562.94LYM091592645ry15.2119.4769.03LYM091592646Iyy13.3916.5759.36LYM091592647Iyy13.6217.6462.90LYM091672700Iyy13.5517.2362.34LYM091672701Iyy15.2819.9472.57LYM091672704ryy13.9718.2764.96LYM091672713Iyy13.4817.7864.23LYM091672714Iyy13.9716.2861.44LYM091672715ry15.2019.6572.32	LYM09	1332	479	1	у		13.89	17.69	61.60	6.03
LYM091445531ry13.3816.7562.94LYM091592645ry15.2119.4769.03LYM0915926461yy13.3916.5759.36LYM0915926471yy13.6217.6462.90LYM0916727001yy13.5517.2362.34LYM0916727011yy15.2819.9472.57LYM091672704ry12.7016.1658.74LYM0916727131yy13.4817.7864.23LYM0916727141yy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1332	486	1	у		3. 3	17.83	64.36	6.14
LYM091592645ry15.2119.4769.03LYM0915926461yy13.3916.5759.36LYM0915926471yy13.6217.6462.90LYM0916727001yy13.5517.2362.34LYM0916727011y15.2819.9472.57LYM091672704ry12.7016.1658.74LYM0916727121yy13.9718.2764.96LYM0916727131yy13.4817.7864.23LYM0916727141yy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1445	531	r	у		13.38	16.75	62.94	6.05
LYM091592646Iyy13.3916.5759.36LYM091592647Iyy13.6217.6462.90LYM091672700Iyy13.5517.2362.34LYM091672701Iyy15.2819.9472.57LYM091672704ry12.7016.1658.74LYM091672712Iyy13.9718.2764.96LYM091672713Iyy13.4817.7864.23LYM091672714Iyy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1592	645	r	у		15.21	19.47	69.03	7.67
LYM091592647Iyy13.6217.6462.90LYM091672700Iyy13.5517.2362.34LYM091672701IyI15.2819.9472.57LYM091672704ryI12.7016.1658.74LYM091672712Iyy13.9718.2764.96LYM091672713Iyy13.4817.7864.23LYM091672714Iyy12.9616.2861.44LYM091672715ryI15.2019.6572.32	LYM09	1592	646	1	у	у	13.39	16.57	59.36	5.91
LYM091672700Iyy13.5517.2362.34LYM091672701Iy15.2819.9472.57LYM091672704ry12.7016.1658.74LYM091672712Iyy13.9718.2764.96LYM091672713Iyy13.4817.7864.23LYM091672714Iyy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1592	647	1	у	у	13.62	17.64	62.90	6.47
LYM0916727011y15.2819.9472.57LYM091672704ry12.7016.1658.74LYM0916727121yy13.9718.2764.96LYM0916727131yy13.4817.7864.23LYM0916727141yy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1672	700	1	у	у	13.55	17.23	62.34	6.42
LYM091672704ry12.7016.1658.74LYM0916727121yy13.9718.2764.96LYM0916727131yy13.4817.7864.23LYM0916727141yy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1672	701	1	у		15.28	19.94	72.57	6.93
LYM0916727121yy13.9718.2764.96LYM0916727131yy13.4817.7864.23LYM0916727141yy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1672	704	r	у		12.70	16.16	58.74	5.50
LYM091672713Iyy13.4817.7864.23LYM091672714Iyy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1672	712	1	у	у	13.97	18.27	64.96	6.64
LYM091672714Iyy12.9616.2861.44LYM091672715ry15.2019.6572.32	LYM09	1672	713	1	у	у	13.48	17.78	64.23	6.11
LYM09 1672 715 r y 15.20 19.65 72.32	LYM09	1672	714	1	у	у	12.96	16.28	61.44	6.16
	LYM09	1672	715	r	у		15.20	19.65	72.32	6.92
LYM09 1689 731 r y 14.23 18.17 66.59	LYM09	1689	731	r	у		14.23	18.17	66.59	6.64

Lyminge - hu	merus								
Site code/	Context	GMM	Side	Meas.	GMM	Bd	Вр	GL	SC
season		ID		Ratio					
LYM09	1730	780	r			13.41	17.27	62.96	6.35
LYM09	1730	786	1	у	у	13.73	17.42	63.18	6.39
LYM09	1737	802	1	у	у	13.95	17.50	65.49	6.10
LYM09	1737	803	r	у		13.44	17.38	61.42	6.36
LYM09	1816	810	r	у		13.80	17.11	62.36	6.13
LYM09	1816	811	r	у		13.78	17.73	64.97	6.52
LYM09	1817	813	r	у		15.89	19.98	72.22	7.41
LYM09	1817	814	1	у	у	13.03	16.53	59.52	6.04
LYMI0	2541a	840	r	у		16.00	20.09	72.29	7.30
LYMI0	2570c	849	r	у		15.49	19.81	73.01	7.32
LYMI0	2572c	851	r	у		12.67	16.42	61.90	6.09
LYMI2	3242	886	1	у	у	13.57	17.26	64.42	5.95
LYMI2	3242	887	r			13.62	17.31	64.17	5.90
LYMI2	3242	888	1	у		13.62	17.75	66.33	6.50
LYMI2	3678	902	1	у	у	13.55	17.37	62.76	6.18
LYMI3	6876	919	r	у		15.76	19.10	71.39	6.96
Lym08	680	ABGI	1	у	у	13.81	18.57	65.52	6.95
Lym08	680	ABGI	r			13.84	18.61	65.87	6.96
Lym09	1837	ABG4	1	у	у	13.65	17.79	63.91	5.99
Lym09	1837	ABG4	r			13.77	18.19	64.44	6.14

Lyminge - hu	merus								
Site code/	Context	GMM	Side	Meas.	GMM	Bd	Вр	GL	SC
season		ID		Ratio					
Lym08	582	ABG5P	r			15.90	20.30	72.10	7.80
Lym08	582	ABG5P	1	у	у	15.90	20.40	72.10	7.90
Lym08	1482	ABG6	r			13.90	18.90	66.80	6.10
Lym09	1600	ABG7	r	У	у	14.20	18.00	65.60	6.20
Lym09	1333	ABG8	r			13.70	18.80	66.10	6.80
Lym09	1333	ABG8	I	у	у	13.80	18.40	66.40	6.40
Lym08	150	ABG10	r			13.40	18.16	64.20	6.50
Lym08	150	ABGI0	I	у	У	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				
L31	74.24	10.29	28.39	21.08	36.24	48.81				
L37	78.01	10.51	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	80.81	10.10	26.70	21.57	37.82	46.81				
L46	79.09	10.17	27.07	21.41	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			
L100	74.87	9.57	28.15	21.07	34.00	45.41			
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			
L135	80.90	9.41	26.76	21.65	35.15	43.45			
L168	77.20	10.16	27.26	21.05	37.26	48.26			
L199	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			
L412	77.47	10.32	27.48	21.29	37.54	48.46			
L441	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	44.41			
Lymi	nge hum	eri meas	urement	ratios					
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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			
L811	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			

Lymi	nge hum	eri meas	urement	ratios		
ID	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd
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
L85 I	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	78.01	9.85	27.68	21.59	35.58	45.61
L919	82.51	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	27.71	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 - f	femur									
Site code/ season	Context	ID	Meas. Ratio	Bd	Вр	Dd	Dp	GL	Lm	sc
LYM08	8	2	у	13.04	13.78	10.62	8.90	66.78	62.90	5.82
LYM08	12	11	у	13.05	13.35	11.56	9.08	68.11	63.83	5.83
LYM08	156	28	у	13.39	13.42	11.35	9.22	69.66	65.66	6.23
LYM08	231	38	у	12.21	13.01	11.28	8.40	65.97	61.76	5.87
LYM08	247	63	у	16.46	16.81	14.24	11.25	83.19	77.61	7.25
LYM08	247	65	у	13.95	14.61	12.12	9.49	69.51	66.14	6.33
LYM09	1296	409	у	13.51	13.66	11.37	9.50	70.69	65.76	6.11
LYM09	1332	510	у	13.72	13.75	11.51	9.05	71.26	66.18	5.80
LYM09	1449	552	у	13.60	14.00	10.97	9.54	72.43	67.15	6.21
LYM09	1449	553	у	13.49	14.02	11.93	9.81	69.93	64.97	6.14
LYM09	1479	565	у	13.58	13.66	11.77	8.96	70.82	65.54	5.93
LYM09	1500	591	у	13.12	13.60	10.75	8.72	67.00	62.16	5.98
LYM09	1552	616	у	13.37	13.52	11.69	9.16	68.26	64.11	6.14
LYM09	1619	657	у	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	у	17.31	17.84	14.13	11.69	83.41	76.88	7.71
LYM09	1672	698	у	12.96	12.71	10.50	8.74	68.69	64.55	5.94

Lyminge -	femur									
Site code/ season	Context	ID	Meas. Ratio	Bd	Вр	Dd	Dp	GL	Lm	sc
LYM09	1672	699	у	13.28	13.14	10.45	9.37	68.76	64.58	5.90
LYM09	1672	705	у	13.49	14.23	11.15	9.13	68.75	64.60	6.50
LYM09	1672	706	у	14.76	14.74	12.50	10.30	71.86	68.22	6.68
LYM09	1672	709	у	12.98	13.62	10.78	9.09	66.00	61.68	5.58
LYM09	1672	720	у	13.41	13.29	10.83	8.44	69.57	64.54	6.73
LYM09	1689	729	у	13.60	14.31	11.75	9.78	70.68	66.88	6.09
LYM09	1689	730	у	13.72	14.57	12.41	9.55	75.45	70.46	6.47
LYM09	1707	746	у	13.22	13.84	11.01	9.00	69.50	65.29	5.86
LYM09	1709	750	у	13.45	13.76	11.34	9.34	69.48	64.13	6.27
LYM09	1730	782	у	15.88	16.51	12.58	10.42	80.12	75.29	6.86
LYM09	1730	788	у	12.88	12.81	10.49	8.75	65.85	62.04	5.60
LYM09	1730	792	у	13.62	13.97	11.52	9.55	71.06	66.50	5.30
LYM09	1730	798	у	13.58	13.28	11.65	8.96	69.54	64.76	5.75
LYM09	1737	801	у	13.88	14.89	11.65	10.08	69.97	64.95	6.39
LYM09	1817	815	у	16.52	16.79	13.51	12.04	78.37	73.20	6.83
LYMI2	3083	857	у	13.68	14.00	11.32	9.84	71.32	65.90	6.26
LYMI2	3041	863	у	13.84	13.79	11.69	9.53	70.30	65.64	5.78
LYMI2	3242	882	у	12.89	13.28	11.04	9.66	70.15	66.09	5.70
LYMI3	6256	913	У	15.53	15.95	12.96	10.94	84.94	79.26	7.08
LYMI3	6256	914	У	13.10	14.08	11.25	9.50	72.65	67.84	6.21

Lyminge -	femur									
Site code/ season	Context	ID	Meas. Ratio	Bd	Вр	Dd	Dp	GL	Lm	sc
LYM09	1600	ABG7	у	14.40	14.20	12.10	9.40	72.70	67.20	6.50
LYM09	1333	ABG8	у	13.80	14.20	11.40	8.90	73.00	68.80	6.40
LYM09	1333	ABG8	у	13.80	14.20	11.10	9.90	73.00	68.80	5.90

3.3.3.2 Measurement ratios – femur

Lymin	ige femoi	ra measu	irement r	atios										
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	18.51	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
L510	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

Lymin	ge femor	ra measu	rement r	atios										
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	44.41	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

Lymin	ge femoi	ra measu	rement r	atios										
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. Ratio	GMM	Dd	Dip	GL	La	sc
LYM08	247	L50	У	У	10.83	18.68	101.25	96.20	5.69
LYM08	247	L5 I	У		11.02	18.63	96.93	93.80	5.51
LYM08	247	L52	у	У	10.24	17.27	94.13	89.71	4.99
LYM08	331	LIII	у		10.53	17.45	94.34	91.30	5.49
LYM08	582	L142	у	У	12.46	18.83	115.59	110.92	6.24
LYM08	639	L163	у		10.96	19.18	100.31	96.48	5.81
LYM08	656	L193	у		12.25	20.60	112.45	108.23	6.25

Lyminge -	tibiotarsus								
Site code/ season	Context	ID	Meas. Ratio	GMM	Dd	Dip	GL	La	sc
LYM08	658	L197	у		12.86	22.57	112.81	107.39	6.51
LYM08	684	L219	у	у	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	у	у	11.17	18.77	99.90	97.45	5.53
LYM08	684	L249	у		11.20	18.78	100.88	96.74	5.63
LYM08	744	L275	у		11.00	16.76	97.61	93.82	5.72
LYM09	1026	L304	у		10.96	18.34	97.17	93.32	5.72
LYM09	1309	L414	у		11.07	18.42	97.83	93.58	5.64
LYM09	1310	L423	у		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		у	11.14	17.74	99.34	95.44	5.21
LYM09	1332	L480	у		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	у		10.52	17.95	99.41	95.12	5.32
LYM09	1449	L541				18.56	105.37	101.66	5.87
LYM09	1506	L597	у		11.60	18.76	103.27	99.19	5.72
LYM09	1506	L598	у		10.64	17.24	94.76	91.75	5.56
LYM09	1665	L665	у		12.55	21.20	111.29	106.64	5.49
LYM09	1672	L697	у		10.69	16.86	98.43	94.02	5.13
LYM09	1730	L785	У		10.48	17.88	96.11	92.34	5.44

ibiotal sus								
Context	ID	Meas. Ratio	GMM	Dd	Dip	GL	La	sc
1730	L790	у	у	11.36	18.18	97.83	93.20	5.29
1730	L795	у	у	12.59	21.48	112.84	106.87	6.40
1730	L796			12.52	21.59	113.12	106.85	6.30
1817	L812	у		12.56	22.28	113.45	107.19	6.01
3242	L889	у	у	10.65	17.67	99.02	94.46	5.07
3678	L898	у		10.32	17.79	97.23	92.55	5.33
3695	ABG2	у		13.29	21.43	115.13	110.13	5.19
3695	ABG2			13.33	21.46	115.65	110.79	5.21
1837	ABG4			10.87	18.00	94.24	91.04	4.58
582	ABG5			11.40	20.19	108.30	104.20	5.70
582	ABG5			11.80	22.60	109.10	104.10	5.90
1482	ABG6			9.80	17.60	95.40	89.90	4.10
1482	ABG6	у	у	9.80	17.10	95.00	89.60	4.50
1600	ABG7	у	у	10.40	19.30	100.20	95.60	4.60
1600	ABG7			10.40	19.20	100.00	95.20	5.20
1333	ABG8	у	У	10.00	18.80	100.40	95.60	5.30
1312	ABG9	у	у	10.20	18.80	102.40	97.60	5.00
	Context 1730 1730 1730 1730 1817 3242 3678 3695 3695 1837 582 1837 582 1837 582 1482 1333 1312	Context ID 1730 L790 1730 L795 1817 L812 3242 L889 3678 L898 3678 ABG2 3695 ABG2 3695 ABG2 3695 ABG3 582 ABG5 582 ABG5 1482 ABG6 1482 ABG6 1600 ABG7 1600 ABG7 1333 ABG8 1312 ABG9	Meas. Meas. Ratio 1730 L790 y 1730 L795 y 1730 L795 y 1730 L795 y 1730 L795 y 1730 L796 y 1817 L812 y 3242 L889 y 3678 L898 y 3695 ABG2 y 3695 ABG2 y 3695 ABG4 y 3695 ABG5 y 1837 ABG5 y 582 ABG5 y 1482 ABG6 y 1482 ABG6 y 1600 ABG7 y 1600 ABG8 y 1333 ABG8 y	Meas. Meas. GMM 1730 L790 y y 1730 L795 y y 1730 L795 y y 1730 L795 y y 1730 L796 y y 1730 L796 y y 1817 L812 y y 3678 L889 y y 3678 L898 y y 3695 ABG2 y y 3695 ABG2 y y 3695 ABG2 y y 3695 ABG2 y y 3695 ABG4 y y 1837 ABG4 y y 582 ABG5 y y 1482 ABG6 y y 1600 ABG7 y y 1600 ABG7 y y 1333 <	Meas. Meas. GMM Dd 1730 L790 y y 11.36 1730 L790 y y 11.36 1730 L795 y y 12.59 1730 L796 y 12.52 1817 L812 y 12.56 3242 L889 y 10.65 3678 L898 y 10.32 3678 L898 y 10.32 3695 ABG2 y 13.33 3695 ABG2 y 13.33 1837 ABG4 I I3.33 1837 ABG5 I I1.40 582 ABG5 I I1.80 1482 ABG6 y 9.80 1482 ABG6 y 9.80 1600 ABG7 y 10.40 1600 ABG7 y 10.40 1333 ABG8 y y	Mean Meas. GMM Dd Dip 1730 L790 y y 11.36 18.18 1730 L790 y y 11.36 18.18 1730 L795 y y 12.59 21.48 1730 L796 12.52 21.59 1817 L812 y 12.56 22.28 3242 L889 y 10.65 17.67 3678 L898 y 10.32 17.79 3695 ABG2 y 10.32 17.67 3695 ABG2 y 13.33 21.46 1837 ABG4 i 10.80 20.19 582 ABG5 i 11.40 20.19 582 ABG6 y	Mease Mease GMM Dd Dip GL 1730 L790 y y 11.36 18.18 97.83 1730 L795 y y 12.59 21.48 112.84 1730 L795 y y 12.52 21.59 113.12 1817 L812 y 12.56 22.28 113.45 3242 L889 y 10.65 17.67 99.02 3678 L898 y 10.32 17.79 97.23 3695 ABG2 y 13.29 21.43 115.13 3695 ABG2 y 13.29 21.43 115.13 3695 ABG2 y 13.33 21.46 115.65 1837 ABG2 y 13.33 21.46 115.65 1837 ABG5 i 11.40 20.19 108.30 582 ABG5 i 11.40 20.19 108.30 <td< td=""><td>Meas. Meas. GMM Dd Dip GL La 1730 L790 y y 11.36 18.18 97.83 93.20 1730 L795 y y 12.59 21.48 112.84 106.87 1730 L795 y y 12.52 21.59 113.12 106.87 1730 L796 12.56 22.28 113.45 107.19 3242 L889 y y 10.65 17.67 99.02 94.46 3678 L898 y y 10.32 17.79 97.23 92.55 3695 ABG2 y 13.29 21.43 115.13 110.13 3695 ABG2 y 13.23 21.46 115.65 110.79 1837 ABG4 13.33 21.46 115.65 110.70 1832 ABG5 11.40 20.19 108.30 104.20</td></td<>	Meas. Meas. GMM Dd Dip GL La 1730 L790 y y 11.36 18.18 97.83 93.20 1730 L795 y y 12.59 21.48 112.84 106.87 1730 L795 y y 12.52 21.59 113.12 106.87 1730 L796 12.56 22.28 113.45 107.19 3242 L889 y y 10.65 17.67 99.02 94.46 3678 L898 y y 10.32 17.79 97.23 92.55 3695 ABG2 y 13.29 21.43 115.13 110.13 3695 ABG2 y 13.23 21.46 115.65 110.79 1837 ABG4 13.33 21.46 115.65 110.70 1832 ABG5 11.40 20.19 108.30 104.20

3.3.4.2 Measurement ratios – tibiotarsus

Lymir	nge tibiota	ırsi meas	urement	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
L51			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
L142			10.78		5.40		11.23	5.63		66.17	16.29	33.14	16.98	95.96	50.08
L163			10.93		5.79		11.36	6.02		57.14	19.12	30.29	19.88	96.18	53.01
L193			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
L221			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

Lymin	ge tibiota	rsi meas	urement	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
L812			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 -	tarsometat	tarsus								
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	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	Ι	у	У	11.39	11.35	62.87	5.33	
LYM08	273	88	Ι	у	У	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 -	Lyminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length			
LYM08	331	109	r			10.36	11.09	62.24					
LYM08	331	112	I	у	у	9.78	11.11	61.19	5.12				
LYM08	524	124	r				12.23	65.70	5.41				
LYM08	544	133	1	у	у	11.47	12.04	64.05	5.37				
LYM08	591	143	r			10.77	11.18	61.04	5.57				
LYM08	592	145	1	у		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	1			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	I	у	у	11.07	11.70	64.73	5.34				
LYM08	628	158	r			11.22	11.60	65.44	5.21				
LYM08	639	164	I	у	у	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	I			13.23	11.91	63.45	5.96	17.26			
LYM08	650	179	I	у	у	11.54	12.25	63.19	5.49				
LYM08	650	180	I	у	У	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 -	Lyminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	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	1	у	у	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	1	у	у	11.47	11.14	61.13	5.27				
LYM08	684	207	1			11.25	11.30	65.58	5.38				
LYM08	684	208	1	у	у	12.19	11.99	66.26	5.88				
LYM08	684	209	1	у	у	11.62	11.48	69.55	5.73				
LYM08	684	210	Ι	у	у	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 -	tarsometat	arsus								
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	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	у	у	12.10	11.89	64.77	5.70	
LYM09	1079	329	r			11.46	11.70	64.93	5.80	
LYM09	1079	330	1	у		12.20	12.19	68.90	5.70	
LYM09	1079	331	r			12.20	11.80	69.09	5.71	
LYM09	1079	332	1	у	у	11.74	11.86	66.91	5.31	
LYM09	1079	333	r			12.31	11.94	68.88	5.89	
LYM09	1079	334	1	у	у	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	1	у	у	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	3	446	r			11.45	11.35	63.88	5.05	
LYM09	1312	447	1			11.71	11.82	69.65		
LYM09	1326	463	r			11.08	12.20	57.53		

Lyminge -	Lyminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length			
LYM09	1327	469	1			11.91	11.84	67.24	5.59				
LYM09	1327	470	r			12.33	11.66	68.57	5.33				
LYM09	1327	471	1			12.33*	12.20*	67.00	6.14*				
LYM09	1327	472	r			12.22*	12.04*	67.88	6.16*				
LYM09	1327	473	1	у	у	12.49	11.63	68.61	5.55				
LYM09	1332	511	1		у	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	у	у	12.42	12.15	70.68	5.92				
LYM09	1349	526	1	у	у	11.59	11.79	66.12	5.17				
LYM09	1349	527	r	у		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	1			11.98	11.85	68.85	5.62				
LYM09	1480	568	r			12.09	11.78	69.72	5.71				
LYM09	1480	569	1	у	у	12.17	11.81	69.56	5.69				
LYM09	1480	570	1	у	у	14.41	13.77	77.02	6.53				
LYM09	1481	571	r			11.59	11.56	66.46	5.60				
LYM09	1482	574	1	у	у	12.12	11.89	64.66	6.07				
LYM09	1482	575	1	у	У	11.74	11.62	64.70	5.44				

Lyminge -	Lyminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length			
LYM09	1482	576	r			11.33	12.00	65.18	5.45				
LYM09	1500	590	1	у	у	11.24	11.58	60.86	5.35				
LYM09	1506	599	I	у	у	12.24	11.77	68.92	5.70				
LYM09	1514	609	r			10.76	10.89	61.39	5.64				
LYM09	1521	611	I	у	у	10.87	11.35	63.17	5.31	10.36			
LYM09	1523	612	I	у	у	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	I	у	у	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	I				11.61	66.15	5.28				
LYM09	1618	651	I	у	у	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	1			11.43	10.78	63.71	5.76				
LYM09	1672	694	r				12.60	69.93	5.22				

Lyminge -	Lyminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	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	у	у	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	Ι	у	у	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	у	у	11.54	12.17	66.76	5.60				
LYM09	1730	799	r			11.56	12.05	66.70	5.73				
LYM09	1825	817	Ι	у	у	14.09	13.65	76.05	6.72				
LYM09	1835	824	Ι			12.41		67.50	6.29				
LYMI0	2508b	835	I			13.90	14.03	84.30		18.36			
LYMI0	2518a	836	Ι			11.96	11.88	70.62	5.83				
LYMI2	3083	858	I	у	у	11.88	12.15	68.93	5.58				
LYMI2	3172	867	r			10.48	10.85	65.33	4.91				
LYMI2	3189	868	Ι	у	у	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 -	-yminge - tarsometatarsus												
Site code/ season	Context	ID number	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length			
LYMI2	3242	884	1	у	у	11.18	11.09	65.59	4.92				
LYMI2	3242	885	r			11.18	11.27	65.97	5.00				
LYMI2	3302	891	1	у	у	11.73	12.10	66.85	5.90				
LYMI2	3302	892	r			11.84	11.72	66.76	6.00				
LYMI2	3555	894	1			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	у	у	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	1	у	у	12.09	12.37	70.86	5.45				
LYMI2	3863	905	r			12.15	12.13	71.52	5.42				
LYMI3	6256	915	1	у	у	11.70	11.32	70.95	5.34				
Lym12	3695	ABG2	1	у	у	13.46	14.10	77.37	6.57				
Lym12	3695	ABG2	r			13.41	13.94	77.92	6.10				
Lym09	1409	ABG3 NO	1					57.57	5.84				
Lym09	1837	ABG4	r			11.54	11.30	62.96	5.53				
Lym09	1837	ABG4	1	у	у	11.42	11.72	62.80	5.53				
Lym09	1600	ABG7	r			12.20	11.90	68.80	5.50				
Lym09	1600	ABG7	1	у	у	11.90	11.60	67.90	5.80				
Lym09	1312	ABG9	r			11.80	11.80	69.50	5.80				

Lyminge - tarsometatarsus												
Site code/	Context	ID number	Side	Meas.	GMM	Bd	Bn	CI	sc	Sour Length		
season	CONCEXT	ib number	Side	Ratio	Grin	bu	Бр	GL	30	Spur Length		
Lym09	1091	ABGII	r					58.44	4.30			

3.3.5.2 Measurement ratios – tarsometatarsus

Lymi	nge ta	rsometa	tarsi me	asuremer	nt 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
L133	u	95.27	46.82	8.38	18.80	17.91	44.60
L145	m	98.83	48.92	8.48	17.55	17.34	48.35
L157	u	94.62	48.24	8.25	18.08	17.10	45.64
L164	u	103.24	46.39	8.74	18.25	18.84	47.90
L179	u	94.20	47.57	8.69	19.39	18.26	44.82
L180	u	97.83	50.93	8.70	17.46	17.08	49.83
L187	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
L210	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					
L521	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					
L65 I	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					

Lymi	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				
L817	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

3.4.1 Flixborough coracoid

3.4.1.1 Standard metrics - coracoid

Flixbor	Flixborough coracoids											
ID	Bb	Bf	GL	Lm	Meas. Ratio	GMM						
FX338	14.80	12.50	56.60	53.90	у	У						
FX339	14.20	11.90	53.80	52.20	у	У						
FX344	15.10	11.50	55.60	53.40	у	у						
FX345	12.70	10.30	46.50	44.20	У	у						
FX346	12.80	10.30	50.10	48.00	У	У						
FX351	13.40	11.50	50.70	48.30	У	У						
FX357	11.70	9.70	48.90	47.00	У	У						
FX358	14.00	12.30	50.70	48.30	У	У						
FX361	14.70	13.40	53.40	50.80	у	У						
FX362	13.70	11.80	51.60	49.00	У	У						
FX363	16.10	13.80	56.50	54.10	у	У						
FX370	12.10	10.10	47.30	45.20	у	У						
FX371	12.60	11.10	47.30	44.30	у	У						
FX377	14.90	13.50	55.30	52.40	У	У						
FX383	15.00	12.60	56.40	53.90	у	У						
FX385	14.12	11.35	53.76	50.18	у	У						

Flixbor	ough c	oracoid	s			
ID	Bb	Bf	GL	Lm	Meas. Ratio	GMM
FX390	15.20	12.70	56.30	53.30	у	у
FX391	14.10	12.00	50.50	47.70	у	у
FX392	12.70	11.90	47.50	46.10	у	у
FX393	11.70	9.90	49.00	46.60	у	у
FX396	14.00	10.90	49.60	47.20	у	у
FX397	12.00	10.60	47.80	45.70	у	у
FX398	14.20	13.10	56.90	54.20	у	у
FX401	14.60	12.30	55.30	52.90	У	у
FX402	12.96	10.89	48.34	46.24	У	у
FX403	15.18	12.77	57.72	55.43	У	у
FX404	12.48	10.49	49.33	46.96	У	у
FX406	12.20	11.80	46.90	44.00	у	у

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			

Flixbor	rough cor	acoids n	neasuren	nent ratio	os	
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

3.5.1 Coracoids

3.5.1.1 Standard metrics - coracoids

Copperg	Coppergate coracoids											
Area	Context	Date From	Date To	ID	Bb	Bf	GL	Lm	Side	Meas. ratio	GMM	
1979.7	17528	mid th	late th	y002	13.23	11.11	48.5 I	46.5 I	I	у	у	
1979.7	17697	mid th	late th	y003	15.31	12.44	58.09	55.72	I	у	у	
1979.7	16895	mid th	late th	y004	15.90	13.52	54.90	52.53	I	у	у	
1979.7	16603	mid th	late th	y007	12.70	11.00	47.74	45.14	I	у	у	
1979.7	19283	mid th	late th	y011	15.88	13.86	58.57	55.94	I	у	у	
1979.7	15013	AD 955/6	early/mid 11th	y015	13.13	10.78	48.03	46.29	I	у	у	
1979.7	15432	AD 955/6	early/mid 11th	y016	12.46	10.30	51.76	49.56	I	у	у	
1979.7	15131	AD 955/6	early/mid 11th	y017	12.18	10.34	50.58	48.55	I	у	у	

Copperg	ate coracoio	ds									
		Date						_		Meas.	
Area	Context	From	Date To	ID	Bb	Bf	GL	Lm	Side	ratio	GMM
1979.7	15628	AD 955/6	early/mid 11th	y019	15.14	12.55	57.01	54.42	I	у	у
1979.7	15483	AD 955/6	early/mid th	y022	15.37	13.67	57.44	53.90	I	у	у
1979.7	6433	AD 955/6	early/mid th	y025	12.99	10.57	49.22	46.72	I	у	у
1979.7	6433	AD 955/6	early/mid th	y026	15.22	13.07	57.52	54.88	I	у	у
1979.7	5247	AD 955/6	early/mid 11th	y027	16.42	13.43	55.88	53.42	I	у	у
1979.7	5416	AD 955/6	early/mid 11th	y028	17.35	14.53	58.19	55.70	I	у	у
1979.7	15338	AD 955/6	early/mid 11th	y029	15.00	13.10	54.88	52.07	I	у	у
1979.7	15931	AD 955/6	early/mid 11th	y031	13.01	10.41	51.13	48.75	I	у	у
1979.7	15371	AD 955/6	early/mid 11th	y032	15.38	13.40	59.72	56.65	I	у	у
1979.7	15207	AD 955/6	early/mid 11th	y033	14.62	11.84	53.05	50.16	I	у	у
1979.7	15705	AD 955/6	early/mid 11th	y034	12.37	10.40	46.24	44.14	I	у	у
1979.7	14843	AD 955/6	early/mid 11th	y035	13.65	11.58	49.34	46.97	I	у	у
1979.7	6578	AD 955/6	early/mid 11th	y037	15.25	12.50	54.89	52.5 I	I	у	у
1979.7	19320	AD 955/6	early/mid 11th	y038	11.88	10.31	47.14	45.37	I	у	у
1979.7	14592	AD 955/6	early/mid 11th	y039	16.14	14.14	56.44	53.29	I	у	у
1979.7	15659	AD 955/6	early/mid 11th	y041	15.10	12.37	53.69	51.26	I	у	у
1979.7	15659	AD 955/6	early/mid 11th	y042	14.86	12.15	54.85	51.93	I	у	у
1979.7	7589	AD 955/6	early/mid 11th	y044	16.24	13.63	58.5 I	55.54	I	у	у
1979.7	22166	AD 955/6	AD 955/6	y045	13.27	11.15	47.44	44.77	I	у	у
1979.7	22104	AD 955/6	AD 955/6	y047	13.10	11.14	48.80	46.73	I	у	у
1979.7	26949	AD 930/5	AD 955/6	y051	13.71	11.22	49.01	46.15		у	у
1979.7	22868	AD 930/5	AD 955/6	y052	14.84	12.02	56.25	53.27		у	у
1979.7	22797	AD 930/5	AD 955/6	y054	15.25	13.07	53.76	51.75		у	у
1979.7	23612	AD 930/5	AD 955/6	y055	12.54	9.87	46.34	44.45	Ι	у	у

Copperg	ate coracoio	ds									
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	у	у
1978.7	7782	AD 930/5	AD 955/6	y057	13.73	11.68	49.39	47.77	I	у	у
1978.7	7782	AD 930/5	AD 955/6	y058	14.70	12.56	55.36	52.16	I	у	у
?	22574	AD 930/5	AD 955/6	y059	12.84	11.17	52.49	50.32	I	у	у
?	22820	AD 930/5	AD 955/6	y060	13.31	11.37	47.00	44.38	I	у	у
?	22423	AD 930/5	AD 955/6	y061	12.54	10.99	47.32	44.96	I	у	у
?	23316	AD 930/5	AD 955/6	y063	15.47	12.51	52.42	49.80	I	у	у
?	22914	AD 930/5	AD 955/6	y067	14.47	12.94	55.64	52.92	I	у	у
?	22560	AD 930/5	AD 955/6	y068	12.61	10.59	50.30	47.47	I	у	у
?	18602	AD 930/5	AD 955/6	y069	15.41	13.22	56.80	54.40	I	у	у
?	22808	AD 930/5	AD 955/6	y070	12.07	10.57	44.98	42.76	I	у	у
1977.7	5484	late 2th	early 13th	y074	13.66	11.24	50.48	48.32	I	у	у
1977.7	5484	late 2th	early 13th	y076	14.88	12.24	55.09	53.14	I	у	у
1977.7	5484	late 2th	early 13th	y077	15.09	12.54	56.81	53.94	I	у	у
1977.7	5484	late 2th	early 13th	y078	13.73	12.07	50.05	47.80	I	у	у
1977.7	4620	late 2th	early 13th	y081	16.91	15.11	57.45	55.54	I	у	у
1977.7	4620	late 2th	early 13th	y082	16.28	13.70	57.92	54.43	I	у	у
1977.7	4620	late 2th	early 13th	y085	13.47	11.40	48.24	45.72	I	у	у
1977.7	4620	late 2th	early 13th	y086	15.81	13.10	57.05	54.77	I	у	у
1977.7	4620	late 2th	early 13th	y087	13.86	11.51	49.00	45.99	I	у	у
1977.7	4620	late 12th	early 13th	y089	13.51	10.86	47.07	44.46	Ι	у	у

3.5.1.2 Measurement ratios – coracoids

Сорр	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	95.51	87.28	27.11	28.39	23.66	24.78						
Y541	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						
Y551	94.92	81.37	26.39	27.80	21.48	22.62						
Y552	95.41	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						

Сорр	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						
Y581	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						

Сорр	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						
Y611	94.78	84.63	27.92	29.46	23.63	24.93						
Y612	96.00	82.86	27.71	28.87	22.96	23.92						
Y613	93.86	83.04	28.29	30.14	23.49	25.03						
Y615	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	у	у	16.47	13.89	58.61	55.92
CHE/AMP04	3084	4550	C34	I	у	у	16.87	13.71	61.42	58.92
CHE/AMP04	3084	4550	C35	I	у	у	14.21	12.37	54.13	51.22
CHE/AMP04	3084	4550	C36	Ι	у	у	15.01	12.72	52.28	48.81
CHE/AMP04	3084	4550	C37	Ι	у	у	16.68	13.02	57.18	55.09
CHE/AMP04	3084	4550	C38	Ι	у	у	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	у	у	16.33	13.68	55.33	51.32
CHE/AMP04	3084	4541	C88	I	у	у	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	C101	Ι	У	у	13.21	10.95	50.63	47.91
CHE/AMP04	3084	4531	C102	r			14.04	11.33	57.54	55.62
CHE/AMP04	3084	4528	C138	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	C158	I	У	у	14.12	11.31	55.47	52.39	
CHE/AMP04	3084	4545	C159	r			14.33	11.24	55.17	52.04	
CHE/AMP04	3084	4549	C166	Ι	у	у	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	Ι	у	у	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	Ι	у	у	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	95.41	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	29.51	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				
C101	94.63	82.89	26.09	27.57	21.63	22.86				
C158	94.45	80.10	25.46	26.95	20.39	21.59				
C166	97.17	87.65	26.28	27.05	23.04	23.71				
C182	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	Вр	GL	SC
CHE/AMP04	3084	none	C4	r			14.48	17.11	66.01	6.22
CHE/AMP04	3084	none	CII	Ι	у	у	14.84	18.95	69.80	7.02
CHE/AMP04	3084	4550	C42	1	у	у	14.30	18.39	67.67	6.77
CHE/AMP04	3084	4550	C43	I	у	у	14.44	17.23	65.72	6.23
CHE/AMP04	3084	4550	C44	I	у	у	15.12	19.42	72.53	6.76
CHE/AMP04	3084	4550	C45	Ι	у	у	15.26	18.82	69.20	6.36
CHE/AMP04	3084	4550	C46	Ι	у	у	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	Вр	GL	SC	
CHE/AMP04	625	4689	C94	r			15.24	19.06	71.72	7.36	
CHE/AMP04	3084	4525	C95	I	у	у	17.81	23.36	81.60	7.79	
CHE/AMP04	3084	4527	C109	I	у	у	18.47	22.85	82.60	8.00	
CHE/AMP04	3084	4527	C110	r			13.83	17.51	62.00	6.47	
CHE/AMP04	3084	4537	C123	r			15.81	19.47	70.12	6.59	
CHE/AMP04	3084	4535	C133	I	у	у	14.58	18.18	68.58	6.48	
CHE/AMP04	3084	4528	C140	r			14.14	17.65	66.04	6.60	
CHE/AMP04	3084	4546	C149	r			18.30	22.79	82.29	7.98	
CHE/AMP04	3084	4545	CI 57	r			16.10	20.59	75.78	7.35	
CHE/AMP04	3084	4545	C160	r			14.17	17.80	67.53	6.51	
CHE/AMP04	3084	4530	C179	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	C212	I	у	у	15.62	20.98	72.54	7.26	
CHE/AMP04	3084	4547	C213	I	у	у	14.42	17.94	66.48	6.68	
CHE/AMP04	3084	4547	C214	I	у	у	16.53	21.15	81.44	7.12	
CHE/AMP04	3084	4547	C215	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	78.31	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			
C109	80.83	9.69	27.66	22.36	35.01	43.31			
C133	80.20	9.45	26.51	21.26	35.64	44.44			
C212	74.45	10.01	28.92	21.53	34.60	46.48			
C213	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 - fe	Chester - femur														
Site code	Context	Sample	ID	Side	Meas. Ratio	Bd	Вр	Dd	Dp	GL	Lm	SC			
CHE/AMP04	3064	-	СІ	I	у	18.84	17.94	15.61	11.90	92.96	86.53	8.02			
CHE/AMP04	3084	-	C9	I	у	17.92	17.63	14.76	13.01	88.54	84.22	8.32			
CHE/AMP04	3084	4550	C30	I	У	17.04	17.85	14.23	12.74	87.10	80.43	7.69			
CHE/AMP04	3084	4550	C32	I	У	13.81	13.68	.4	9.16	68.99	64.68	6.08			
CHE/AMP04	3084	4541	C81	I	У	15.39	16.89	12.49	10.81	78.73	73.03	6.84			
CHE/AMP04	3084	4546	C151	I	У	17.19	17.48	14.59	11.87	90.02	84.73	7.40			
CHE/AMP04	3084	4546	C152	I	у	14.40	14.44	11.57	10.23	74.07	69.06	6.51			
CHE/AMP04	3084	4549	C165	I	У	14.09	15.38	11.86	10.03	73.76	68.95	6.45			
CHE/AMP04	3084	4548	C195	I	У	15.93	16.19	12.72	10.67	81.85	76.07	6.92			
CHE/AMP04	3084	4536	C209	I	У	17.29	17.00	13.84	11.19	86.46	79.77	7.73			
CHE/AMP04	3084	4547	C221	I	У	13.84	14.67	12.04	9.64	73.56	68.85	5.90			

Chest	er femor	a measu	rement r	atios										
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
C081	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
CI51	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
C165	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
C221	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

3.6.3.2 Measurement ratios- femur

3.6.4 Chester tibiotarsus

3.6.4.1 Standard metrics - tibiotarsus

Chester - til	Chester - tibiotarsus														
Site code	Context	Sample no	ID	Side	Meas. 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	C18	r			14.35	14.58	26.20	102.31	96.85	9.44			
CHE/AMP04	3084	4550	C24		у	у	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			у	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		у	у	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	C100	I	у	у	11.34	11.41	19.29	103.86	100.17	5.74			
CHE/AMP04	3084	4527	C108	I	у	у	12.19	11.73	19.97	109.67	105.66	6.41			
CHE/AMP04	3084	4535	C132	I	у	у	10.17	10.60	18.48	103.73	99.03	5.86			
CHE/AMP04	3084	4540	C146	I	у	у	11.34	12.85	21.79	114.08	110.19	6.42			
CHE/AMP04	3084	4546	C148	r			11.55	11.45	18.78	103.53	99.63	5.70			
CHE/AMP04	3084	4546	C150	1	у	у	10.85	11.39	19.70	102.54	98.24	6.01			
CHE/AMP04	3084	4549	C170	I	у	У	13.18	13.54	23.93	126.81	122.24	7.49			

Chester - tib	Chester - tibiotarsus													
Site code	Context	Sample no	ID	Side	Meas. Ratio	GMM	Bd	Dd	Dip	GL	La	sc		
CHE/AMP04	3084	4530	C174	r			12.92	13.39	23.58	127.14	123.28	6.50		
CHE/AMP04	3084	4530	C175	I	у	у	12.82	13.43	23.33	126.48	122.26	7.10		
CHE/AMP04	3084	4530	C176	I	у	у	11.61	11.93	19.76	106.46	103.60	5.66		
CHE/AMP04	3084	4530	C177	1	у	У	11.02	11.45	19.01	103.52	99.89	5.80		
CHE/AMP04	3084	4530	C178	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

Chest	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
C100	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
C108	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
C132	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
C146	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
C150	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

Chest	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
C170	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
C175	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
C176	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
C177	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 - ta	rsometata	rsus									
Site code	Context	Sample no	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length
CHE/AMP04	3021	-	C002	I	у	у	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	C021	r			13.06	12.76	75.96	5.83	
CHE/AMP04	3084	4550	C022	I	У	У	13.29	12.77	70.57	6.08	
CHE/AMP04	3084	4550	C023	I	У	У	13.32	13.15	74.06	6.06	
CHE/AMP04	3084	4537	C124	I	У	У	15.01	15.58	87.78	6.86	
CHE/AMP04	3084	4534	C126	I	У	У	13.44	12.74	75.58	6.18	

Chester - ta	Chester - tarsometatarsus													
Site code	Context	Sample no	ID	Side	Meas. Ratio	GMM	Bd	Вр	GL	sc	Spur Length			
CHE/AMP04	3084	4534	CI27	r			14.34	14.44	87.81	7.72	13.69			
CHE/AMP04	3084	4528	C139	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	C171	r			14.41	14.63	85.4	7.23				
CHE/AMP04	3084	4530	C180	I	у	У	14.81	14.35	84.71	7.16	9.59			
CHE/AMP04	3084	4530	C181	r			15.05	14.7	87.87	7.68	10.74			
CHE/AMP04	3084	4544	C193	I	у	У	12.27	11.49	68.53	6.07				
CHE/AMP04	3084	4547	C217	I	у	У	14.53	13.84	84.66	7.3	9.82			
CHE/AMP04	3084	4547	C218	I	у	у	12.51	12.18	68.41	5.95				

3.6.5.2 Measurement ratios – tarsometatarsus

Chest	er tar	sometat	arsi mea	surement	t ratios		
ID	Sex	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp
C002	u	96.35	51.13	8.52	17.30	16.66	49.26
C022	u	104.07	45.75	8.62	18.10	18.83	47.61
C023	u	101.29	45.50	8.18	17.76	17.99	46.08
CI24	m	96.34	45.70	7.81	17.75	17.10	44.03
C126	u	105.49	45.98	8.18	16.86	17.78	48.51
C180	m	103.21	48.35	8.45	16.94	17.48	49.90

Chest	Chester tarsometatarsi measurement ratios												
ID	Sex	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp						
C193	u	106.79	49.47	8.86	16.77	17.90	52.83						
C217	m	104.99	50.24	8.62	16.35	17.16	52.75						
C218	u	102.71	47.56	8.70	17.80	18.29	48.85						

3.7 Archaeological GLs for Kernel Density Estimates

3.7.1 Lyminge

Lyminge											
Cor	acoid	Hum	nerus	Fer	nur	Tibio	tarsus	Tarsome	etatarsus	UI	na
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
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	69.5 I	-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	-0.0621	61.04	-0.1003	60.87	-0.0907

Lyminge											
Cor	acoid	Hum	erus	Fen	nur	Tibiot	arsus	Tarsome	etatarsus	UI	na
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
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	-0.055 I	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	-0.0251
55.57	-0.0133	68.3 I	-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	-0.0641	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
50.5 I	-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											
Cor	acoid	Hum	erus	Fer	nur	Tibiot	tarsus	Tarsome	etatarsus	U	na
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
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	70.5 I	-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	Lyminge										
Cor	acoid	Hum	erus	Fen	nur	Tibio	tarsus	Tarsome	etatarsus	U	Ina
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
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	-0.0541		
								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											
Cor	acoid	Hun	nerus	Fe	mur	Tibic	otarsus	Tarsome	etatarsus	U	na
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
								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										na	
GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled	GL	Log scaled
								69.50	-0.0439		
								58.44	-0.1192		

3.7.2 Chester

Chest	Chester											
С	oracoid	н	umerus		Femur	Tib	oiotarsus	Tarso	metatarsus		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	

Uley											
C	Coracoid	н	umerus		Femur	Tib	oiotarsus	Tarso	ometatarsus		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								

3.7.3 Uley

Uley											
C	Coracoid	н	umerus		Femur	Tił	piotarsus	Tarso	ometatarsus		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										

Fis	hbourne		Сорре	ergate		Flix	kborough
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

3.7.4 Fishbourne, Coppergate and Flixborough coracoids

Fis	hbourne		Сорре	ergate		Flix	cborough
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
		51.13	-0.0495	55.09	-0.0171	49.33	-0.0650
		59.72	0.0180	56.81	-0.0037	46.90	-0.0870
		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		
		58.5 I	0.0091	49.06	-0.0674		
		47.44	-0.0820	47.07	-0.0854		
		51.44	-0.0469				

3.7.5 R code for producing kernel density plots - example

densityplot(~ Cor + Hum + Uln + Fem + Tbt + Tmt, data = CHEEL.csv, auto.key = TRUE, main=expression("Chester elements"), xlab = "Log-scaled 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				
h011	Dorking	f	30.4740694	41.7944639	27.7314668	I.02208603I				
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	41.9448641	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	41.4128496	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				
r65 l	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	28.0837941	0.991328341				
t041	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	1.002291242				
ABG7	Lyminge	f	30.1910299	41.6112957	28.1976744	1.01863354				
ABG9	Lyminge	f	30.1219512	41.6260163	28.2520325	n/a				
SRD719	W Deeping	f	29.8706717	41.5936588	28.5356696	1.019047619				

Appendix D: Statistical Analysis Linear Biometrics

4.1 Measurement ratios

4.1.1 Skewness

Bold = highly skewed <-1 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	-0.921	0.984	-1.686	-1.248	1.593	1.570			
Asian Game	-1.221	-0.840	-1.849	-1.408	-0.392	0.625			

Humerus - skewness										
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd				
Dorking	0.086	-0.029	-1.383	0.629	0.086	0.251				
Hamburgh	0.129	0.119	-1.161	0.815	0.177	0.527				
RJF	0.471	-0.585	-0.152	-0.589	-2.118	-0.654				
O E Game	-0.039	0.078	0.526	-0.833	0.116	-1.330				
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 - skew	rness														
	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	-1.341	-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	-1.641	-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			

4.1.2 Normality tests

Null hypothesis is that distribution is normal. Non-normal distributions are in bold.

4.1.2.1 Coracoids – measurement ratios

Dorking coracoids						
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
Shapiro-Wilk W	0.881	0.9412	0.9167	0.9186	0.931	0.9425
p(normal)	0.1609	0.5942	0.3658	0.3807	0.4905	0.6085
Anderson-Darling A	0.5011	0.2491	0.3501	0.2891	0.3138	0.26
p(normal)	0.1507	0.6552	0.3845	0.5302	0.476	0.6158
p(Monte Carlo)	0.158	0.709	0.3981	0.5737	0.5092	0.6765
Jarque-Bera JB	1.362	0.6274	0.8969	0.7768	0.7183	0.5255
p(normal)	0.5062	0.7307	0.6386	0.6781	0.6983	0.7689
p(Monte Carlo)	0.117	0.551	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 corace	oids					
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
Shapiro-Wilk W	0.9731	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	0.1831	0.1351	0.2961	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	0.3521
p(normal)	0.8988	0.7837	0.7816	0.8072	0.8272	0.8386
p(Monte Carlo)	0.9108	0.6461	0.6481	0.7163	0.778	0.7922

Old English Game co	racoids					
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
Shapiro-Wilk W	0.9605	0.9389	0.952	0.9472	0.8525	0.8603
p(normal)	0.804	0.5706	0.7125	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	0.04322	0.05079
p(Monte Carlo)	0.8452	0.5199	0.7158	0.6525	0.0418	0.0503
Jarque-Bera JB	0.4825	0.6029	0.5558	0.429	1.232	1.254
p(normal)	0.7856	0.7397	0.7574	0.807	0.5401	0.5342
p(Monte Carlo)	0.6914	0.5603	0.6204	0.7341	0.1401	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 coracoid	s					
	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						
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm
N	61	60	61	61	61	61
Shapiro-Wilk W	0.9618	0.9813	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)	6.62E-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								
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/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	0.6168		
Anderson-Darling A	0.3412	0.334	0.4	0.3556	0.3205	0.2483		
p(normal)	0.462	0.4806	0.3334	0.427	0.5101	0.7184		
p(Monte Carlo)	0.4718	0.4899	0.3431	0.4394	0.5292	0.7425		
Jarque-Bera JB	2.169	0.3321	1.179	1.156	0.7359	0.5843		
p(normal)	0.3381	0.847	0.5547	0.5609	0.6922	0.7466		
p(Monte Carlo)	0.1208	0.8251	0.343	0.3684	0.5857	0.674		

Flixborough coracoids									
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/Lm			
N	28	28	28	28	28	28			
Shapiro-Wilk W	0.949	0.9565	0.9681	0.9675	0.9589	0.9703			
p(normal)	0.1871	0.2875	0.5303	0.5163	0.3276	0.5891			
Anderson-Darling A	0.6218	0.6561	0.3306	0.2677	0.4221	0.3721			
p(normal)	0.09502	0.07772	0.4971	0.659	0.3004	0.3969			
p(Monte Carlo)	0.0974	0.0763	0.5062	0.6741	0.3044	0.402			
Jarque-Bera JB	0.643	1.13	0.9575	1.063	0.7264	0.6557			
p(normal)	0.7251	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								
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/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	0.8671	0.9995	0.3446	0.7893		
Anderson-Darling A	0.2782	0.335	0.2177	0.1279	0.358	0.2401		
p(normal)	0.5883	0.4515	0.7977	0.9771	0.3961	0.7211		
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								
	Lm/GL	Bf/Bb	Bb/GL	Bb/Lm	Bf/GL	Bf/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	0.2961	0.4263	0.3606	0.4235	0.3617	0.3366		
p(normal)	0.5811	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	1.258	1.701	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								
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd		
Shapiro-Wilk W	0.9391	0.9488	0.8737	0.9346	0.9593	0.9077		
p(normal)	0.5726	0.6767	0.1347	0.5264	0.7906	0.2998		
Anderson-Darling A	0.2924	0.307	0.5322	0.2743	0.1895	0.3542		
p(normal)	0.5231	0.4955	0.1231	0.5694	0.8596	0.3753		
p(Monte Carlo)	0.5631	0.518	0.1271	0.6288	0.8878	0.4026		
Jarque-Bera JB	0.7382	0.4908	2.02	0.5274	0.4763	0.9318		
p(normal)	0.6914	0.7824	0.3643	0.7682	0.7881	0.6276		
p(Monte Carlo)	0.4329	0.6692	0.0631	0.6463	0.6975	0.269		

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								
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/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	0.01007	0.6878		
Anderson-Darling A	0.2925	0.2633	0.2546	0.2127	0.8365	0.2982		
p(normal)	0.5142	0.5905	0.6206	0.7764	0.0169	0.5053		
p(Monte Carlo)	0.5573	0.6517	0.6863	0.81	0.0168	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	0.0071	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								
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd		
Shapiro-Wilk W	0.9127	0.9212	0.9712	0.9365	0.9094	0.9479		
p(normal)	0.4151	0.4792	0.907	0.6078	0.392	0.7102		
Anderson-Darling A	0.3221	0.2926	0.2167	0.2622	0.383	0.2588		
p(normal)	0.4224	0.5043	0.745	0.5759	0.289	0.5871		
p(Monte Carlo)	0.4548	0.5403	0.8005	0.6437	0.3082	0.6538		
Jarque-Bera JB	0.6739	0.7051	0.1367	0.542	0.6253	0.3403		
p(normal)	0.7139	0.7029	0.9339	0.7626	0.7315	0.8435		
p(Monte Carlo)	0.4239	0.3874	0.957	0.5837	0.4865	0.8162		

Asian Game humeri								
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd		
Ν	6	6	6	6	6	6		
Shapiro-Wilk W	0.9732	0.9197	0.8728	0.9412	0.7955	0.885		
p(normal)	0.9131	0.503	0.2374	0.6685	0.05348	0.2928		
Anderson-Darling A	0.1733	0.258	0.5519	0.2475	0.62	0.3521		
p(normal)	0.8711	0.5651	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							
	Bd/Bp	SC/GL	Bp/GL	Bd/GL	SC/Bp	SC/Bd	
N	63	63	63	63	63	63	
Shapiro-Wilk W	0.9855	0.9724	0.9723	0.9753	0.9926	0.9611	
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)	0.8172	0.3423	0.12	0.384	0.8891	0.03846	
p(Monte Carlo)	0.8173	0.338	0.1293	0.3876	0.8946	0.0386	

Jarque-Bera JB	0.9385	2.32	2.451	3.582	0.4142	1.3
p(normal)	0.6255	0.3135	0.2936	0.1668	0.813	0.5221
p(Monte Carlo)	0.5579	0.1871	0.1794	0.0892	0.7917	0.4217

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	1	I	1	1	1
	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	1	1	1	1	1

	Dd/Bp	Dp/Dd	Dd/GL	Dd/Lm	SC/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	0.8521
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	0.711	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	Bd/GL
Shapiro-Wilk W	0.942	0.9125	0.9477	0.9136	0.7375
p(normal)	0.603	0.3335	0.6651	0.3421	0.003886
Anderson-Darling A	0.2362	0.3327	0.2204	0.3484	0.9926
p(normal)	0.703	0.4263	0.7614	0.3885	0.006872
p(Monte Carlo)	0.7426	0.4535	0.8033	0.4059	0.007
Jarque-Bera JB	0.5828	0.7805	0.5294	0.9892	6.899
p(normal)	0.7472	0.6769	0.7674	0.6098	0.03175
p(Monte Carlo)	0.581	0.395	0.6353	0.2299	0.0034
Hamburgh femora					
	Bp/GL	Bd/Lm	Bp/Lm	SC/Lm	SC/Bp
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
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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					1
	Dd/Bp x 100	Dp/Dd x 100	Dd/GL x 100	Dd/Lm x 100	SC/Dd x 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	1	1	1	1	1			
	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	Bd/GL				
Shapiro-Wilk W	0.9307	0.9003	0.9191	0.7722	0.937				
p(normal)	0.4544	0.2207	0.3498	0.006655	0.5202				
Anderson-Darling A	0.2961	0.4542	0.33	1.105	0.3438				
p(normal)	0.5231	0.2105	0.4435	0.003678	0.4092				
p(Monte Carlo)	0.5647	0.2186	0.4682	0.0037	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	L								
	Bp/GL	Bd/Lm	Bp/Lm	SC/Lm	SC/Bp				
Shapiro-Wilk W	0.9659	0.8941	0.9517	0.7845	0.9643				
p(normal)	0.8505	0.1886	0.6888	0.009404	0.8336				
Anderson-Darling A	0.2432	0.5053	0.2928	1.028	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	0.921	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	•			1	
	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	ı	1	I	1	I
	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	0.9251	0.9079
p(normal)	0.7172	0.7197	0.9455	0.5431	0.4228
Anderson-Darling A	0.2265	0.2913	0.1542	0.2759	0.2941
p(normal)	0.6814	0.4829	0.9108	0.5183	0.4748
p(Monte Carlo)	0.7643	0.5292	0.9669	0.5841	0.526
Jarque-Bera JB	0.5034	0.126	0.3602	0.5891	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	I	I	I	I	I
	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			I		
	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	I	I	I		I
	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	2.401	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

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	0.0741	0.0138
<u>Uley</u>					
	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					
	Bd/Dip	Bd/GL	Dd/GL	SC/Bd	SC/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	1	1	1		1			
	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		1	1	1	I
	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	•				1
	Dip/GL	SC/Dip	Dip/La	La/GL	SC/Dd

Shapiro-Wilk W	0.9684	0.9388	0.9481	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	0.6151	0.474	0.5234
Jarque-Bera JB	0.3711	0.6715	0.4941	0.603	0.7749
p(normal)	0.8307	0.7148	0.7811	0.7397	0.6788
p(Monte Carlo)	0.7862	0.4571	0.6677	0.5409	0.355

arsi				
Bd/Dip	Bd/GL	Dd/GL	SC/Bd	SC/GL
0.8953	0.9254	0.9587	0.898	0.9838
0.2618	0.4748	0.7976	0.2772	0.9793
0.3982	0.382	0.1813	0.4368	0.1352
0.2767	0.306	0.8738	0.217	0.9597
0.2985	0.3237	0.9112	0.2355	0.9867
0.583	0.6602	0.5043	0.7026	0.2571
0.7471	0.7188	0.7771	0.7038	0.8794
0.5593	0.4796	0.652	0.4377	0.8788
Bd/La	Dd/La	SC/La	Bd/Dd	Dd/Dip
0.9086	0.9742	0.9716	0.9152	0.7833
0.3444	0.9288	0.9101	0.3921	0.01891
	arsi Bd/Dip 0.8953 0.2618 0.3982 0.2767 0.2985 0.583 0.7471 0.5593 Bd/La 0.9086 0.3444	arsi Bd/Dip Bd/GL 0.8953 0.9254 0.2618 0.4748 0.3982 0.382 0.2767 0.306 0.2985 0.3237 0.583 0.6602 0.7471 0.7188 0.5593 0.4796 Bd/La Dd/La 0.9086 0.9742 0.3444 0.9288	Bd/Dip Bd/GL Dd/GL 0.8953 0.9254 0.9587 0.2618 0.4748 0.7976 0.3982 0.382 0.1813 0.2767 0.306 0.8738 0.2985 0.3237 0.9112 0.583 0.6602 0.5043 0.7471 0.7188 0.7771 0.5593 0.4796 0.652 Bd/La Dd/La SC/La 0.9086 0.9742 0.9716 0.3444 0.9288 0.9101	Bd/Dip Bd/GL Dd/GL SC/Bd 0.8953 0.9254 0.9587 0.898 0.2618 0.4748 0.7976 0.2772 0.3982 0.382 0.1813 0.4368 0.2767 0.306 0.8738 0.217 0.2985 0.3237 0.9112 0.2355 0.583 0.6602 0.5043 0.7026 0.7471 0.7188 0.7771 0.7038 0.5593 0.4796 0.652 0.4377 Bd/La Dd/La SC/La Bd/Dd 0.9086 0.9742 0.9716 0.9152 0.3444 0.9288 0.9101 0.3921

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		1	1	1	I
	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	Bd/GL	Dd/GL	SC/Bd	SC/GL	
Shapiro-Wilk W	0.9086	0.934	0.909	0.9047	0.8812	
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	1	1	1	1	1
	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		1	1	1	1
	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	1	1	1	1	1

	Dip/GL	SC/Dip	Dip/La	La/GL	SC/Dd
Shapiro-Wilk W	0.9713	0.8767	0.8817	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	i				
	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	0.831

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	Bd/GL	Dd/GL	SC/Bd	SC/GL				
Shapiro-Wilk W	0.947	0.9674	0.8757	0.9513	0.9149				
p(normal)	0.5941	0.8812	0.07717	0.656	0.2463				
Anderson-Darling A	0.4071	0.195	0.5984	0.2958	0.4464				

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	1	1	1	I	1
	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	1	1	1	1	1
	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	0.04881	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		0.9155
p(normal)			0.169		0.01574
Anderson-Darling A			0.5529		0.9128
p(normal)			0.1419		0.01769
p(Monte Carlo)			0.145		0.0208
Jarque-Bera JB			2.605		4.649
p(normal)			0.2718		0.09783
p(Monte Carlo)			0.1059		0.0514
Lyminge				1	
	Bd/La	Dd/La	SC/La	Bd/Dd	Dd/Dip
Shapiro-Wilk W		0.9641	0.9038		0.9647
p(normal)		0.3543	0.007765		0.3668
Anderson-Darling A		0.3762	0.9992		0.5225
p(normal)		0.3912	0.0107		0.17
p(Monte Carlo)		0.3961	0.0092		0.176
Jarque-Bera JB		1.691	5.691		0.215
p(normal)		0.4293	0.05809		0.8981
p(Monte Carlo)		0.2328	0.0378		0.8918

Lyminge								
	Dip/GL	SC/Dip	Dip/La	La/GL	SC/Dd			
Shapiro-Wilk W	0.9399	0.9344	0.935	0.9841	0.8696			
p(normal)	0.07437	0.05204	0.05394	0.9061	0.001137			
Anderson-Darling A	0.6687	0.9825	0.7946	0.2313	1.097			
p(normal)	0.07331	0.01179	0.03521	0.7853	0.006075			
p(Monte Carlo)	0.0734	0.0119	0.0374	0.7898	0.0053			
Jarque-Bera JB	7.546	2.871	6.538	0.2616	19.32			
p(normal)	0.02298	0.238	0.03804	0.8774	6.38E-05			
p(Monte Carlo)	0.0223	0.0981	0.0279	0.864	0.0029			

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									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.8424	0.8492	0.8023	0.8604	0.7412	0.9172			
p(normal)	0.06137	0.07298	0.02171	0.09684	0.004283	0.3697			
Anderson-Darling A	0.6016	0.5335	0.735	0.5264	1.093	0.3975			
p(normal)	0.08092	0.122	0.03486	0.1278	0.003659	0.289			
p(Monte Carlo)	0.0794	0.128	0.034	0.1355	0.0038	0.3025			
Jarque-Bera JB	1.998	3.165	5.349	3.278	2.239	0.831			
p(normal)	0.3682	0.2055	0.06895	0.1942	0.3264	0.66			
p(Monte Carlo)	0.0608	0.0277	0.0083	0.0272	0.0544	0.3424			

Hamburgh tarsometatarsi									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.97	0.991	0.9357	0.8773	0.8615	0.9413			
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	0.0531	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)	0.7161	0.9206	0.8173	0.2474	0.2071	0.9226			

Red Junglefowl tarsometatarsi									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.9618	0.9437	0.9403	0.9652	0.8881	0.8715			
p(normal)	0.8273	0.648	0.6143	0.8583	0.2245	0.156			
Anderson-Darling A	0.2024	0.3501	0.3184	0.2365	0.4992	0.5091			
p(normal)	0.8115	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									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.8535	0.9246	0.9465	0.9146	0.8924	0.9559			
p(normal)	0.0639	0.397	0.6277	0.3141	0.1802	0.7385			
Anderson-Darling A	0.568	0.3541	0.246	0.4448	0.4623	0.1902			
p(normal)	0.1046	0.3852	0.6778	0.2232	0.2001	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	1.088	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									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.9366	0.9544	0.9495	0.942	0.9373	0.8932			
p(normal)	0.6081	0.7694	0.7253	0.6567	0.6145	0.292			
Anderson-Darling A	0.2385	0.2277	0.2241	0.2911	0.2465	0.33			
p(normal)	0.6611	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										
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/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	1.418	1.449	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	0.0611	0.0581	0.4903	0.3585	0.4179				

Chester tarsometatarsi									
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp			
Shapiro-Wilk W	0.8763	0.8843	0.935	0.9334	0.9866	0.9543			
p(normal)	0.1436	0.1741	0.53	0.5143	0.9895	0.7371			
Anderson-Darling A	0.4968	0.4468	0.3314	0.343	0.1391	0.2321			
p(normal)	0.1549	0.2129	0.4295	0.4012	0.9571	0.7186			
p(Monte Carlo)	0.1621	0.2247	0.4589	0.4265	0.9832	0.7544			
Jarque-Bera JB	1.04	0.9229	0.7632	0.6651	0.2255	0.1843			
p(normal)	0.5944	0.6304	0.6828	0.7171	0.8934	0.912			
p(Monte Carlo)	0.2088	0.2824	0.4091	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			

1.0						
Oley 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	1.041	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

4.1.3 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			
Dorking	95.07	78.67	29.34	30.87	23.08	24.29			
Hamburgh	96.27	83.74	27.98	29.06	23.42	24.32			
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	30.80	33.01	24.88	26.67			
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	86.45	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			
Dorking	78.96	9.76	28.43	22.43	34.35	43.54			
Hamburgh	79.61	9.21	26.09	20.77	35.29	44.33			
RJF	80.57	9.51	25.56	20.59	37.20	46.17			
O E Game	77.98	9.95	27.23	21.22	36.55	46.90			
Silkie	81.37	9.74	27.82	22.63	35.02	43.06			
Asian Game	79.84	9.57	28.28	22.58	33.86	42.42			
Uley	79.68	9.73	26.71	21.28	36.45	45.76			
Lyminge	78.07	9.90	27.40	21.38	36.13	46.30			
Chester	78.98	9.67	27.30	21.55	35.42	44.87			

4.1.3.3 Femur

Femur										
	Dd/Bd	SC/Bd	SC/GL	Bd/GL	Bp/GL	Bd/Lm	Bp/Lm			
Dorking	82.98	43.92	9.34	21.27	21.02	23.08	22.81			
Hamburgh	84.43	46.01	8.97	19.50	19.90	20.86	21.29			
RJF	83.08	45.98	8.60	18.71	19.23	19.85	20.40			
O E Game	84.73	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	9.41	21.70	21.23	23.37	22.86			
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										
	SC/Lm	SC/Bp	Dd/Bp	Dp/Dd	Dd/GL	Dd/Lm	Sc/Dd			
Dorking	10.13	44.44	83.99	84.90	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	85.93	81.89	18.24	19.64	51.72			
Uley	9.39	41.80	80.66	83.71	15.76	16.82	55.87			
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
Dorking	58.32	11.93	11.68	52.44	6.25	12.45	12.19	6.52	102.22
Hamburgh	53.17	9.89	10.73	58.14	5.73	10.27	11.14	5.95	92.31
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	61.16	12.22	12.00	54.94	6.71	12.70	12.40	6.86	101.94
Asian Game	54.22	11.12	11.40	58.41	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	60.05	20.00	33.55	20.61	96.49	55.84			
Asian Game	55.60	20.52	31.66	21.37	96.05	56.96			
Uley	56.77	18.59	30.05	19.24	96.62	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

Tarsometata	Tarsometatarsus											
	Bd/Bp	SC/Bd	SC/GL	Bp/GL	Bd/GL	SC/Bp						
Dorking	101.92	48.88	9.54	19.19	19.55	49.74						
Hamburgh	107.81	46.30	8.52	17.12	18.40	49.81						
RJF	96.90	49.83	8.59	17.81	17.21	48.27						
O E Game	101.91	49.90	8.89	17.50	17.82	50.83						
Silkie	93.60	53.19	10.11	20.42	19.13	49.57						
Asian Game	97.51	54.14	9.98	18.93	18.44	52.68						
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

4.1.4 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		0.0324	0.0004	0.0554	0.0044	0.0083			
Hamburgh	0.0324		0.0034	0.1236	0.0004	0.0007			
RJF	0.0004	0.0034		0.0367	0.0003	0.0004			
O E Game	0.0554	0.1236	0.0367		0.0020	0.0008			
Silkie	0.0044	0.0004	0.0003	0.0020		0.0419			
Asian Game	0.0083	0.0007	0.0004	0.0008	0.0419				

P-values of Permanova for Bb/GL v Bb/Lm									
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game			
Dorking		0.0218	0.0003	0.0457	0.6011	0.0272			
Hamburgh	0.0218		0.0080	0.8057	0.0040	0.0005			
RJF	0.0003	0.0080		0.0326	0.0012	0.0004			
O E Game	0.0457	0.8057	0.0326		0.0255	0.0023			
Silkie	0.6011	0.0040	0.0012	0.0255		0.0146			
Asian Game	0.0272	0.0005	0.0004	0.0023	0.0146				

P-values of Permanova for Bf/Bb v Bb/GL										
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game				
Dorking		0.0045	0.0080	0.0023	0.1563	0.1465				
Hamburgh	0.0045		0.0368	0.8767	0.1999	0.0194				
RJF	0.0080	0.0368		0.0342	0.0904	0.0005				
O E Game	0.0023	0.8767	0.0342		0.1179	0.0064				
Silkie	0.1563	0.1999	0.0904	0.1179		0.3940				
Asian Game	0.1465	0.0194	0.0005	0.0064	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		0.0062	0.0002	0.0023	0.5717	0.3522			
Hamburgh	0.0062		0.0258	0.0033	0.0255	0.0038			
RJF	0.0002	0.0258		0.0389	0.0005	0.0010			
O E Game	0.0023	0.0033	0.0389		0.0027	0.0008			
Silkie	0.5717	0.0255	0.0005	0.0027		0.5725			
Asian Game	0.3522	0.0038	0.0010	0.0008	0.5725				

P-values of Permanova for Bp/GL v Bd/GL									
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game			
Dorking		0.0001	0.0003	0.0031	0.1614	0.8695			
Hamburgh	0.0001		0.2063	0.0301	0.0002	0.0005			
RJF	0.0003	0.2063		0.0040	0.0001	0.0008			
O E Game	0.0031	0.0301	0.0040		0.0132	0.0216			
Silkie	0.1614	0.0002	0.0001	0.0132		0.5794			
Asian Game	0.8695	0.0005	0.0008	0.0216	0.5794				

P-values of Permanova for Bp/GL v SC/Bp										
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game				
Dorking		0.0001	0.0002	0.0017	0.3590	0.6927				
Hamburgh	0.0001		0.0140	0.0134	0.0405	0.0012				
RJF	0.0002	0.0140		0.0124	0.0029	0.0008				
O E Game	0.0017	0.0134	0.0124		0.0780	0.0029				
Silkie	0.3590	0.0405	0.0029	0.0780		0.2548				
Asian Game	0.6927	0.0012	0.0008	0.0029	0.2548					

P-values of Permanova for Bd/GL v SC/Bp									
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game			
Dorking		0.0024	0.0001	0.0013	0.4538	0.6557			
Hamburgh	0.0024		0.0129	0.0429	0.0209	0.0039			
RJF	0.0001	0.0129		0.2197	0.0032	0.0012			
O E Game	0.0013	0.0429	0.2197		0.0183	0.0011			
Silkie	0.4538	0.0209	0.0032	0.0183		0.3133			
Asian Game	0.6557	0.0039	0.0012	0.0011	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		0.0003	0.0002	0.0002	0.1018	0.7049		
Hamburgh	0.0003		0.0314	0.1569	0.0052	0.0015		
RJF	0.0002	0.0314		0.0003	0.0002	0.0005		
O E Game	0.0002	0.1569	0.0003		0.0327	0.0031		
Silkie	0.1018	0.0052	0.0002	0.0327		0.1140		
Asian Game	0.7049	0.0015	0.0005	0.0031	0.1140			
P-values of Permanova for Bd/Lm v Bd/GL								
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	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0003	0.0001	0.0003	0.0660	0.4370		
Hamburgh	0.0003		0.0428	0.1630	0.0029	0.0012		
RJF	0.0001	0.0428		0.0010	0.0004	0.0004		
O E Game	0.0003	0.1630	0.0010		0.0182	0.0023		
Silkie	0.0660	0.0029	0.0004	0.0182		0.1020		
Asian Game	0.4370	0.0012	0.0004	0.0023	0.1020			

P-values of Permanova for Dd/GL v Bd/GL								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0003	0.0001	0.0024	0.1773	0.2591		
Hamburgh	0.0003		0.0065	0.1495	0.0024	0.0013		
RJF	0.0001	0.0065		0.0001	0.0004	0.0004		
O E Game	0.0024	0.1495	0.0001		0.0258	0.0031		
Silkie	0.1773	0.0024	0.0004	0.0258		0.0692		
Asian Game	0.2591	0.0013	0.0004	0.0031	0.0692			

P-values of Permanova for Dd/Lm v Bd/GL							
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game	
Dorking		0.0003	0.0001	0.0017	0.1043	0.3528	
Hamburgh	0.0003		0.0034	0.1292	0.0018	0.0009	
RJF	0.0001	0.0034		0.0001	0.0003	0.0004	
O E Game	0.0017	0.1292	0.0001		0.0288	0.0039	

Silkie	0.1043	0.0018	0.0003	0.0288		0.0685
Asian Game	0.3528	0.0009	0.0004	0.0039	0.0685	

P-values of Permanova for Bd/Lm v Bp/GL								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0004	0.0001	0.0007	0.1135	0.6589		
Hamburgh	0.0004		0.0241	0.2451	0.0054	0.0004		
RJF	0.0001	0.0241		0.0013	0.0003	0.0002		
O E Game	0.0007	0.2451	0.0013		0.0442	0.0034		
Silkie	0.1135	0.0054	0.0003	0.0442		0.1149		
Asian Game	0.6589	0.0004	0.0002	0.0034	0.1149			

P-values of Permanova for SC/Lm v Bd/Lm								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0003	0.0001	0.0007	0.1216	0.7386		
Hamburgh	0.0003		0.0287	0.1536	0.0062	0.0007		
RJF	0.0001	0.0287		0.0001	0.0001	0.0004		
O E Game	0.0007	0.1536	0.0001		0.0388	0.0034		
Silkie	0.1216	0.0062	0.0001	0.0388		0.1237		
Asian Game	0.7386	0.0007	0.0004	0.0034	0.1237			

P-values of Permanova for Dd/GL v Bd/Lm								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0005	0.0001	0.0009	0.0631	0.3667		
Hamburgh	0.0005		0.0042	0.1366	0.0025	0.0014		
RJF	0.0001	0.0042		0.0001	0.0001	0.0006		
O E Game	0.0009	0.1366	0.0001		0.0210	0.0033		
Silkie	0.0631	0.0025	0.0001	0.0210		0.0695		
Asian Game	0.3667	0.0014	0.0006	0.0033	0.0695			

P-values of Permanova for Dd/Lm v Bd/Lm								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0004	0.0001	0.0011	0.0445	0.4836		
Hamburgh	0.0004		0.0036	0.1344	0.0017	0.0011		
RJF	0.0001	0.0036		0.0001	0.0002	0.0003		
O E Game	0.0011	0.1344	0.0001		0.0234	0.0033		
Silkie	0.0445	0.0017	0.0002	0.0234		0.0744		
Asian Game	0.4836	0.0011	0.0003	0.0033	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		0.0002	0.0006	0.0009	0.0051	0.0001	
RJF	0.0002		0.0062	0.0001	0.0005	0.0178	
O E Game	0.0006	0.0062		0.0015	0.0211	0.1239	
Silkie	0.0009	0.0001	0.0015		0.0007	0.0001	
Asian Game	0.0051	0.0005	0.0211	0.0007		0.0003	
Hamburgh	0.0001	0.0178	0.1239	0.0001	0.0003		

P-values of Permanova for Bd/Dip v SC/GL								
	Dorking	RJF	O E Game	Silkie	Asian Game	Hamburgh		
Dorking		0.1945	0.0021	0.0292	0.0045	0.0081		
RJF	0.1945		0.0191	0.0016	0.0269	0.0389		
O E Game	0.0021	0.0191		0.0002	0.5795	0.6943		
Silkie	0.0292	0.0016	0.0002		0.001	0.0009		
Asian Game	0.0045	0.0269	0.5795	0.001		0.5072		
Hamburgh	0.0081	0.0389	0.6943	0.0009	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		0.0001	0.0022	0.0002	0.0047	0.2783	
Hamburgh	0.0001		0.3515	0.2973	0.0002	0.0012	
RJF	0.0022	0.3515		0.6274	0.001	0.0243	
O E Game	0.0002	0.2973	0.6274		0.0001	0.0124	
Silkie	0.0047	0.0002	0.001	0.0001		0.0211	
Asian Game	0.2783	0.0012	0.0243	0.0124	0.0211		

P-values of Permanova for Bd/Bp v Bd/GL								
	Dorking	Hamburgh	RJF	O E Game	Silkie	Asian Game		
Dorking		0.0254	0.1119	0.294	0.0116	0.1204		
Hamburgh	0.0254		0.0085	0.0272	0.0018	0.0092		
RJF	0.1119	0.0085		0.0664	0.1185	0.6834		
O E Game	0.294	0.0272	0.0664		0.0012	0.0311		
Silkie	0.0116	0.0018	0.1185	0.0012		0.1859		
Asian Game	0.1204	0.0092	0.6834	0.0311	0.1859			

4.1.5 DFA classification modern breeds/types

Discriminant function analysis of all measurement ratios of modern chicken breeds/types - coracoid: classification before and after cross-validation.

4.1.5.1 Modern Coracoid

Modern coracoids – see Table 15				
Point	Given group	Classification	Cross-validated	
a003	Dorking	Dorking	Dorking	
e001	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	
h011	Dorking	Asian Game	Asian Game	
k001	Asian Game	Silkie	Silkie	
n001	O E Game	O E Game	Hamburgh	
r651	Hamburgh	RJF	RJF	
r657	Asian Game	Asian Game	Asian Game	
r658	Asian Game	Dorking	Dorking	
r660	Silkie	Silkie	Silkie	
r661	Silkie	Silkie	Asian Game	

Modern coracoids – see Table 15				
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	
r741	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	0 E Game	
t065	Dorking	Dorking	Dorking	

Modern coracoids – see Table 15				
Point	Given group	Classification	Cross-validated	
t 43	RJF	RJF	RJF	
t 44	RJF	RJF	RJF	
t 46	RJF	O E Game	O E Game	
w518	O E Game	RJF	RJF	
w519	RJF	RJF	RJF	
w528	Dorking	Dorking	Dorking	
w537	Dorking	Dorking	Dorking	
w611	O E Game	Hamburgh	Hamburgh	
w612	O E Game	O E Game	O E Game	
z001	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	
e001	Dorking	Silkie	Silkie	
e004	Hamburgh	Hamburgh	Hamburgh	
e010	RJF	RJF	RJF	
e013	O E Game	Silkie	Silkie	
e014	Dorking	Silkie	Silkie	

Moder	Modern humeri – see Table 20			
Point	Given group	Classification	Cross-validated	
h003	Silkie	Silkie	O E Game	
h011	Dorking	Dorking	O E Game	
k001	Asian Game	Hamburgh	Hamburgh	
n001	O E Game	O E Game	Dorking	
r651	Hamburgh	Hamburgh	Silkie	
r657	Asian Game	Asian Game	Asian Game	
r658	Asian Game	Asian Game	Asian Game	
r660	Silkie	Dorking	Dorking	
r661	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	
r741	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	
t041	O E Game	Hamburgh	Hamburgh	
t059	RJF	RJF	RJF	
t060	Hamburgh	RJF	RJF	
t065	Dorking	Asian Game	Asian Game	
t143	RJF	RJF	RJF	
t 44	RJF	O E Game	O E Game	
t145	RJF	RJF	RJF	
t 46	RJF	Hamburgh	Hamburgh	
t 47	Hamburgh	Hamburgh	Hamburgh	
w518	O E Game	O E Game	O E Game	
w519	RJF	RJF	RJF	
w528	Dorking	Silkie	Silkie	
w537	Dorking	Dorking	O E Game	
w611	O E Game	O E Game	O E Game	
w612	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	
e001	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	
h011	Dorking	Dorking	Dorking	
k001	Asian Game	Asian Game	Dorking	
n001	O E Game	O E Game	Hamburgh	
r651	Hamburgh	Dorking	Dorking	
r657	Asian Game	Asian Game	Silkie	
r658	Asian Game	Asian Game	Silkie	
r660	Silkie	Silkie	Silkie	
r66 l	Silkie	Silkie	Silkie	

Moder	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	
t041	O E Game	O E Game	Silkie	
t059	RJF	RJF	RJF	
t060	Hamburgh	Hamburgh	O E Game	

Moder	Modern femora – see Table 24			
Point	Given group	Classification	Cross-validated	
t065	Dorking	Dorking	Asian Game	
t 43	RJF	RJF	RJF	
t 44	RJF	RJF	O E Game	
t145	RJF	Hamburgh	Hamburgh	
t 46	RJF	RJF	Hamburgh	
t 47	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	
z001	RJF	RJF	RJF	

4.1.5.4 Modern Tibiotarsus

Moder	Modern tibiotarsi: all ratios – see Table 29			
Point	Given group	Classification	Cross-validated	
a003	Dorking	Dorking	Dorking	
e001	Dorking	Dorking	Dorking	
e010	RJF	RJF	Hamburgh	
e013	O E Game	Hamburgh	Hamburgh	
e014	Dorking	Dorking	Dorking	
h003	Silkie	Silkie	Silkie	
h011	Dorking	Dorking	Asian Game	
k001	Asian Game	O E Game	O E Game	
n001	O E Game	Dorking	Dorking	
r651	Hamburgh	Hamburgh	Asian Game	
r657	Asian Game	Asian Game	Asian Game	
r658	Asian Game	Asian Game	Asian Game	
r660	Silkie	Silkie	Silkie	
r66 l	Silkie	Silkie	Silkie	
r662	Asian Game	O E Game	0 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	0 E Game
t007	Silkie	Silkie	Hamburgh
t022	Hamburgh	Hamburgh	0 E Game
t023	Asian Game	Asian Game	Asian Game
t024	Asian Game	Asian Game	Asian Game
t032	Sillio	Silkie	Silkie
	SIRIC	Since	Unkie
t034	Silkie	Dorking	Dorking
t034 t041	Silkie O E Game	Dorking Hamburgh	Dorking Hamburgh
t034 t041 t059	Silkie O E Game RJF	Dorking Hamburgh RJF	Dorking Hamburgh O E Game
t034 t041 t059 t060	Silkie O E Game RJF Hamburgh	Dorking Hamburgh RJF Hamburgh	Dorking Hamburgh O E Game O E Game
t034 t041 t059 t060 t065	Silkie O E Game RJF Hamburgh Dorking	Dorking Hamburgh RJF Hamburgh Dorking	Dorking Hamburgh O E Game O E Game O E Game
t034 t041 t059 t060 t065 t143	Silkie O E Game RJF Hamburgh Dorking RJF	Dorking Hamburgh RJF Hamburgh Dorking RJF	Dorking Hamburgh O E Game O E Game O E Game RJF
t034 t041 t059 t060 t065 t143 t144	Silkie O E Game RJF Hamburgh Dorking RJF RJF	Dorking Hamburgh RJF Hamburgh Dorking RJF RJF	Dorking Hamburgh O E Game O E Game O E Game RJF RJF
t034 t041 t059 t060 t065 t143 t144 t145	Silkie O E Game RJF Hamburgh Dorking RJF RJF	Dorking Hamburgh RJF Hamburgh Dorking RJF RJF	Dorking Hamburgh O E Game O E Game O E Game RJF RJF

Modern tibiotarsi: all ratios – see Table 29				
Point	Given group	Classification	Cross-validated	
t 47	Hamburgh	Hamburgh	RJF	
w518	O E Game	O E Game	O E Game	
w519	RJF	RJF	Asian Game	
w528	Dorking	Dorking	Dorking	
w537	Dorking	Dorking	Dorking	
w611	O E Game	O E Game	RJF	
w612	O E Game	O E Game	O E Game	
z001	RJF	RJF	RJF	

Modern tibiotarsi: six ratio combinations – see Table 30				
Point	Given group	Classification	Cross-validated	
a003	Dorking	Dorking	Dorking	
e001	Dorking	Dorking	Dorking	
e010	RJF	RJF	Hamburgh	
e013	O E Game	Hamburgh	Hamburgh	
e014	Dorking	Dorking	Dorking	
h003	Silkie	Silkie	Silkie	
h011	Dorking	Silkie	Silkie	
k001	Asian Game	Asian Game	O E Game	
n001	O E Game	Dorking	Dorking	

Modern tibiotarsi: six ratio combinations – see Table 30				
Point	Given group	Classification	Cross-validated	
r651	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	
r741	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	
t041	O E Game	Hamburgh	Hamburgh	
t059	RJF	RJF	RJF	
t060	Hamburgh	Hamburgh	Hamburgh	
t065	Dorking	Dorking	O E Game	
t 43	RJF	RJF	RJF	
t 44	RJF	RJF	RJF	
t145	RJF	RJF	RJF	
t 46	RJF	RJF	O E Game	
t 47	Hamburgh	RJF	RJF	
w518	O E Game	O E Game	O E Game	
w519	RJF	RJF	RJF	
w528	Dorking	Dorking	Dorking	
w537	Dorking	Dorking	Silkie	
w611	O E Game	Hamburgh	Hamburgh	
w612	O E Game	O E Game	Hamburgh	
z001	RJF	RJF	RJF	

4.1.5.5 Modern Tarsometatarsus

Modern tarsometatarsi – see Table 35			
Point	Given group	Classification	Cross-validated
a003	Dorking	Silkie	Silkie
e001	Dorking	Dorking	Dorking
e004	Hamburgh	Hamburgh	RJF
e010	RJF	O E Game	0 E Game
e013	O E Game	O E Game	RJF
e014	Dorking	Asian Game	Asian Game
h003	Silkie	Silkie	Silkie
h011	Dorking	Dorking	Dorking
k001	Asian Game	O E Game	0 E Game
n001	O E Game	RJF	RJF
r651	Hamburgh	Dorking	Dorking
r657	Asian Game	Asian Game	Dorking
r658	Asian Game	Asian Game	Asian Game
r660	Silkie	Dorking	Dorking
r661	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

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
r741	Hamburgh	Hamburgh	Hamburgh
r742	Hamburgh	Hamburgh	Dorking
t007	Silkie	Silkie	Silkie
t022	Hamburgh	0 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
t034 t041	Silkie O E Game	Silkie O E Game	Silkie O E Game
t034 t041 t059	Silkie O E Game RJF	Silkie O E Game RJF	Silkie O E Game RJF
t034 t041 t059 t065	Silkie O E Game RJF Dorking	Silkie O E Game RJF O E Game	Silkie O E Game RJF O E Game
t034 t041 t059 t065 t143	Silkie O E Game RJF Dorking RJF	Silkie O E Game RJF O E Game Hamburgh	Silkie O E Game RJF O E Game Hamburgh
t034 t041 t059 t065 t143 t144	Silkie O E Game RJF Dorking RJF RJF	Silkie O E Game RJF O E Game Hamburgh O E Game	Silkie O E Game RJF O E Game Hamburgh O E Game
t034 t041 t059 t065 t143 t144 t145	Silkie O E Game RJF Dorking RJF RJF RJF	Silkie O E Game RJF O E Game Hamburgh O E Game RJF	Silkie O E Game RJF O E Game Hamburgh O E Game RJF
t034 t041 t059 t065 t143 t144 t145 t146	Silkie O E Game RJF Dorking RJF RJF RJF RJF	Silkie O E Game RJF O E Game Hamburgh O E Game RJF O E Game	Silkie O E Game RJF O E Game Hamburgh O E Game RJF O E Game

Modern tarsometatarsi – see Table 35					
w518	O E Game	Dorking	Dorking		
w519	RJF	RJF	RJF		
w528	Dorking	Dorking	Dorking		
w537	Dorking	Dorking	Dorking		
w611	O E Game	RJF	RJF		
w612	O E Game	O E Game	O E Game		
z001	RJF	Silkie	Silkie		

4.1.6 DFA classification archaeological

4.1.6.1 Coracoid

Roman coracoids – see Table 16				
Point	Given group	Classification	Cross-validated	
FBI	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 16				
Point	Given group	Classification	Cross-validated	
FB9	Fishbourne	Fishbourne	Fishbourne	
FB10	Fishbourne	Uley	Uley	
FBII	Fishbourne	Fishbourne	Fishbourne	
FB12	Fishbourne	Fishbourne	Fishbourne	
FB13	Fishbourne	Uley	Uley	
FB14	Fishbourne	Fishbourne	Fishbourne	
U4	Uley	Uley	Uley	
U23	Uley	Uley	Uley	
U25	Uley	Uley	Uley	
U31	Uley	Uley	Uley	
U40	Uley	Uley	Uley	
U43	Uley	Uley	Uley	
U50	Uley	Uley	Uley	
U57	Uley	Uley	Fishbourne	
U61	Uley	Uley	Uley	
U75	Uley	Uley	Uley	
U91	Uley	Uley	Uley	
U96	Uley	Uley	Uley	
U110	Uley	Uley	Fishbourne	
UII7	Uley	Uley	Uley	
UI2I	Uley	Uley	Uley	

Roman coracoids – see Table 16				
Point	Given group	Classification	Cross-validated	
UI27	Uley	Fishbourne	Fishbourne	
U139	Uley	Uley	Uley	
UI5I	Uley	Uley	Uley	
U163	Uley	Uley	Uley	
U180	Uley	Uley	Uley	
U186	Uley	Fishbourne	Fishbourne	
U198	Uley	Uley	Uley	

Saxon coracoids -see Table 17				
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	
Y541	Coppergate	Flixborough	Flixborough	
Y542	Coppergate	Lyminge	Lyminge	
Y543	Coppergate	Lyminge	Lyminge	
Y545	Coppergate	Lyminge	Lyminge	
Y548	Coppergate	Flixborough	Flixborough	

Saxon coracoids –see Table 17				
Point	Given group	Classification	Jackknifed	
Y551	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	
Y561	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	
Y571	Coppergate	Coppergate	Coppergate	
Y573	Coppergate	Coppergate	Coppergate	
Y577	Coppergate	Coppergate	Lyminge	
Y578	Coppergate	Lyminge	Lyminge	
Y580	Coppergate	Coppergate	Coppergate	

Saxon coracoids -see Table 17				
Point	Given group	Classification	Jackknifed	
Y581	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	
Y611	Coppergate	Coppergate	Coppergate	
Y612	Coppergate	Coppergate	Coppergate	
Y613	Coppergate	Coppergate	Coppergate	

Saxon c	Saxon coracoids –see Table 17				
Point	Given group	Classification	Jackknifed		
Y615	Coppergate	Coppergate	Lyminge		
FX338	Flixborough	Flixborough	Flixborough		
FX339	Flixborough	Flixborough	Coppergate		
FX344	Flixborough	Lyminge	Lyminge		
FX345	Flixborough	Lyminge	Lyminge		
FX346	Flixborough	Lyminge	Lyminge		
FX351	Flixborough	Flixborough	Flixborough		
FX357	Flixborough	Lyminge	Lyminge		
FX358	Flixborough	Coppergate	Coppergate		
FX361	Flixborough	Flixborough	Coppergate		
FX362	Flixborough	Flixborough	Flixborough		
FX363	Flixborough	Coppergate	Coppergate		
FX370	Flixborough	Lyminge	Lyminge		
FX371	Flixborough	Flixborough	Flixborough		
FX377	Flixborough	Flixborough	Flixborough		
FX383	Flixborough	Flixborough	Flixborough		
FX385	Flixborough	Lyminge	Lyminge		
FX390	Flixborough	Coppergate	Coppergate		
FX391	Flixborough	Coppergate	Coppergate		
FX392	Flixborough	Coppergate	Coppergate		
FX393	Flixborough	Lyminge	Lyminge		

Saxon co	Saxon coracoids –see Table 17				
Point	Given group	Classification	Jackknifed		
FX396	Flixborough	Lyminge	Lyminge		
FX397	Flixborough	Flixborough	Flixborough		
FX398	Flixborough	Flixborough	Flixborough		
FX401	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		
LIOI	Lyminge	Coppergate	Coppergate		
LII5	Lyminge	Flixborough	Flixborough		
L127	Lyminge	Coppergate	Coppergate		
L134	Lyminge	Lyminge	Lyminge		
L147	Lyminge	Flixborough	Flixborough		
L149	Lyminge	Lyminge	Lyminge		
L152	Lyminge	Flixborough	Flixborough		

Saxon coracoids –see Table 17				
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	
L341	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 17				
Point	Given group	Classification	Jackknifed	
L617	Lyminge	Flixborough	Flixborough	
L702	Lyminge	Coppergate	Coppergate	
L708	Lyminge	Lyminge	Lyminge	
L710	Lyminge	Lyminge	Lyminge	
L711	Lyminge	Lyminge	Lyminge	
L716	Lyminge	Lyminge	Lyminge	
L741	Lyminge	Flixborough	Flixborough	
L759	Lyminge	Flixborough	Flixborough	
L781	Lyminge	Lyminge	Lyminge	
L787	Lyminge	Lyminge	Lyminge	
L791	Lyminge	Lyminge	Lyminge	
L797	Lyminge	Lyminge	Lyminge	
L816	Lyminge	Coppergate	Coppergate	
L823	Lyminge	Coppergate	Coppergate	
Lvi	Lyminge	Coppergate	Coppergate	
L881	Lyminge	Lyminge	Lyminge	
L893	Lyminge	Lyminge	Flixborough	
L901	Lyminge	Coppergate	Coppergate	
L916	Lyminge	Flixborough	Flixborough	
L917	Lyminge	Lyminge	Lyminge	
LABGI	Lyminge	Lyminge	Lyminge	

Saxon coracoids -see Table 17			
Point	Given group	Classification	Jackknifed
LABG2	Lyminge	Lyminge	Lyminge
LABG7	Lyminge	Lyminge	Lyminge
LABG8	Lyminge	Lyminge	Coppergate
LABG9	Lyminge	Lyminge	Lyminge
LABG10	Lyminge	Lyminge	Lyminge

4.1.6.2 Humeri

All archaeological humeri – see Table 21				
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	
C109	Chester	Chester	Lyminge	
C133	Chester	Uley	Uley	
C212	Chester	Chester	Lyminge	
C213	Chester	Uley	Uley	

All archaeological humeri – see Table 21			
Point	Given group	Classification	Cross-validated
C214	Chester	Chester	Uley
L31	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
L100	Lyminge	Chester	Chester
LII3	Lyminge	Lyminge	Lyminge
LII6	Lyminge	Chester	Chester
L135	Lyminge	Chester	Chester
L168	Lyminge	Lyminge	Lyminge
L199	Lyminge	Uley	Uley
L230	Lyminge	Lyminge	Uley
L261	Lyminge	Uley	Uley
L276	Lyminge	Lyminge	Lyminge
L306	Lyminge	Lyminge	Uley
L307	Lyminge	Uley	Uley

All archaeological humeri – see Table 21			
Point	Given group	Classification	Cross-validated
L366	Lyminge	Lyminge	Lyminge
L369	Lyminge	Lyminge	Lyminge
L371	Lyminge	Lyminge	Lyminge
L400	Lyminge	Uley	Uley
L412	Lyminge	Lyminge	Lyminge
L441	Lyminge	Lyminge	Lyminge
L453	Lyminge	Lyminge	Lyminge
L478	Lyminge	Chester	Chester
L479	Lyminge	Chester	Chester
L486	Lyminge	Lyminge	Lyminge
L531	Lyminge	Uley	Uley
L645	Lyminge	Lyminge	Lyminge
L646	Lyminge	Chester	Chester
L647	Lyminge	Lyminge	Lyminge
L700	Lyminge	Lyminge	Lyminge
L701	Lyminge	Lyminge	Lyminge
L704	Lyminge	Chester	Chester
L712	Lyminge	Lyminge	Lyminge
L713	Lyminge	Lyminge	Lyminge
L714	Lyminge	Uley	Uley
L715	Lyminge	Lyminge	Lyminge

All archaeological humeri – see Table 21				
Point	Given group	Classification	Cross-validated	
L731	Lyminge	Lyminge	Lyminge	
L786	Lyminge	Lyminge	Lyminge	
L802	Lyminge	Chester	Chester	
L803	Lyminge	Lyminge	Lyminge	
L810	Lyminge	Chester	Chester	
L811	Lyminge	Lyminge	Lyminge	
L813	Lyminge	Lyminge	Lyminge	
L814	Lyminge	Lyminge	Lyminge	
L840	Lyminge	Lyminge	Lyminge	
L849	Lyminge	Lyminge	Lyminge	
L851	Lyminge	Uley	Uley	
L886	Lyminge	Chester	Chester	
L888	Lyminge	Lyminge	Lyminge	
L902	Lyminge	Lyminge	Lyminge	
L919	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 21			
Point	Given group	Classification	Cross-validated
L262	Lyminge	Lyminge	Lyminge
U3	Uley	Lyminge	Lyminge
U7	Uley	Uley	Uley
UI0	Uley	Chester	Chester
U21	Uley	Uley	Uley
U34	Uley	Uley	Uley
U35	Uley	Uley	Uley
U55	Uley	Uley	Lyminge
U71	Uley	Lyminge	Lyminge
U72	Uley	Chester	Chester
U77	Uley	Chester	Chester
U81	Uley	Uley	Uley
U97	Uley	Chester	Chester
U109	Uley	Uley	Uley
UI24	Uley	Uley	Lyminge
UI28	Uley	Chester	Chester
UI29	Uley	Chester	Chester
UI48	Uley	Lyminge	Lyminge
UI49	Uley	Uley	Chester
UI55	Uley	Chester	Chester
UI58	Uley	Uley	Uley

All arc	All archaeological humeri – see Table 21			
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	
L510	Lyminge	Lyminge	Chester	
L552	Lyminge	Uley	Uley	
L553	Lyminge	Lyminge	Lyminge	
L565	Lyminge	Lyminge	Lyminge	
L591	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	
L801	Lyminge	Chester	Chester	
L815	Lyminge	Lyminge	Chester	
L857	Lyminge	Lyminge	Chester	
L863	Lyminge	Lyminge	Lyminge	
All archaeological femora – see Table 25				
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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	
C001	Chester	Lyminge	Lyminge	
C009	Chester	Uley	Uley	
C030	Chester	Chester	Chester	
C032	Chester	Lyminge	Lyminge	
C081	Chester	Chester	Lyminge	
C151	Chester	Chester	Lyminge	
C152	Chester	Chester	Uley	
C165	Chester	Chester	Lyminge	
C195	Chester	Chester	Chester	
C209	Chester	Chester	Uley	
C221	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	
U104	Uley	Lyminge	Lyminge	
UIII	Uley	Uley	Uley	
UII3	Uley	Uley	Chester	
UII6	Uley	Uley	Chester	
UI23	Uley	Uley	Lyminge	
UI45	Uley	Chester	Chester	
U165	Uley	Uley	Uley	
U173	Uley	Lyminge	Lyminge	
U190	Uley	Uley	Uley	
U194	Uley	Chester	Chester	

4.1.6.4 Tibiotarsi

All archaeological tibiotarsi – see Table 31				
Point	Given group	Classification	Cross-validated	
C024	Chester	Uley	Lyminge	
C026	Chester	Chester	Chester	
C028	Chester	Chester	Lyminge	

All archaeological tibiotarsi – see Table 31				
Point	Given group	Classification	Cross-validated	
C100	Chester	Chester	Chester	
C108	Chester	Chester	Chester	
C132	Chester	Chester	Lyminge	
C146	Chester	Lyminge	Lyminge	
C150	Chester	Chester	Chester	
C170	Chester	Uley	Uley	
C175	Chester	Chester	Chester	
C176	Chester	Chester	Chester	
C177	Chester	Chester	Chester	
L50	Lyminge	Lyminge	Lyminge	
L51	Lyminge	Chester	Chester	
L52	Lyminge	Lyminge	Lyminge	
LIII	Lyminge	Lyminge	Lyminge	
L142	Lyminge	Lyminge	Lyminge	
L163	Lyminge	Chester	Chester	
L193	Lyminge	Lyminge	Lyminge	
L197	Lyminge	Lyminge	Lyminge	
L219	Lyminge	Chester	Chester	
L221	Lyminge	Chester	Chester	
L249	Lyminge	Lyminge	Lyminge	
L275	Lyminge	Lyminge	Lyminge	

All archaeological tibiotarsi – see Table 31				
Point	Given group	Classification	Cross-validated	
L304	Lyminge	Lyminge	Lyminge	
L414	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	
L812	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	
U011	Uley	Uley	Uley	

All archaeological tibiotarsi – see Table 31					
Point	t Given group Classification Cross-valid				
	• •				
U028	Uley	Uley	Uley		
	,	,	-		
U029	Uley	Uley	Uley		
	,	,	-		
U102	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	
C124	Chester	Lyminge	Lyminge	
C126	Chester	Chester	Chester	
C180	Chester	Chester	Chester	
C193	Chester	Chester	Chester	
C217	Chester	Chester	Chester	
C218	Chester	Lyminge	Lyminge	
L87	Lyminge	Lyminge	Lyminge	
L88	Lyminge	Lyminge	Lyminge	
LII2	Lyminge	Uley	Uley	
L133	Lyminge	Lyminge	Lyminge	

Archaeological tarsometatarsi – see Table 36				
Point	Given group	Classification	Cross-validated	
L145	Lyminge	Lyminge	Lyminge	
L157	Lyminge	Lyminge	Lyminge	
L164	Lyminge	Lyminge	Lyminge	
L179	Lyminge	Lyminge	Lyminge	
L180	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	
L521	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	
L611	Lyminge	Lyminge	Lyminge	
L612	Lyminge	Lyminge	Lyminge	
L620	Lyminge	Chester	Chester	
L651	Lyminge	Chester	Chester	
L718	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	
L891	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	
U105	Uley	Uley	Uley	
UII2	Uley	Uley	Chester	
UI54	Uley	Lyminge	Lyminge	
UI56	Uley	Lyminge	Lyminge	
U171	Uley	Uley	Uley	
U177	Uley	Uley	Uley	

4.1.7 Mann-Whitney tests

4.1.7.1 Tests to distinguish two Roman coracoid assemblages

Flixborough v Uley coracoids – Bb/GL ratio				
Fishbourne		Uley		
N:	14	N:	22	
Mean rank:	3.8611	Mean rank:	14.639	
Mann-Whitney				
U :	34			
		p (same		
z :	-3.878	med.):	0.0001	
Monte Carlo		p (same	0.0001	
permutation:		med.):		

Flixborough v Uley coracoids – Bf/Bb ratio				
Fishbourne		Uley		
N:	14	N:	22	
Mean rank:	9.2222	Mean rank:	9.2778	
Mann-Whitney				
U:	81			
		p (same		
z :	-2.3526	med.):	0.0186	
Monte Carlo		p (same	0.0184	
permutation:		med.):		

Tibiotarsus Bd/La ratio: tests for equal medians				
Female		Male		
N:	21	N:	27	
Mean rank:	13.458	Mean rank:	11.042	
Mann-Whitney				
U:	152			
		p (same		
z :	-2.7233	med.):	0.0064625	
Monte Carlo		p (same	0.0052	
permutation:		med.):		

4.1.7.2 Tests to distinguish male and female - tibiotarsus

Tibiotarsus Bd/Dip ratio: tests for equal medians				
Female		Male		
N:	21	N:	27	
Mean rank:	14.646	Mean rank:	9.8542	
Mann-Whitney				
U :	95			
		р (same		
z :	-3.9071	med.):	9.3395E-05	
Monte Carlo		р (same	0.0002	
permutation:		med.):		

Tibiotarsus Bd/GL ratio: tests for equal medians				
Female		Male		
N:	21	N:	27	
Mean rank:	13.479	Mean rank:	11.021	
Mann-Whitney				
U:	151			
		р (same		
z :	-2.7435	med.):	0.0060796	
Monte Carlo		p (same	0.0049	
permutation:		med.):		

Tibiotarsus SC/Bd ratio: tests for equal medians				
Female		Male		
N:	21	N:	27	
Mean rank:	6.5208	Mean rank:	17.979	
Mann-Whitney				
U:	82			
		р (same		
z :	-4.1773	med.):	29497E-05	
Monte Carlo		p (same	0.0001	
permutation:		med.):		

Tibiotarsus Bd/Dd ratio: tests for equal medians				
Female		Male		
N:	21	N:	27	
Mean rank:	13.865	Mean rank:	10.635	
Mann-Whitney				
U :	132.5			
		р (same		
z :	-3.1279	med.):	0.0017608	
Monte Carlo		p (same	0.0017	
permutation:		med.):		

4.1.7.3 Tests to distinguish male and female - tarsometatarsus

Tarsometatarsus Bp/GL ratio: tests for equal medians				
Female		Male		
N:	22	N:	26	
Mean rank:	13.76	Mean rank:	10.74	
Mann-Whitney				
U:	164.5			
		p (same		
z :	-2.5038	med.):	0.012288	
Monte Carlo		p (same	0.0108	
permutation:		med.):		

Tarsometatarsus Bd/GL ratio: tests for equal medians				
Female		Male		
N:	22	N:	26	
Mean rank:	14.667	Mean rank:	9.8333	
Mann-Whitney				
U:	121			
		p (same		
z :	-3.404	med.):	0.00066417	
Monte Carlo		р (same	0.0003	
permutation:		med.):		

Tarsometatarsus SC/Bd ratio: tests for equal medians							
Female		Male					
N:	22	N:	26				
Mean rank:	9	Mean rank:	15.5				
Mann-Whitney							
U:	179						
	p (same						
z :	-2.2037	med.):	0.027548				
Monte Carlo		p (same	0.0288				
permutation:		med.):					

Tarsometatarsus SC/Bp ratio: tests for equal medians				
Female		Male		
N:	22	N:	26	
Mean rank:	7.9479	Mean rank:	16.554	
Mann-Whitney				
U :	128.5			
		р (same		
z :	-3.2487	med.):	0.0011594	
Monte Carlo		p (same	0.0009	
permutation:		med.):		

4.1.8 BGPCA loadings - modern breeds/types

4.1.8.1 Coracoid

Coracoid					
	PC I	PC 2	PC 3	PC 4	PC 5
Lm/GL x 100	-0.24561	0.058547	0.92804	0.2434	0.094132
Bf/Bb x 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
Bb/Lm x 100	0.60026	0.02256	0.010491	0.65666	0.13475
Bf/GL x 100	0.32481	0.28972	0.19467	-0.61012	0.56924
Bf/Lm x 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 x 100	-0.13917	0.81919	0.40506	0.17546	0.2153
SC/GL x 100	-0.00116	-0.11549	0.2827	0.4186	0.44935
Bp/GL x 100	-0.38136	-0.44736	0.49215	-0.35466	0.42712
Bd/GL x 100	-0.34333	-0.13105	0.49861	0.24497	-0.73909
SC/Bp x 100	0.48943	0.16694	0.41112	-0.65388	-0.15059
SC/Bd x 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 x 100	0.001907	0.015091	0.5974	-0.33756	0.52226
SC/Bd x 100	-0.31419	0.069905	0.46431	0.23393	0.19237
SC/GL x 100	0.076377	0.030773	0.077354	0.14649	0.034263
Bd/GL x 100	0.31563	0.041769	-0.04205	0.16143	-0.0934
Bp/GL x 100	0.20973	0.028853	-0.00219	0.194	0.20211
Bd/Lm x 100	0.37613	0.082199	-0.05703	0.31029	0.015245
Bp/Lm x 100	0.26305	0.068228	-0.01249	0.34328	0.34052
SC/Lm x 100	0.0993	0.049889	0.078686	0.21822	0.090278

SC/Bp x 100	-0.08292	0.10504	0.39561	0.31094	-0.33054
Dd/Bp x 100	0.44311	0.066068	0.4458	-0.31795	-0.55303
Dp/Dd x 100	-0.08617	0.97573	-0.13289	-0.14727	0.025047
Dd/GL x 100	0.26604	0.038234	0.088375	0.070899	0.029873
Dd/Lm x 100	0.3171	0.071294	0.085822	0.19071	0.12911
SC/Dd x 100	-0.38643	0.058831	0.14861	0.47284	-0.28613

4.1.8.4 Tibiotarsus

Tibiotarsus								
	PC I	PC 2	PC 3	PC 4	PC 5			
Bd/Dip x 100	0.51804	-0.41067	0.18442	0.1146	-0.16321			
Bd/GL x 100	0.1653	0.10003	0.036458	0.29788	0.085596			
Dd/GL x 100	0.087291	0.073513	0.044505	0.33369	0.058282			
SC/Bd x 100	-0.31999	0.15229	0.60124	0.089789	-0.31946			
SC/GL x 100	0.057007	0.073705	0.092046	0.15144	0.076685			
Bd/La x 100	0.16465	0.11929	0.010265	0.22073	-0.10421			
Dd/La x 100	0.084619	0.091419	0.020945	0.26271	-0.13197			
SC/La x 100	0.051574	0.088698	0.072427	0.072324	-0.07449			
Bd/Dd x 100	0.70579	0.25652	-0.06049	-0.37075	-0.03547			
Dd/Dip x 100	0.10901	-0.58456	0.20833	0.23257	-0.02842			
Dip/GL x 100	0.11246	0.32521	0.008804	0.43013	0.13668			
SC/Dip x 100	0.11232	-0.14337	0.44583	0.016147	0.099444			

Dip/La x 100	0.11012	0.36002	-0.02595	0.33384	-0.1309
La/GL x 100	-0.0109	-0.06546	0.067252	0.12005	0.85623
SC/Dd x 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 x 100	-0.84713	0.38439	0.11858	0.34708	-0.00393				
SC/Bd x 100	0.48242	0.54161	-0.13354	0.62968	0.089288				
SC/GL x 100	0.10363	0.14843	0.294	-0.01887	0.70069				
Bp/GL x 100	0.18589	0.022738	0.6466	0.19207	-0.61766				
Bd/GL x 100	0.032659	0.096856	0.66783	-0.23731	0.2637				
SC/Bp x 100	0.05727	0.72593	-0.13262	-0.62408	-0.22364				

4.1.9 BGPCA loadings – archaeological

4.1.9.1 Coracoids

Coracoids – Fishbourne and modern BGPCA loadings								
PC1 PC2 PC3 PC4 PC5 PC6								
Lm/GL x 100 -0.15886 -0.08117 0.94432 0.043331 0.27272 0.0137								
Bf/Bb x 100 -0.47008 0.83459 -0.01242 0.28555 -0.02753 -0.00545								

Bb/GL x 100	0.49032	0.1343	0.24414	0.37544	-0.60081	0.42428
Bb/Lm x 100	0.56942	0.16892	-0.04621	0.48061	0.48683	-0.42084
Bf/GL x 100	0.27697	0.33395	0.21386	-0.55661	-0.36263	-0.56983
Bf/Lm x 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
Lm/GL x 100	-0.24319	0.066677	0.92814	0.12017	0.24495	0.023004
Bf/Bb x 100	-0.224	0.91752	-0.12284	0.27107	-0.13762	-0.02183
Bb/GL x 100	0.49284	0.023659	0.29002	0.12683	-0.7142	0.38246
Bb/Lm x 100	0.60023	0.002979	0.010168	0.60776	0.29841	-0.42567
Bf/GL x 100	0.3346	0.27941	0.19445	-0.67519	-0.0974	-0.55389
Bf/Lm x 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								
Lm/GL x 100	-0.22401	-0.03326	0.93454	0.050807	0.26902	0.019651			
Bf/Bb x 100	-0.44374	0.84203	-0.07556	0.29133	-0.05669	-0.01681			
Bb/GL x 100	0.4797	0.13227	0.27963	0.3183	-0.6447	0.39654			
Bb/Lm x 100	0.57971	0.15128	-0.00379	0.50773	0.44976	-0.42539			
Bf/GL x 100	0.26552	0.33983	0.2044	-0.61346	-0.2903	-0.55824			
Bf/Lm x 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	
Lm/GL x 100	-0.22148	0.057652	0.93398	0.063413	0.26641	0.017686	
Bf/Bb x 100	-0.25876	0.90959	-0.11667	0.29447	-0.07227	-0.01155	
Bb/GL x 100	0.49842	0.040322	0.27617	0.27791	-0.6558	0.40788	
Bb/Lm x 100	0.59883	0.023668	-0.00725	0.53638	0.41844	-0.42189	
Bf/GL x 100	0.33096	0.29019	0.18861	-0.61784	-0.26434	-0.56488	
Bf/Lm x 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								
Lm/GL x 100	-0.2443	0.019052	0.93002	0.069167	0.26395	0.023798			
Bf/Bb x 100	-0.35697	0.87697	-0.11	0.29043	-0.07988	-0.02602			
Bb/GL x 100	0.48569	0.092867	0.28777	0.27305	-0.67649	0.3748			
Bb/Lm x 100	0.59312	0.092066	0.007068	0.52997	0.41729	-0.42976			
Bf/GL x 100	0.29168	0.32144	0.19699	-0.6492	-0.22787	-0.54719			
Bf/Lm x 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 x 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		
Bb/Lm x 100	0.59751	0.059735	0.004969	0.58993	0.33212	-0.42553		

Bf/GL x 100	0.30874	0.30612	0.19616	-0.73617	0.43571	-0.20174
Bf/Lm x 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 x 100	-0.12817	0.82094	0.40467	0.18345	0.25241	-0.22024
SC/GL x 100	0.004125	-0.1146	0.28337	0.41563	0.31391	0.79704
Bp/GL x 100	-0.37352	-0.44438	0.50036	-0.34171	0.48226	-0.2516
Bd/GL x 100	-0.33363	-0.12814	0.50637	0.22988	-0.75004	-0.0212
SC/Bp x 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						
	PC1 PC2 PC3 PC4 PC5 PC				PC 6	
Bd/Bp x 100	-0.23767	-0.78025	0.43534	0.16802	0.2268	-0.25599
SC/GL x 100	0.017673	0.12504	0.27864	0.42798	0.42695	0.7355
Bp/GL x 100	-0.31467	0.5088	0.4788	-0.3662	0.43474	-0.2996
Bd/GL x 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						
	PC1 PC2 PC3 PC4 PC5 PC				PC 6	
Bd/Bp x 100	-0.15129	0.82362	0.39162	0.17554	0.18168	-0.28561
SC/GL x 100	-0.00018	-0.11154	0.28406	0.42467	0.53101	0.66675
Bp/GL x 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 x 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 x 100	0.11676	-0.18734	0.69196	-0.35798	0.35607	0.25259
SC/Bd x 100	-0.26587	-0.06029	0.46324	0.26466	0.20202	-0.3862
SC/GL x 100	0.075798	0.024634	0.046212	0.15187	0.062758	-0.16274
Bd/GL x 100	0.29186	0.087829	-0.10881	0.18756	-0.04487	-0.13494
Bp/GL x 100	0.20368	0.04566	-0.02984	0.12526	0.24437	-0.11688
Bd/Lm x 100	0.34864	0.13516	-0.12158	0.26491	0.14463	0.26954
Bp/Lm x 100	0.25432	0.089897	-0.03657	0.20015	0.45193	0.17509
SC/Lm x 100	0.097521	0.045084	0.047269	0.19393	0.15008	-0.04728
SC/Bp x 100	-0.07325	0.036563	0.30227	0.49454	-0.25445	-0.31157
Dd/Bp x 100	0.48442	-0.01576	0.36932	-0.00522	-0.64687	0.20949
Dp/Dd x 100	-0.11964	0.95549	0.1793	-0.19975	-0.01043	-0.00635
Dd/GL x 100	0.2681	0.037008	0.046811	0.097619	0.022614	-0.23724

Dd/Lm x 100	0.3173	0.073308	0.045367	0.16145	0.18038	0.02924
SC/Dd x 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 x 100	-0.00761	0.005302	0.49644	-0.61367	0.35437	-0.01844
SC/Bd x 100	-0.29568	0.16928	0.46504	0.070748	0.26005	0.32079
SC/GL x 100	0.084296	0.056951	0.087394	0.11202	0.076064	0.25785
Bd/GL x 100	0.32527	0.054813	-0.02074	0.20209	-0.05361	0.50662
Bp/GL x 100	0.21358	0.029213	0.001532	0.10357	0.23999	0.36533
Bd/Lm x 100	0.38705	0.08933	-0.04152	0.24715	0.15893	-0.2015
Bp/Lm x 100	0.26764	0.061367	-0.01643	0.13779	0.47855	-0.32353
SC/Lm x 100	0.10797	0.074566	0.085719	0.13158	0.18132	-0.07409
SC/Bp x 100	-0.05233	0.23053	0.43099	0.3126	-0.1401	-0.30821
Dd/Bp x 100	0.45714	0.10926	0.41784	-0.1647	-0.61616	-0.06911
Dp/Dd x 100	-0.04924	0.91554	-0.31023	-0.24909	-0.01963	0.020943
Dd/GL x 100	0.27209	0.046895	0.085199	0.043445	0.035509	0.35446
Dd/Lm x 100	0.32402	0.074819	0.076252	0.071233	0.22021	-0.25176
SC/Dd x 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 x 100	0.0448	0.45242	0.17072	-0.50668	0.49797	0.086182
SC/Bd x 100	-0.26481	0.4458	0.21993	0.13634	0.269	0.31146
SC/GL x 100	0.08555	0.065188	0.054467	0.12497	0.072427	-0.00512
Bd/GL x 100	0.31473	-0.05472	0.027242	0.18047	-0.06715	0.18554
Bp/GL x 100	0.20629	-0.04123	0.01875	0.14346	0.25216	-0.34658
Bd/Lm x 100	0.37393	-0.08224	0.061003	0.31044	0.055084	0.50866
Bp/Lm x 100	0.25795	-0.068	0.051764	0.26613	0.40801	-0.12571
SC/Lm x 100	0.10848	0.059156	0.072769	0.18445	0.1397	0.052544
SC/Bp x 100	-0.03041	0.40971	0.24444	0.30641	-0.1932	-0.59281
Dd/Bp x 100	0.49296	0.38444	0.20024	-0.26389	-0.55879	0.11874
Dp/Dd x 100	-0.11004	-0.44046	0.88151	-0.12546	-0.02406	-0.00444
Dd/GL x 100	0.27346	0.044031	0.057175	0.046202	0.063846	-0.21964
Dd/Lm x 100	0.32402	0.028111	0.087078	0.14627	0.17761	-0.03111
SC/Dd x 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 x 100	0.87566	0.3417	-0.01878	0.3407	0.005382	7.82E-05
SC/Bd x 100	-0.45389	0.52913	-0.24657	0.6251	-0.17934	0.17405
SC/GL x 100	-0.07631	0.22573	0.25624	-0.02933	0.82829	0.43662
Bp/GL x 100	-0.14384	0.20426	0.62981	0.19795	0.11195	-0.69943
Bd/GL x 100	0.011879	0.26124	0.61389	-0.25063	-0.5181	0.47277
SC/Bp x 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 4	PC 5	PC 6		
Bd/Bp x 100	-0.82806	0.43183	0.098183	0.34368	0.003107	0.008732	
SC/Bd x 100	0.50633	0.51589	-0.16452	0.62372	0.092674	-0.22979	
SC/GL x 100	0.11132	0.15806	0.28413	-0.03328	0.72327	0.59806	
Bp/GL x 100	0.1899	0.055264	0.64461	0.1997	-0.60032	0.38092	
Bd/GL x 100	0.039711	0.1312	0.66036	-0.2433	0.23676	-0.65566	
SC/Bp x 100	0.089005	0.70861	-0.17597	-0.62664	-0.2277	0.12026	

Tarsometatarsus – Chester and modern BGPCA loadings						
	PC1 PC2 PC3 PC4 PC5 PC6					
Bd/Bp x 100	-0.82534	0.43142	0.098759	0.35051	-0.00312	0.008778
SC/Bd x 100 0.50673 0.50832 -0.18375 0.62578 0.091226 -0.2261						-0.22618

SC/GL x 100	0.11494	0.16441	0.28072	-0.02024	0.69976	0.62521
Bp/GL x 100	0.19838	0.062104	0.63962	0.196	-0.61758	0.35757
Bd/GL x 100	0.04708	0.14361	0.65964	-0.23323	0.26456	-0.64626
SC/Bp x 100	0.085236	0.70991	-0.18285	-0.62636	-0.22498	0.11127

Appendix E: Statistical Analysis Geometric Morphometrics

5.1 Coracoids

5.1.1 Complete dataset variance percentages

Modern breed coracoids – complete dataset							
PC	Eigenvalues	% Variance	Cumulative %				
Ι	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					
РС	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		

Modern breeds/types - coracoids					
PCs	Eigenvalues	% Variance	Cumulative %		
I	0.00021171	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		

5.1.2 Modern breeds/types PCA. Percentages of variance

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		

5.1.3 Modern breeds/types. DFA classifications

Modern breeds/types – DFA classifications					
Point	Given group Classification		Cross-validated		
e001	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		
r651	Hamburgh	Hamburgh	OEG		
r657	Asian G	Asian G	Asian G		
r658	Asian G	Asian G	Asian G		
r660	Silkie	Silkie	Dorking		
r661	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	
r741	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	
t143	X-B JF	X-B JF	X-B JF	
t144	X-B JF	X-B JF	X-B JF	
tl46	X-B JF	X-B JF	X-B JF	

Modern breeds/types – DFA classifications				
Point	Given group	Classification	Cross-validated	
n001	OEG	OEG	Hamburgh	
w518	OEG	Hamburgh	Hamburgh	
w519	X-B JF	X-B JF	X-B JF	
w528	Dorking	Dorking	Dorking	
w537	Dorking	Hamburgh	Hamburgh	
w611	OEG	OEG	Hamburgh	
w612	OEG	OEG	Hamburgh	

5.1.4 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	1 1	0.41713	0.25826	0.32744	0.001797	-0.10888
ProcCoord3	2	0.16685	-0.21354	-0.40488	0.17033	0.074085
ProcCoord4	2	-0.12911	-0.60384	0.089878	-0.17987	0.14974
ProcCoord5	2	-0.18037	0.063292	0.049846	-0.20034	0.039238
ProcCoord6	3	0.077486	0.14326	0.057214	0.3327	-0.01065
ProcCoord7	Λ	-0.14037	-0.03477	0.073241	0.16132	-0.21389
ProcCoord8	4	-0.52296	0.017333	-0.11531	-0.14737	-0.30008
ProcCoord9	-	0.18044	0.019318	-0.17306	-0.04983	0.28369
ProcCoord10	5	-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	C	0.026074	-0.00076	-0.02677	0.15853	0.043249
ProcCoord12	D	-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	0	0.062544	-0.03849	0.24203	0.006128	0.4143
ProcCoord16	ð	-0.18162	0.1531	-0.12507	-0.0025	-0.01752
ProcCoord17	0	-0.07859	0.05841	0.17706	0.21208	-0.04408
ProcCoord18	9	-0.03788	-0.3064	0.15854	0.22314	-0.0326
ProcCoord19	10	-0.08395	0.018366	-0.033	0.27569	-0.05421
ProcCoord20	10	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	12	0.13043	-0.08354	-0.03861	-0.26349	-0.10986
ProcCoord25	10	0.21023	-0.06192	-0.24998	-0.10406	-0.11132
ProcCoord26	13	0.12697	0.21696	0.13492	-0.27653	0.13976
ProcCoord27	14	-0.04716	0.070947	0.01075	0.21885	-0.10113
ProcCoord28	14	0.36748	-0.01514	-0.12124	-0.12177	-0.18126

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	

5.1.5 Saxon coracoids PCA. Percentages of variance

5.1.6 Saxon coracoids. DFA classifications

Saxon coracoids – DFA classifications					
Point	Given group	Classification	Cross-validated		
L054	Lyminge	Lyminge	Lyminge		
L127	Lyminge	Lyminge	Lyminge		
L134	Lyminge	Flixborough	Flixborough		

Saxon coracoids – DFA classifications				
Point	Given group	Classification	Cross-validated	
L152	Lyminge	Lyminge	Coppergate	
L169	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	
L710	Lyminge	Flixborough	Flixborough	
L741	Lyminge	Coppergate	Coppergate	
L791	Lyminge	Lyminge	Lyminge	
L797	Lyminge	Lyminge	Lyminge	
L823	Lyminge	Lyminge	Coppergate	
L881	Lyminge	Flixborough	Flixborough	
L901	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	
L261	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	
L781	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	
Y011	Coppergate	Coppergate	Flixborough	
Y015	Coppergate	Flixborough	Flixborough	
Y016	Coppergate	Flixborough	Flixborough	
Y017	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	
Y031	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	
Y041	Coppergate	Coppergate	Coppergate	
Y042	Coppergate	Lyminge	Lyminge	
Y044	Coppergate	Coppergate	Coppergate	
Y045	Coppergate	Coppergate	Lyminge	
Y047	Coppergate	Coppergate	Coppergate	
Y051	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					
Y061	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					
Y081	Coppergate	Coppergate	Coppergate					
Y082	Coppergate	Coppergate	Coppergate					
Y085	Coppergate	Coppergate	Coppergate					
Y086	Coppergate	Flixborough	Flixborough					
Saxon coracoids – DFA classifications								
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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					
F351	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					
F371	Flixborough	Flixborough	Coppergate					
F377	Flixborough	Lyminge	Lyminge					
F382	Flixborough	Flixborough	Flixborough					
F383	Flixborough	Flixborough	Lyminge					
F385	Flixborough	Lyminge	Lyminge					
F390	Flixborough	Lyminge	Lyminge					

Saxon	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							

5.1.7 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				
U061	Uley	Uley	Uley				
U075	Uley	Uley	Chester				
UIIO	Uley	Uley	Uley				
UII7	Uley	Uley	Lyminge				
UI27	Uley	Uley	Uley				

Uley, Chester and Lyminge – DFA classifications								
Point	Given group	Classification	Cross-validated					
UI 39	Uley	Uley	Lyminge					
UI5I	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					
L261	Lyminge	Chester	Chester					
L005	Lyminge	Lyminge	Lyminge					
L057	Lyminge	Lyminge	Lyminge					
LI47	Lyminge	Chester	Chester					
L408	Lyminge	Chester	Chester					
L560	Lyminge	Lyminge	Lyminge					
L617	Lyminge	Lyminge	Lyminge					
L781	Lyminge	Chester	Chester					
L816	Lyminge	Chester	Chester					
L916	Lyminge	Lyminge	Lyminge					
L917	Lyminge	Lyminge	Lyminge					
L054	Lyminge	Uley	Uley					
L127	Lyminge	Lyminge	Lyminge					

Uley, Chester and Lyminge – DFA classifications								
Point	Given group	Classification	Cross-validated					
L134	Lyminge	Uley	Uley					
L152	Lyminge	Lyminge	Lyminge					
L169	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					
L5019	Lyminge	Lyminge	Lyminge					
L530	Lyminge	Lyminge	Lyminge					
L702	Lyminge	Lyminge	Lyminge					
L703	Lyminge	Lyminge	Uley					
L710	Lyminge	Lyminge	Chester					
L741	Lyminge	Lyminge	Lyminge					
L791	Lyminge	Lyminge	Lyminge					
L797	Lyminge	Chester	Chester					
L823	Lyminge	Chester	Chester					
L881	Lyminge	Lyminge	Uley					
L901	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		0.0002	0.0028	0.0036	0.5477	0.0843			
Hamburgh	0.0002		0.0013	0.3561	0.0004	0.0024			
X-B JF	0.0028	0.0013		0.0008	0.0004	0.0044			
OEG	0.0036	0.3561	0.0008		0.0019	0.0058			
Silkie	0.5477	0.0004	0.0004	0.0019		0.1626			
Asian G	0.0843	0.0024	0.0044	0.0058	0.1626				

P-values - modern breeds/types and Uley							
	Dorking	Hamburgh	X-B JF	OEG	Silkie	Asian G	Uley
Dorking		0.0101	0.0016	0.0645	0.8751	0.1824	0.0002
Hamburgh	0.0101		0.0007	0.516	0.0005	0.0032	0.0009
X-B JF	0.0016	0.0007		0.0005	0.0009	0.0049	0.0001
OEG	0.0645	0.516	0.0005		0.0122	0.0083	0.0001
Silkie	0.8751	0.0005	0.0009	0.0122		0.2385	0.0001
Asian G	0.1824	0.0032	0.0049	0.0083	0.2385		0.0005
Uley	0.0002	0.0009	0.0001	0.0001	0.0001	0.0005	

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		0.0029	0.0023	0.0129	0.7283	0.1226	0.0001		
Hamburgh	0.0029		0.001	0.5149	0.0009	0.0036	0.1987		
X-B JF	0.0023	0.001		0.0003	0.0004	0.0042	0.0001		
OEG	0.0129	0.5149	0.0003		0.0021	0.004	0.0016		
Silkie	0.7283	0.0009	0.0004	0.0021		0.1677	0.0001		
Asian G	0.1226	0.0036	0.0042	0.004	0.1677		0.0001		
Coppergate	0.0001	0.1987	0.0001	0.0016	0.0001	0.0001			

P-values – modern breeds/types and Lyminge								
	Dorking	Hamburgh	X-B JF	OEG	Silkie	Asian G	Lyminge	
Dorking		0.0074	0.0018	0.048	0.8227	0.1314	0.0001	
Hamburgh	0.0074		0.0013	0.6806	0.0003	0.0032	0.0013	
X-B JF	0.0018	0.0013		0.0002	0.001	0.0044	0.0001	
OEG	0.048	0.6806	0.0002		0.0088	0.0033	0.0001	
Silkie	0.8227	0.0003	0.001	0.0088		0.1546	0.0001	
Asian G	0.1314	0.0032	0.0044	0.0033	0.1546		0.0002	
Lyminge	0.0001	0.0013	0.0001	0.0001	0.0001	0.0002		

P-values – modern breeds/types and Chester									
	Dorking	Hamburgh	X-B JF	OEG	Silkie	Asian G	Chester		
Dorking		0.0082	0.0011	0.0482	0.6424	0.1176	0.0002		
Hamburgh	0.0082		0.0021	0.7553	0.0007	0.0036	0.0004		
X-B JF	0.0011	0.0021		0.006	0.0006	0.0044	0.0001		
OEG	0.0482	0.7553	0.006		0.0288	0.0135	0.0006		
Silkie	0.6424	0.0007	0.0006	0.0288		0.3861	0.0001		
Asian G	0.1176	0.0036	0.0044	0.0135	0.3861		0.0008		
Chester	0.0002	0.0004	0.0001	0.0006	0.0001	0.0008			

5.2 Humeri

5.2.1 Complete dataset variance percentages

Percentages of variance - humeri					
РС	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		

Perc	Percentages of variance - humeri						
РС	Eigenvalues	Eigenvalues % Variance					
19	0.0000033	0.517	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	0.0000082	0.128	99.421				
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	0.0000023	0.037	99.977				

Percentages of variance - humeri							
PC	PC Eigenvalues % Variance Cumulative						
40	0.0000014	0.023	100				

5.2.2 Modern breeds/types percentages of variance – humeri

Percentages of variance – breeds/types - humeri						
PC	Eigenvalues	% Variance	Cumulative %			
Ι	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						
РС	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	0.0000086	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	0.0000035	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					
РС	Eigenvalues	% Variance	Cumulative %		
37	0.00000006	0.01	99.99		
38	0.0000003	0.01	99.99		
39	0.0000002	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		
e001	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		
k001	Asian G	Asian G	O E Game		
r651	Hamburgh	Hamburgh	O E Game		
r657	Asian G	Asian G	Asian G		
r658	Asian G	Asian G	Asian G		
r660	Silkie	Silkie	Silkie		
r661	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		
r741	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		
t041	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		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	O E Game		
t145	X-B JF	Hamburgh	Hamburgh		
t 46	X-B JF	X-B JF	X-B JF		
n001	O E Game	O E Game	O E Game		
w518	O E Game	Dorking	Dorking		
w519	X-B JF	X-B JF	Hamburgh		
w528	Dorking	Dorking	Dorking		
w537	Dorking	Dorking	O E Game		
w611	O E Game	O E Game	O E Game		
w612	O E Game	Hamburgh	Hamburgh		
a003	Dorking	Dorking	Asian G		
h011	Dorking	Dorking	Dorking		

5.2.4 Modern breeds/types loadings for BGPCA

Coordinates	Landmark	PC I	PC 2	PC 3	PC 4	PC 5
ProcCoordI	- I	0.11909	0.39032	0.089013	0.074732	0.14865
ProcCoord2		0.29864	-0.2222	-0.03841	0.12921	-0.17279
ProcCoord3	n	-0.04502	-0.15734	0.069741	0.097231	-0.00058
ProcCoord4	2	-0.19241	-7.63E-06	0.064536	0.17371	-0.02933

Coordinates	Landmark	PC I	PC 2	PC 3	PC 4	PC 5
ProcCoord5	2	0.13684	-0.10342	0.049278	-0.03734	0.056486
ProcCoord6	5	-0.08586	-0.20926	0.23406	0.060009	0.053222
ProcCoord7	4	-0.06307	-0.07227	-0.12739	0.20017	0.31945
ProcCoord8	т	0.013657	-0.07476	-0.33756	0.33999	0.12782
ProcCoord9	5	-0.09477	-0.10284	0.20191	-0.14317	-0.00888
ProcCoord10	J	-0.16508	0.14216	0.12565	-0.17526	0.008231
ProcCoordII	6	-0.09567	-0.09468	-0.03037	0.043517	0.11363
ProcCoord12	0	-0.24206	0.14089	-0.14758	0.14411	0.11945
ProcCoord13	7	-0.14837	-0.18652	-0.05957	-0.24246	0.081827
ProcCoord14	,	-0.10682	0.19969	0.08392	-0.13303	-0.22573
ProcCoord15	8	-0.2723	-0.07339	-0.02719	-0.05428	-0.03439
ProcCoord16		-0.04036	0.1129	-0.01992	0.071059	-0.20654
ProcCoord17	9	-0.15437	0.059136	-0.01158	-0.17422	-0.32413
ProcCoord18		-0.0838	0.18707	-0.29652	-0.12535	0.25798
ProcCoord19	10	0.025413	-0.01745	-0.00276	-0.15115	-0.00275
ProcCoord20	10	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	13	0.005688	0.013695	0.010493	-0.17454	0.043278
ProcCoord24	12	-0.11783	-0.00839	0.11056	0.093894	0.05754
ProcCoord25	13	0.051557	0.070803	-0.10134	-0.12659	0.026091
ProcCoord26	15	-0.15122	-0.04689	0.20216	0.005511	0.20553
ProcCoord27	14	0.062776	0.027484	-0.09346	-0.09448	-0.00751
ProcCoord28	17	-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	10	-0.05779	-0.18019	-0.04151	0.010014	-0.16004
ProcCoord33	17	-0.02265	-0.10192	-0.01361	0.093933	-0.04807
ProcCoord34	17	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	10	0.14332	-0.12409	-0.05559	0.24581	0.099387
ProcCoord38	17	0.24063	-0.12011	-0.21751	-0.1147	-0.12092
ProcCoord39	20	0.060542	0.074111	-0.09028	-0.28002	-0.1232
ProcCoord40	20	0.25408	0.16183	0.040029	-0.22985	0.13471
ProcCoord41	21	0.1773	0.25701	0.015902	0.15529	0.14176
ProcCoord42	21	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						
РС	Eigenvalues	% Variance	Cumulative %			
Ι	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	0.0000084	0.45	97.40			

Percentages of variance – archaeological humeri					
РС	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	0.0000003	0.02	100.00		

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			
u071	Uley	Uley	Lyminge			
u072	Uley	Uley	Uley			
u077	Uley	Uley	Uley			
u081	Uley	Uley	Uley			
u097	Uley	Uley	Chester			
u109	Uley	Uley	Uley			
ul24	Uley	Uley	Uley			
ul 28	Uley	Uley	Uley			
ul 29	Uley	Uley	Uley			
ul 48	Uley	Uley	Uley			
ul 49	Uley	Uley	Uley			
u155	Uley	Uley	Uley			
ul 58	Uley	Uley	Chester			
u167	Uley	Uley	Uley			

5.2.6 Archaeological humeri DFA classifications

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			

Archa	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			
c011	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			
c123	Chester	Chester	Chester			
c133	Chester	Chester	Chester			
c212	Chester	Chester	Chester			
c213	Chester	Chester	Chester			
c214	Chester	Chester	Lyminge			

P-values - modern breeds/types						
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Dorking		0.0002	0.0004	0.0115	0.0317	0.0003
Hamburgh	0.0002		0.865	0.0004	0.0002	0.0003
X-B JF	0.0004	0.865		0.0018	0.0012	0.0025
O E Game	0.0115	0.0004	0.0018		0.1944	0.0007
Silkie	0.0317	0.0002	0.0012	0.1944		0.0005
Asian G	0.0003	0.0003	0.0025	0.0007	0.0005	

5.2.7 One-way Permanova tests for BGPCAs

D values m	adama hua	ada/maraa	مطالمي				
F-values - II	iodern bre	eds/types a	and Oley				
	Uley	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Uley		0.0001	0.0001	0.0028	0.0348	0.0002	0.0001
Dorking	0.0001		0.0001	0.0004	0.0136	0.0312	0.0003
Hamburgh	0.0001	0.0001		0.8665	0.0002	0.0002	0.0004
X-B JF	0.0028	0.0004	0.8665		0.0019	0.0012	0.0030
O E Game	0.0348	0.0136	0.0002	0.0019		0.2097	0.0003
Silkie	0.0002	0.0312	0.0002	0.0012	0.2097		0.0006
Asian G	0.0001	0.0003	0.0004	0.003	0.0003	0.0006	

P-values - modern breeds/types and Lyminge							
	Lyminge	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Lyminge		0.0001	0.0001	0.0001	0.0074	0.0004	0.0001
Dorking	0.0001		0.0002	0.0001	0.0141	0.0358	0.0003
Hamburgh	0.0001	0.0002		0.9792	0.0005	0.0005	0.0004
X-B JF	0.0001	0.0001	0.9792		0.0014	0.0014	0.0018
O E Game	0.0074	0.0141	0.0005	0.0014		0.2773	0.0003
Silkie	0.0004	0.0358	0.0005	0.0014	0.2773		0.0006
Asian G	0.0001	0.0003	0.0004	0.0018	0.0003	0.0006	

P-values - modern breeds/types and Chester							
	Chester	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Chester		0.0008	0.0001	0.0001	0.8098	0.1358	0.0002
Dorking	0.0008		0.0001	0.0007	0.014	0.0346	0.0001
Hamburgh	0.0001	0.0001		0.9409	0.0008	0.0004	0.0007
X-B JF	0.0001	0.0007	0.9409		0.0015	0.0016	0.0026
O E Game	0.8098	0.014	0.0008	0.0015		0.2543	0.0002
Silkie	0.1358	0.0346	0.0004	0.0016	0.2543		0.0009
Asian G	0.0002	0.0001	0.0007	0.0026	0.0002	0.0009	

5.3 Tibiotarsi

5.3.1 Complete dataset variance percentages

Principal				
Component	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	
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	
	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	0.0000068	0.09	100.00	

ComponentI0.0001555539.0239.0210.0000871321.8560.8730.0000507712.7473.6140.000026496.6480.2550.000017054.2888.8770.000012323.0991.9680.000009432.3794.3390.00000561.4095.73100.000004631.1696.89110.000002690.6898.56130.00001230.3199.32140.000001230.3199.32150.00000590.1599.91180.00000360.09100.00	Principal	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 0.00000269 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	Component			
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 0.00000123 0.31 99.32 14 0.00000123 0.31 99.32 15 0.0000019 0.27 99.59 16 0.0000067 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	I	0.00015555	39.02	39.02
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 0.00000123 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 0.0000036 0.09 100.00	2	0.00008713	21.85	60.87
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 0.00000269 0.68 98.56 13 0.00000123 0.31 99.32 14 0.00000123 0.31 99.32 15 0.0000067 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	3	0.00005077	12.74	73.61
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 0.00000269 0.68 98.56 13 0.00000123 0.31 99.32 14 0.00000123 0.31 99.32 15 0.0000067 0.17 99.76 17 0.00000059 0.15 99.91 18 0.0000036 0.09 100.00	4	0.00002649	6.64	80.25
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 0.00000123 0.31 99.32 14 0.00000123 0.31 99.32 15 0.00000167 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	5	0.00001732	4.35	84.60
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 0.00000167 0.17 99.76 17 0.00000059 0.15 99.91 18 0.0000036 0.09 100.00	6	0.00001705	4.28	88.87
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 0.00000167 0.17 99.76 17 0.00000059 0.15 99.91 18 0.00000036 0.09 100.00	7	0.00001232	3.09	91.96
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 0.0000067 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	8	0.00000943	2.37	94.33
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 0.0000036 0.09 100.00	9	0.0000056	1.40	95.73
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 0.00000167 0.17 99.76 16 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	10	0.00000463	1.16	96.89
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 0.0000067 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	11	0.00000393	0.99	97.88
13 0.00000182 0.46 99.01 14 0.00000123 0.31 99.32 15 0.00000109 0.27 99.59 16 0.0000067 0.17 99.76 17 0.0000059 0.15 99.91 18 0.0000036 0.09 100.00	12	0.00000269	0.68	98.56
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 0.0000036 0.09 100.00	13	0.00000182	0.46	99.01
15 0.00000109 0.27 99.59 16 0.00000067 0.17 99.76 17 0.00000059 0.15 99.91 18 0.0000036 0.09 100.00	14	0.00000123	0.31	99.32
16 0.0000067 0.17 99.76 17 0.00000059 0.15 99.91 18 0.0000036 0.09 100.00	15	0.00000109	0.27	99.59
17 0.00000059 0.15 99.91 18 0.00000036 0.09 100.00	16	0.00000067	0.17	99.76
18 0.0000036 0.09 100.00	17	0.00000059	0.15	99.91
	18	0.0000036	0.09	100.00

5.3.2 Modern breeds/types percentages of variance - tibiotarsi

5.3.3 DFA Classifications – tibiotarsi, modern breeds/types

Classifications tibiotarsi DFA mod breeds						
Point	Given group	Classification	Cross-validated			
a003	Dorking	Dorking	Dorking			
e001	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			
h011	Dorking	Dorking	Dorking			
k001	Asian G	O E Game	O E Game			
n001	O E Game	O E Game	Dorking			
r651	Hamburgh	Silkie	Silkie			
r657	Asian G	Asian G	Asian G			
r658	Asian G	Asian G	Asian G			
r660	Silkie	Silkie	Silkie			
r66 l	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			
r741	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			
t041	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			
t 46	X-B JF	Hamburgh	Hamburgh			

Classif	ications tibiota	rsi DFA mod bi	reeds
Point	Given group	Classification	Cross-validated
w518	O E Game	O E Game	O E Game
w519	X-B JF	X-B JF	X-B JF
w528	Dorking	Dorking	Asian G
w537	Dorking	Dorking	Dorking
w611	O E Game	O E Game	O E Game
w612	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
ProcCoordI	1	-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	2	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	-0.56881	-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
ProcCoord10		-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
ProcCoord12		-0.12147	0.17227	-0.02731	-0.12516	0.049659
ProcCoord13	7	-0.05088	0.10761	-0.16867	-0.18052	0.12498
ProcCoord14		-0.02087	-0.13174	-0.03404	-0.09009	-0.0132
ProcCoord15	8	-0.09379	0.15018	-0.00608	0.072449	0.13446
ProcCoord16		0.12498	-0.28286	0.12771	-0.07074	0.18966
ProcCoord17	9	0.053746	0.054591	0.10512	-0.45078	-0.29406
ProcCoord18		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
ProcCoord21	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

РС	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

РС	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	0.0000087	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	0.0000004	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				
c100	Chester	Chester	Chester				
c108	Chester	Chester	Chester				
c132	Chester	Lyminge	Lyminge				
c146	Chester	Lyminge	Lyminge				
c150	Chester	Lyminge	Lyminge				
c170	Chester	Lyminge	Lyminge				
c175	Chester	Chester	Chester				
c176	Chester	Chester	Chester				
c177	Chester	Lyminge	Lyminge				

P-values - modern breeds/types							
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G	
Dorking		0.0005	0.0002	0.0012	0.0052	0.0072	
Hamburgh	0.0005		0.0007	0.0089	0.0012	0.0018	
X-B JF	0.0002	0.0007		0.0001	0.0006	0.0009	
O E Game	0.0012	0.0089	0.0001		0.0005	0.0043	
Silkie	0.0052	0.0012	0.0006	0.0005		0.4177	
Asian G	0.0072	0.0018	0.0009	0.0043	0.4177		

5.3.7 One-way Permanova tests for BGPCAs

P-values - modern breeds/types and Lyminge							
	Lyminge	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Lyminge		0.0001	0.0197	0.0218	0.0023	0.0014	0.0273
Dorking	0.0001		0.0005	0.0001	0.0009	0.0092	0.0086
Hamburgh	0.0197	0.0005		0.0007	0.0152	0.0015	0.0021
X-B JF	0.0218	0.0001	0.0007		0.0003	0.0006	0.0003
O E Game	0.0023	0.0009	0.0152	0.0003		0.0022	0.0033
Silkie	0.0014	0.0092	0.0015	0.0006	0.0022		0.4498
Asian G	0.0273	0.0086	0.0021	0.0003	0.0033	0.4498	

P-values - modern breeds/types and Chester							
	Chester	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Chester		0.0001	0.0782	0.0101	0.0018	0.0003	0.0057
Dorking	0.0001		0.0002	0.0001	0.001	0.0057	0.0055
Hamburgh	0.0782	0.0002		0.0008	0.0187	0.0004	0.0023
X-B JF	0.0101	0.0001	0.0008		0.0001	0.001	0.001
O E Game	0.0018	0.001	0.0187	0.0001		0.0006	0.0021
Silkie	0.0003	0.0057	0.0004	0.001	0.0006		0.3726
Asian G	0.0057	0.0055	0.0023	0.001	0.0021	0.3726	

5.4 Tarsometatarsi

5.4.1 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						
РС	Eigenvalues	% Variance	Cumulative %			
8	0.00001146	1.40	91.04			
9	0.00001051	1.28	92.33			
10	0.00000888	1.08	93.41			
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	0.0000082	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	0.000003	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	0.0000037	0.09	99.90
29	0.00000015	0.04	99.94
30	0.00000013	0.03	99.97
31	0.0000009	0.02	99.99
32	0.00000004	0.01	100.00

Classifications tarsometatarsi DFA mod breeds				
Point	Given group	Classification	Cross-validated	
a003	Dorking	Dorking	O E Game	
e001	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	
e014	Dorking	Dorking	Hamburgh	
h003	Silkie	Silkie	Silkie	
h011	Dorking	Dorking	Dorking	
k001	Asian G	Asian G	Asian G	
n001	O E Game	O E Game	O E Game	
r651	Hamburgh	Hamburgh	Dorking	
r657	Asian G	Asian G	Asian G	
r658	Asian G	Asian G	Asian G	
r660	Silkie	Silkie	Silkie	
r66 l	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	

5.4.3 DFA Classifications modern breeds tarsometatarsi

Classif	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		
r741	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		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	X-B JF		
t145	X-B JF	X-B JF	O E Game		
t 46	X-B JF	X-B JF	X-B JF		
w518	O E Game	Dorking	Dorking		

Classifications tarsometatarsi DFA mod breeds				
Point	Given group	Classification	Cross-validated	
w519	X-B JF	X-B JF	X-B JF	
w528	Dorking	Dorking	Dorking	
w611	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
ProcCoord1	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
ProcCoord10		-0.31823	0.035731	-0.24659	0.10845	-0.31513
ProcCoordII	6	-0.16321	-0.44129	0.34917	-0.11578	-0.04378
ProcCoord12		-0.03009	0.030714	-0.12918	-0.02765	-0.0718
ProcCoord13	7	-0.13241	-0.26221	0.20654	0.08694	-0.12197

Coordinates	Landmark	PC I	PC 2	PC 3	PC 4	PC 5
ProcCoord14		0.093745	0.016747	0.070279	-0.02582	0.22429
ProcCoord15	8	-0.03927	0.13369	0.071948	0.20707	-0.0486
ProcCoord16	Ū	-0.25461	-0.06063	-0.2849	-0.05518	0.066043
ProcCoord17	9	0.13743	0.14348	-0.24735	-0.32294	0.075741
ProcCoord18		-0.16528	-0.09075	0.058057	-0.4	-0.17662
ProcCoord19	10	0.005452	0.17087	-0.02977	-0.18179	-0.04548
ProcCoord20		-0.12467	-0.02748	0.18145	-0.2243	0.059563
ProcCoord21	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	12	-0.05554	0.040196	0.068435	0.15638	0.008413
ProcCoord25	13	-0.09086	0.062633	0.11749	-0.02298	-0.00168
ProcCoord26	. 13	-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	. 15	0.10851	-0.04243	0.036476	0.10539	-0.08038
ProcCoord31	16	0.18895	-0.09718	0.009979	0.39007	-0.22155
ProcCoord32	. 10	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	0.28328	0.27201	-0.2002	-0.11127

5.4.5 Archaeological tarsometatarsi – percentages of variance

PC	Eigenvalues	% Variance	Cumulative %
Ι	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

РС	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	0.0000093	0.54	97.60
22	0.0000083	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	0.0000036	0.21	99.55
28	0.0000034	0.20	99.75
29	0.00000017	0.10	99.85
30	0.00000012	0.07	99.92
31	0.0000008	0.05	99.97
32	0.0000006	0.03	100.00

Archaeological tarsometatarsi – DFA classifications				
Point	Given group	Classification	Cross-validated	
L087	Lyminge	Lyminge	Chester	
L088	Lyminge	Chester	Chester	
LII2	Lyminge	Chester	Chester	
L133	Lyminge	Lyminge	Lyminge	
L145	Lyminge	Lyminge	Lyminge	
LI57	Lyminge	Lyminge	Lyminge	
L164	Lyminge	Lyminge	Lyminge	
L179	Lyminge	Lyminge	Lyminge	
L180	Lyminge	Chester	Chester	
L187	Lyminge	Chester	Chester	
L206	Lyminge	Lyminge	Lyminge	
L208	Lyminge	Lyminge	Lyminge	
L209	Lyminge	Uley	Uley	
L210	Lyminge	Chester	Chester	
L234	Lyminge	Lyminge	Lyminge	
L246	Lyminge	Lyminge	Lyminge	
L253	Lyminge	Chester	Chester	
L328	Lyminge	Lyminge	Lyminge	
L330	Lyminge	Lyminge	Lyminge	

5.4.6 Archaeological tarsometatarsi – DFA classifications

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	
L511	Lyminge	Lyminge	Lyminge	
L521	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	
L611	Lyminge	Lyminge	Lyminge	
L612	Lyminge	Lyminge	Lyminge	
L620	Lyminge	Lyminge	Lyminge	
L651	Lyminge	Lyminge	Lyminge	
L718	Lyminge	Lyminge	Lyminge	
L783	Lyminge	Lyminge	Lyminge	
L793	Lyminge	Lyminge	Lyminge	
L817	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	
U105	Uley	Uley	Uley	
UII2	Uley	Chester	Chester	
U171	Uley	Uley	Chester	
C002	Chester	Chester	Uley	
C022	Chester	Chester	Lyminge	
C023	Chester	Lyminge	Lyminge	
C124	Chester	Chester	Chester	
C126	Chester	Chester	Chester	
C180	Chester	Uley	Uley	
C193	Chester	Chester	Chester	
C217	Chester	Uley	Uley	
C218	Chester	Lyminge	Lyminge	

P-values - modern breeds/types						
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G
Dorking		0.0008	0.0005	0.0018	0.0007	0.0453
Hamburgh	0.0008		0.0042	0.1578	0.0004	0.0093
X-B JF	0.0005	0.0042		0.0157	0.0007	0.0005
O E Game	0.0018	0.1578	0.0157		0.0002	0.1515
Silkie	0.0007	0.0004	0.0007	0.0002		0.0008
Asian G	0.0453	0.0093	0.0005	0.1515	0.0008	

5.4.7 One-way Permanova tests for BGPCAs

Disaluan wandawa kwanda/wana and Illau							
r-values - m	P-values - modern breeds/types and Oley						
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G	Uley
Dorking		0.001	0.0006	0.0021	0.0003	0.0365	0.0013
Hamburgh	0.001		0.0014	0.1595	0.0006	0.0176	0.0073
X-B JF	0.0006	0.0014		0.0197	0.0008	0.0011	0.1185
O E Game	0.0021	0.1595	0.0197		0.0005	0.1654	0.0127
Silkie	0.0003	0.0006	0.0008	0.0005		0.0007	0.0014
Asian G	0.0365	0.0176	0.0011	0.1654	0.0007		0.002
Uley	0.0013	0.0073	0.1185	0.0127	0.0014	0.002	

P-values - modern breeds/types and Lyminge							
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G	Lyminge
Dorking		0.0007	0.0005	0.0011	0.0006	0.0326	0.0001
Hamburgh	0.0007		0.0027	0.1341	0.0006	0.0079	0.0001
X-B JF	0.0005	0.0027		0.0341	0.0006	0.0005	0.0231
O E Game	0.0011	0.1341	0.0341		0.0001	0.0949	0.0002
Silkie	0.0006	0.0006	0.0006	0.0001		0.0005	0.0001
Asian G	0.0326	0.0079	0.0005	0.0949	0.0005		0.0001
Lyminge	0.0001	0.0001	0.0231	0.0002	0.0001	0.0001	

P-values - modern breeds/types and Chester							
	Dorking	Hamburgh	X-B JF	O E Game	Silkie	Asian G	Chester
Dorking		0.0007	0.0008	0.0029	0.0003	0.0439	0.0003
Hamburgh	0.0007		0.0023	0.1537	0.0006	0.0091	0.015
X-B JF	0.0008	0.0023		0.014	0.0003	0.0002	0.3107
O E Game	0.0029	0.1537	0.014		0.0001	0.1514	0.0694
Silkie	0.0003	0.0006	0.0003	0.0001		0.0013	0.0003
Asian G	0.0439	0.0091	0.0002	0.1514	0.0013		0.0012
Chester	0.0003	0.015	0.3107	0.0694	0.0003	0.0012	

Appendix F: Classifying archaeological coracoids

6.1 Uley

6.1.1 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	1/1	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.

Six modern groups and Uley 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		
h003	Silkie	Dorking	Dorking		
r651	Hamburgh	Hamburgh	Hamburgh		
r657	Asian G	Asian G	Asian G		
r658	Asian G	Asian G	Asian G		
r660	Silkie	Silkie	Silkie		
r661	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		

Classification table for DFA with six modern groups and Uley replaced by '?'

Six modern groups and Uley classifications					
Point	Given group	Classification	Cross-validated		
r736	Hamburgh	Hamburgh	OEG		
r740	Hamburgh	Hamburgh	Hamburgh		
r741	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		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	X-B JF		
t 46	X-B JF	X-B JF	X-B JF		
n001	OEG	OEG	OEG		
w518	OEG	X-B JF	X-B JF		
w519	X-B JF	X-B JF	X-B JF		
w528	Dorking	Dorking	Dorking		
w537	Dorking	Hamburgh	Hamburgh		
w611	OEG	OEG	OEG		
w612	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			
u061	?	Dorking			
u075	?	Dorking			
ull0	?	Hamburgh			
ull7	?	OEG			
u127	?	OEG			
u139	?	Hamburgh			
ul5l	?	OEG			
u180	?	Hamburgh			
u186	?	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	1/1	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	1/1	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 n	Four modern groups and Uley 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				
r651	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		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	X-B JF		
t 46	X-B JF	X-B JF	X-B JF		
n001	OEG	OEG	OEG		
w518	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		
w611	OEG	OEG	OEG		

Four modern groups and Uley classifications					
Point	Given group	Classification	Cross-validated		
w612	OEG	OEG	Hamburgh		
u004	?	OEG			
u023	?	Dorking			
u025	?	Dorking			
u040	?	Hamburgh			
u043	?	Hamburgh			
u050	?	Dorking			
u057	?	OEG			
u061	?	Dorking			
u075	?	Dorking			
ullO	?	Hamburgh			
ull7	?	OEG			
u127	?	OEG			
ul 39	?	Hamburgh			
ul5l	?	OEG			
u180	?	Hamburgh			
u186	?	Hamburgh			

6.2 Flixborough

6.2.1 Flixborough with six modern groups

Confusion r	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	1/1	0/0	0/1	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	1/1	5/4	1/1	1/1	1/2	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	0/1	3/2	0/0	4
Flixborough	0/0	2/3	0/0	5/5	0/0	0/0	24/23	31
Total	7/6	10/8	7/7	10/12	7/8	4/3	25/26	70

DFA with six modern groups and Flixborough as named group

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		
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		
h003	Silkie	Dorking	Dorking		
r651	Hamburgh	Hamburgh	Hamburgh		
r657	Asian G	Asian G	Asian G		
r658	Asian G	Asian G	Asian G		
r660	Silkie	Silkie	Silkie		
r661	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		
r741	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		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	X-B JF		
t 46	X-B JF	X-B JF	X-B JF		
n001	OEG	OEG	OEG		
w518	OEG	X-B JF	X-B JF		
w519	X-B JF	X-B JF	X-B JF		
w528	Dorking	Dorking	Dorking		
w537	Dorking	Hamburgh	Hamburgh		
w611	OEG	OEG	OEG		
w612	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	?	Hamburgh			
f371	?	OEG			
f377	?	OEG			
f382	?	Hamburgh			
f383	?	Hamburgh			
f385	?	Hamburgh			
f390	?	OEG			
f391	?	OEG			
f392	?	Hamburgh			
f393	?	Hamburgh			

Six modern groups and Flixborough classifications					
Point	Given group	Classification	Cross-validated		
f394	?	Silkie			
f396	?	Hamburgh			
f397	?	OEG			
f398	?	OEG			
f401	?	OEG			
f402	?	OEG			
f403	?	OEG			
f404	?	OEG			
f406	?	OEG			

6.2.2 Flixborough with four modern groups

Confusion matrix four modern groups and Flixborough: before/after c-v						
	Dorking	Hamburgh	X-B JF	OEG	Flixborough	Total
Dorking	5/4	1/1	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	11/11	7/7	10/11	26/26	59

DFA with four modern groups and Flixborough as named group

81.36% correct/76.27% after cross-validation

Classification table for DFA with four modern groups and Flixborough replaced by '?'

Four n	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			
r651	Hamburgh	Hamburgh	Hamburgh			

Four n	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			
t 43	X-B JF	X-B JF	X-B JF			
t 44	X-B JF	X-B JF	X-B JF			
t 46	X-B JF	X-B JF	X-B JF			
n001	OEG	OEG	OEG			
w518	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			
w611	OEG	OEG	OEG			

Four n	Four modern groups and Flixborough classifications						
Point	Given group	Classification	Cross-validated				
w612	OEG	OEG	Hamburgh				
f338	?	OEG					
f339	?	Hamburgh					
f344	?	OEG					
f345	?	OEG					
f346	?	OEG					
f351	?	Hamburgh					
f357	?	Hamburgh					
f358	?	Hamburgh					
f361	?	OEG					
f362	?	OEG					
f363	?	OEG					
f368	?	Hamburgh					
f370	?	OEG					
f371	?	OEG					
f377	?	OEG					
f382	?	OEG					
f383	?	Hamburgh					
f385	?	Hamburgh					
f390	?	OEG					
f391	?	OEG					

Four modern groups and Flixborough classifications				
Point	Given group	Classification	Cross-validated	
f392	?	Hamburgh		
f393	?	Hamburgh		
f394	?	OEG		
f396	?	Dorking		
f397	?	OEG		
f398	?	OEG		
f401	?	OEG		
f402	?	OEG		
f403	?	OEG		
f404	?	OEG		
f406	?	OEG		

6.3 Coppergate

6.3.1 Coppergate with six modern groups

Confusion r	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	0/1	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	1/1	1/1	2/2	9
Silkie	1/1	0/0	0/0	0/0	6/5	0/1	0/0	7
Asian G	1/1	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

DFA with six modern groups and Coppergate as named group

80.43% correct/70.65% after cross-validation.

Classification table for DFA with six modern groups and Coppergate replaced by '?'

Six mo	Six modern groups and Coppergate 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			
h003	Silkie	Dorking	Dorking			
r651	Hamburgh	Hamburgh	Hamburgh			
r657	Asian G	Asian G	Asian G			
r658	Asian G	Asian G	Asian G			
r660	Silkie	Silkie	Silkie			
r661	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
r741	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
t 43	X-B JF	X-B JF	X-B JF
t 44	X-B JF	X-B JF	X-B JF
t 46	X-B JF	X-B JF	X-B JF
n001	OEG	OEG	OEG
w518	OEG	X-B JF	X-B JF
w519	X-B JF	X-B JF	X-B JF
w528	Dorking	Dorking	Dorking
w537	Dorking	Hamburgh	Hamburgh
w611	OEG	OEG	OEG
w612	OEG	OEG	Hamburgh
y002	?	OEG	

Six modern groups and Coppergate classifications				
Point	Given group	Classification	Cross-validated	
y003	?	OEG		
y004	?	OEG		
y007	?	OEG		
y011	?	OEG		
y015	?	Hamburgh		
y016	?	OEG		
y017	?	X-B JF		
y019	?	Hamburgh		
y022	?	Hamburgh		
y025	?	Hamburgh		
y026	?	Hamburgh		
y027	?	Dorking		
y028	?	OEG		
y029	?	OEG		
y031	?	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		
y041	?	Hamburgh		
y042	?	OEG		
y044	?	OEG		
y045	?	OEG		
y047	?	OEG		
y051	?	OEG		
y052	?	OEG		
y054	?	OEG		
y055	?	Hamburgh		
y056	?	OEG		
y057	?	OEG		
y058	?	OEG		
y059	?	Hamburgh		
y060	?	OEG		
y061	?	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		
y081	?	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	1/1	6/5	2/2	9
Coppergate	2/2	3/3	1/2	6/6	41/40	53
Total	8/5	9/11	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
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
r651	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	
r741	Hamburgh	Hamburgh	Hamburgh	
r742	Hamburgh	Hamburgh	Hamburgh	
t022	Hamburgh	Hamburgh	X-B JF	
t059	X-B JF	X-B JF	X-B JF	
t 43	X-B JF	X-B JF	X-B JF	
t 44	X-B JF	X-B JF	X-B JF	
t 46	X-B JF	X-B JF	X-B JF	
n001	OEG	OEG	OEG	
w518	OEG	X-B JF	X-B JF	
w519	X-B JF	X-B JF	X-B JF	
w528	Dorking	Dorking	Hamburgh	
w537	Dorking	Hamburgh	Hamburgh	
w611	OEG	OEG	OEG	
w612	OEG	OEG	Hamburgh	
y002	?	OEG		
Four modern groups and Coppergate classifications				
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Point	Given group	Classification	Cross-validated	
y003	?	OEG		
y004	?	OEG		
y007	?	Hamburgh		
y011	?	OEG		
y015	?	OEG		
y016	?	OEG		
y017	?	X-B JF		
y019	?	OEG		
y022	?	OEG		
y025	?	OEG		
y026	?	Hamburgh		
y027	?	Dorking		
y028	?	OEG		
y029	?	OEG		
y031	?	X-B JF		
y032	?	Hamburgh		
y033	?	OEG		
y034	?	OEG		
y035	?	OEG		
y037	?	Hamburgh		
y038	?	OEG		

Four n	Four modern groups and Coppergate classifications				
Point	Given group	Classification	Cross-validated		
y039	?	OEG			
y041	?	Hamburgh			
y042	?	OEG			
y044	?	OEG			
y045	?	OEG			
y047	?	Hamburgh			
y051	?	OEG			
y052	?	OEG			
y054	?	OEG			
y055	?	Hamburgh			
y056	?	OEG			
y057	?	OEG			
y058	?	OEG			
y059	?	Hamburgh			
y060	?	OEG			
y061	?	OEG			
y063	?	OEG			
y067	?	OEG			
y068	?	OEG			
y069	?	OEG			
y070	?	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

6.4.1 Lyminge with six modern groups

DFA with six modern groups and Lyminge as named grou	d Lyminge as named group	groups and	DFA with six modern
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Confusion	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	1/1	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	1/1	0/2	9
Silkie	1/1	0/0	0/0	0/0	6/6	0/0	0/0	7
Asian G	1/1	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 mo	Six modern groups and Lyminge 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		
h003	Silkie	Dorking	Dorking		
r651	Hamburgh	Hamburgh	Hamburgh		
r657	Asian G	Asian G	Asian G		
r658	Asian G	Asian G	Asian G		
r660	Silkie	Silkie	Silkie		
r661	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	
r741	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	
t 43	X-B JF	X-B JF	X-B JF	
t 44	X-B JF	X-B JF	X-B JF	
t 46	X-B JF	X-B JF	X-B JF	
n001	OEG	OEG	OEG	
w518	OEG	X-B JF	X-B JF	
w519	X-B JF	X-B JF	X-B JF	
w528	Dorking	Dorking	Dorking	
w537	Dorking	Hamburgh	Hamburgh	
w611	OEG	OEG	OEG	
w612	OEG	OEG	OEG	
L228	?	Hamburgh		

Six modern groups and Lyminge classifications				
Point	Given group	Classification	Cross-validated	
L236	?	OEG		
L249	?	OEG		
L255	?	Dorking		
L261	?	X-B JF		
L005	?	Hamburgh		
L057	?	OEG		
LI47	?	OEG		
L408	?	OEG		
L560	?	Dorking		
L617	?	OEG		
L781	?	OEG		
L816	?	Hamburgh		
L916	?	Hamburgh		
L917	?	Hamburgh		
L054	?	Dorking		
L127	?	OEG		
L134	?	OEG		
L152	?	OEG		
L169	?	Hamburgh		
L222	?	Hamburgh		
L226	?	OEG		

Six modern groups and Lyminge classifications				
Point	Given group	Classification	Cross-validated	
L340	?	Hamburgh		
L346	?	Hamburgh		
L477	?	OEG		
L509	?	Hamburgh		
L519	?	OEG		
L530	?	Hamburgh		
L702	?	OEG		
L703	?	Hamburgh		
L710	?	Hamburgh		
L741	?	OEG		
L791	?	OEG		
L797	?	OEG		
L823	?	Dorking		
L881	?	Hamburgh		
L901	?	OEG		

6.4.2 Lyminge with four modern groups

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	1/1	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	1/1	1/2	32/29	36
Total	6/6	9/11	7/7	8/9	34/31	64

DFA with four modern groups and Lyminge as named group

85.94% correct/79.69% after cross-validation.

Classification table for DFA with four modern groups and Lyminge replaced by '?'

-					
Four n	Four modern groups and Lyminge 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		
r651	Hamburgh	Hamburgh	Hamburgh		

Four n	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		
r741	Hamburgh	Hamburgh	Hamburgh		
r742	Hamburgh	Hamburgh	X-B JF		
t022	Hamburgh	Hamburgh	X-B JF		
t059	X-B JF	X-B JF	Hamburgh		
t 43	X-B JF	X-B JF	X-B JF		
t 44	X-B JF	X-B JF	X-B JF		
t 46	X-B JF	X-B JF	X-B JF		
n001	OEG	OEG	OEG		
w518	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		
w611	OEG	OEG	OEG		

Four modern groups and Lyminge classifications			
Point	Given group	Classification	Cross-validated
w612	OEG	OEG	Hamburgh
1228	?	OEG	
1236	?	OEG	
1249	?	OEG	
1255	?	Dorking	
1261	?	X-B JF	
1005	?	Hamburgh	
1057	?	OEG	
1147	?	OEG	
1408	?	Dorking	
1560	?	Dorking	
1617	?	OEG	
1781	?	OEG	
1816	?	OEG	
1916	?	Hamburgh	
1917	?	Hamburgh	
1054	?	Dorking	
1127	?	OEG	
1134	?	Hamburgh	
1152	?	OEG	
1169	?	OEG	

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	?	OEG	
1703	?	Hamburgh	
1710	?	Hamburgh	
1741	?	OEG	
1791	?	OEG	
1797	?	OEG	
1823	?	Dorking	
1881	?	OEG	
1901	?	OEG	

6.5 Chester

6.5.1 Chester with six modern groups

	Dorking	Hamburgh	X-B JF	OEG	Silkie	Asian G	Chester	Tota
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	1/1	1/1	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	12/11	52

DFA with six modern groups and Chester as named group

Six modern groups and Chester 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	
h003	Silkie	Dorking	Dorking	
r651	Hamburgh	Hamburgh	Hamburgh	
r657	Asian G	Asian G	Asian G	
r658	Asian G	Asian G	Asian G	
r660	Silkie	Silkie	Silkie	
r661	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	

Classification table for DFA with six modern groups and Chester replaced by '?'

Six modern groups and Chester classifications			
Point	Given group	Classification	Cross-validated
r736	Hamburgh	Hamburgh	OEG
r740	Hamburgh	Hamburgh	Hamburgh
r741	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
t 43	X-B JF	X-B JF	X-B JF
t 44	X-B JF	X-B JF	X-B JF
t 46	X-B JF	X-B JF	X-B JF
n001	OEG	OEG	OEG
w518	OEG	Hamburgh	X-B JF
w519	X-B JF	X-B JF	X-B JF
w528	Dorking	Dorking	Dorking
w537	Dorking	Hamburgh	Hamburgh
w611	OEG	OEG	OEG
w612	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	
c101	?	Hamburgh	
c158	?	X-B JF	
c166	?	Hamburgh	
c182	?	X-B JF	
c219	?	OEG	

6.5.2 Chester with four modern groups

Confusion matrix four modern groups and Chester: before/after c-v						
_	Chester	Dorking	Hamburgh	X-B JF	OEG	Total
Chester	11/10	1/1	1/1	0/1	0/0	13
Dorking	1/1	5/4	0/0	0/0	0/1	6
Hamburgh	0/0	0/0	6/6	0/0	1/1	7
X-B JF	0/0	0/0	0/0	6/6	0/0	6
OEG	1/1	0/0	0/0	0/0	8/8	9
Total	13/12	6/5	7/7	6/7	9/10	41

DFA with four modern groups and Chester as named group

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	
c101	?	Hamburgh	
c158	?	Dorking	
c166	?	Hamburgh	
c182	?	X-B JF	
c219	?	OEG	
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
r651	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
r741	Hamburgh	Hamburgh	Hamburgh
r742	Hamburgh	Hamburgh	X-B JF
t022	Hamburgh	Hamburgh	Hamburgh
t059	X-B JF	X-B JF	X-B JF
t 43	X-B JF	X-B JF	X-B JF
t 44	X-B JF	X-B JF	X-B JF
t 46	X-B JF	X-B JF	X-B JF
n001	OEG	OEG	OEG
w518	OEG	OEG	Dorking
w519	X-B JF	X-B JF	X-B JF
w528	Dorking	Dorking	Hamburgh
w537	Dorking	Hamburgh	Hamburgh
w611	OEG	OEG	OEG
w612	OEG	OEG	OEG

Appendix G - Species differentiation study using GMM

7.1 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				
РС	Eigenvalues	% Variance	Cumulative %	
I	0.00029531	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	0.0000073	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	
e019	Pheasant	Pheasant	Pheasant	
re020	Pheasant	Pheasant	Pheasant	
e021	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	
w614	Guinea fowl	Guinea fowl	Guinea fowl	
w615	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	
u061	Uley	Uley	Uley	
u075	Uley	Uley	Uley	
ull0	Uley	Uley	Uley	
ull7	Uley	Uley	Uley	
u127	Uley	Uley	Uley	
u I 39	Uley	Uley	Uley	
ul5l	Uley	Uley	Uley	
u180	Uley	Uley	Uley	
u186	Uley	Uley	Uley	

7.2 Humerus

Regression analysis – 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 %	
1	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 squares0.02525		
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	
u071	Uley	Uley	Uley	
u072	Uley	Uley	Uley	
u077	Uley	Uley	Uley	
u081	Uley	Uley	Uley	
u097	Uley	Uley	Uley	
u109	Uley	Uley	Uley	
u124	Uley	Uley	Uley	
u128	Uley	Uley	Uley	

DFA classification of PC scores after BGPCA				
Point	Given group	Classification	Cross-validated	
ul 29	Uley	Uley	Uley	
u148	Uley	Uley	Uley	
u149	Uley	Uley	Uley	
u155	Uley	Uley	Uley	
u I 58	Uley	Uley	Uley	
u167	Uley	Uley	Uley	
e015	Pheasant	Pheasant	Pheasant	
e016	Pheasant	Pheasant	Pheasant	
e017	Pheasant	Pheasant	Pheasant	
e018	Pheasant	Pheasant	Pheasant	
e019	Pheasant	Pheasant	Pheasant	
e020	Pheasant	Pheasant	Pheasant	
e021	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	
t081	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	
t 25	Black grouse	Black grouse	Black grouse	
t 28	Black grouse	Black grouse	Black grouse	
t 36	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	
w615	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 %
	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	15.51	
P-value	0.0001	

DFA classifications of PC scores after BGPCA			
Point	Given group	Classification	Cross-validated
e017	Pheasant	Pheasant	Pheasant
e018	Pheasant	Pheasant	Pheasant
e019	Pheasant	Pheasant	Pheasant
e020	Pheasant	Pheasant	Pheasant
e021	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
e031	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
t 25	Black grouse	Black grouse	Black grouse
t 26	Black grouse	Black grouse	Black grouse
t 28	Black grouse	Black grouse	Black grouse
t 36	Black grouse	Black grouse	Black grouse
w614	Guinea fowl	Lyminge	Lyminge
w615	Guinea fowl	Guinea fowl	Guinea fowl
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
z010	Black grouse	Black grouse	Black grouse
1050	Lyminge	Lyminge	Lyminge
1052	Lyminge	Lyminge	Lyminge
1142	Lyminge	Lyminge	Lyminge
1219	Lyminge	Lyminge	Lyminge
1221	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 component	Eigenvalues	% Variance	Cumulative %
1	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	0.0000893	2.626	84.984
9	0.0000781	2.296	87.280
10	0.00000643	1.981	89.171

Tarsometatarsus			
Principal component	Eigenvalues	% Variance	Cumulative %
11	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 c	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	
e021	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		
t081	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		
w614	Guinea fowl	Guinea fowl	Guinea fowl		
w615	Guinea fowl	Guinea fowl	Guinea fowl		
DFA classification of PC scores after BGPCA					
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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		
1112	Lyminge	Lyminge	Lyminge		
1133	Lyminge	Lyminge	Lyminge		
1145	Lyminge	Lyminge	Lyminge		
1157	Lyminge	Lyminge	Lyminge		
1164	Lyminge	Lyminge	Lyminge		
1179	Lyminge	Lyminge	Lyminge		
1180	Lyminge	Lyminge	Lyminge		
1187	Lyminge	Lyminge	Lyminge		
1206	Lyminge	Lyminge	Lyminge		
1208	Lyminge	Lyminge	Lyminge		
1209	Lyminge	Lyminge	Lyminge		
1210	Lyminge	Lyminge	Lyminge		
1212	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		
15	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		
l65 l	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)						
F-value > F-sta	tistic = can reje	ct null hypot	thesis (same)			
F-value > F-sta	tistic = can reje Guinea Fowl	ct null hypot Chicken	thesis (same) Black Grouse	Pheasant		
F-value > F-sta Guinea Fowl	tistic = can reje Guinea Fowl	ct null hypot Chicken tbt, tmt	thesis (same) Black Grouse tbt	Pheasant tbt, tmt		
F-value > F-sta Guinea Fowl Chicken	tistic = can reje Guinea Fowl tbt, tmt	ct null hypot Chicken tbt, tmt	thesis (same) Black Grouse tbt hum, tbt	Pheasant tbt, tmt cor, hum		
F-value > F-sta Guinea Fowl Chicken Black Grouse	tistic = can reje Guinea Fowl tbt, tmt tbt	ct null hypot Chicken tbt, tmt hum, tbt	thesis (same) Black Grouse tbt hum, tbt	Pheasant tbt, tmt cor, hum		