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**A methodological approach to the identification of duck and goose remains  
from archaeological sites with an application to Roman Britain**

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## **Abstract~**

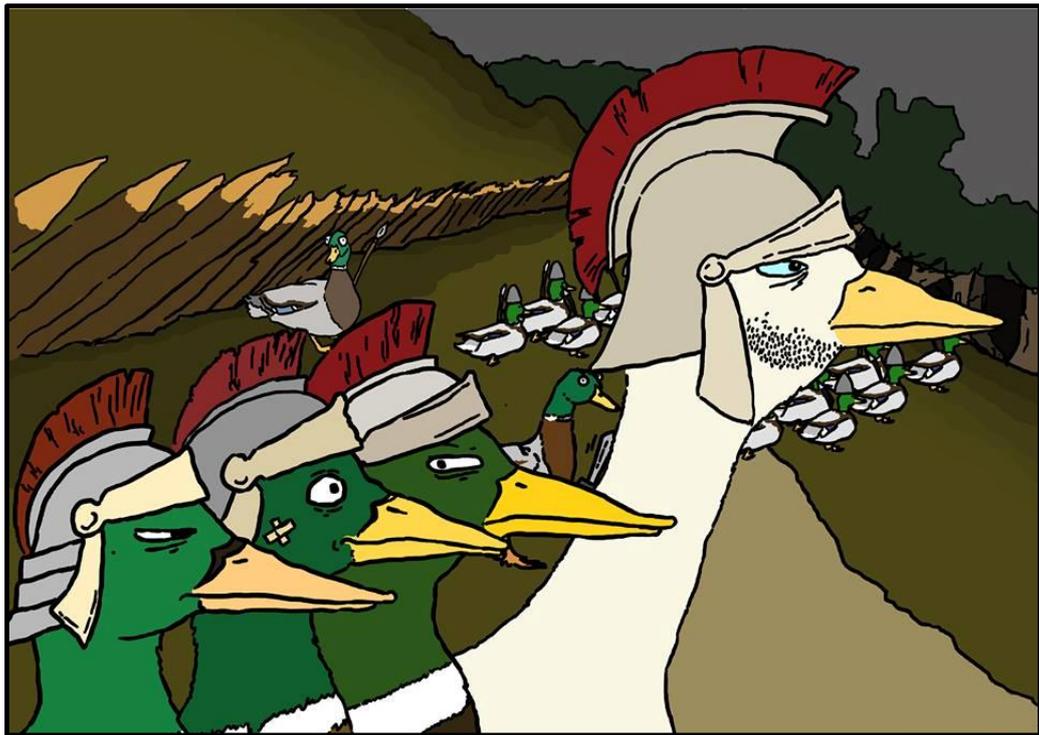
The use of ducks and geese in Roman Britain is poorly understood and rarely discussed despite the frequent recovery of their osteological remains from archaeological sites. This is because it can be difficult to distinguish between the different genera, let alone different species, using a comparative reference collection. The main aim of this project was to develop a reliable method of taxonomic identification using morphometry in order to analyse archaeological assemblages and develop our understanding of the use of ducks and geese in the past.

Linear measurements were taken from modern reference material to create a database of the different European anatids. Taxon distinguishing criteria was then identified using statistical analysis and the simplest reliable identification criteria are presented here for nine bones of the avian skeleton. The reliable taxon distinguishing criteria were applied to various archaeological assemblages from a range of Roman sites in Britain to discuss which taxa were used and in what way. Key questions that are discussed include the use of wild birds compared to domestic ones, the use of ducks compared to geese and whether there is variation in the use of anatids between types of sites.

Further applications of this research will be that the identification method could readily be used by other researchers interested in the role of ducks and geese in the past, and that we will have a much better context for discussing the changes in the way ducks and geese were used during the Saxon and medieval periods in Britain.



'Ged's first Tufted Duck' - N. Ellis, watercolour, 01/01/2016



'Roman quack troops' - C.A. Hay, 2014

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## **Chapter 1~** **Introduction**

There are many questions about the Roman period in Britain that zooarchaeology can aid in answering; questions of economy, environmental opportunities and constraints, ritual activity, regional variations, differences between types of settlement and major changes in human activity through time to name but a few (Reitz and Wing 1999: 7-8). Previously there has been a lot of focus on the use of mammals throughout this period, with little discussion of birds aside from to list the taxa that are present on site. There are exceptions to this such as Parker (1988), Albarella (2005), and Gál and Kunst (2014), and an ongoing project on changing scientific and cultural perspectives on human-chicken interactions will help to illuminate the role of chickens during this period (<http://chickenco-op.net/>). However, there has been almost no discussion of the ducks and geese that have been recovered from Roman archaeological sites in Britain. The main reason for this is a lack of reliable identification criteria despite work on duck and goose assemblages being carried out for a number of decades. This is a great shame as the information that could be gathered from these assemblages could be extremely useful in answering some key questions, not only about the use of ducks and geese in Britain during the Roman period, but also about the nature and variation of patterns of Roman life in Britain and their relations with the rest of the Roman world.

## **The use of ducks and geese in the past**

The role of ducks and geese in Britain today is much reduced compared to their importance in the past. The current importance of chickens, advances in technology and the mass-produced synthetic materials that have replaced some of the uses for duck and goose products have led to the diminished social and economic role of these birds. Although we still see occasional consumption and use of duck and goose products in Britain today, past use was much more frequent and in a much greater range of ways, not only in Britain but in many places around the world.

### **Meat**

The first usage of ducks and geese for consideration is meat consumption. Before the development of domestic ducks and geese, wild forms of these birds were a valuable source of protein and fat to many people in the past. There are a number of examples of wildfowling from historical and pictographic sources that suggest that the practice was important in many areas of the world (Cabot 2009: 8-9). Duck and goose meat is rich in fat and so may have been an important foodstuff for people able to access it (Shrubb 2013: 74). One time of the year that ducks and geese are particularly easy to catch is when they are moulting. At such time they cannot fly and so it is difficult for them to evade hunters (Cabot 2009: 17). There are a number of ethnographic examples of wildfowling using various techniques to collect ducks and geese such as in nets, with dogs, with clubs and with blunted arrows (Clark 1948: 116-117). An archaeological example of prehistoric wildfowling comes from the Finnish site of Jettböle I in Jomala where the bird assemblage is mainly comprised of two species of duck - the Eider (*Somateria mollissima*) and the Velvet Scoter (*Melanitta fusca*). A relatively high percentage of the bones contained medullary bone suggesting that they were killed during a laying season, and possibly the same laying season (Mannermaa

2003). An assemblage containing many individuals of the same species killed in a short space of time could be the result of wildfowling using nets to catch many ducks in one go. This is an activity that is still undertaken in a number of places in the arctic circle today (Cabot 2009: 17).

Based upon historical, pictographic and archaeological evidence it appears that geese have been domesticated for much longer than ducks, and domestic geese were almost certainly available in ancient Egypt, Greece and then Rome (Albarella 2005: 253). Domestic ducks however may only have been available in Europe from the medieval period (Clayton 1984: 335-336). In any case since both domestic variants became established they have been utilised in many different parts of the world to varying degrees. Ducks and geese take much longer to be table ready than modern chickens but that is because chickens have been intensively bred for at least the last century to produce birds that are ready in a matter of days, rather than months (Clayton 1984, Crawford 1984). Prior to this, the growing speed of ducks, geese, and chickens may not have been so different and the meat of ducks and geese was probably more popular in Britain than it is today. There is a wealth of archaeological evidence of the use of geese, and to a lesser extent ducks, on many sites in Britain from the medieval period until the 17<sup>th</sup> century (Yalden and Albarella 2009: 103). Their favour seems to have dwindled at this point, but even after this date geese may have been regarded as birds for special occasions. We only have to think of the Christmas goose from the Victorian period to understand that eating these animals can cause strong nostalgic reactions associated with religious festivals and family gatherings.

## Eggs

The other main food product that can be obtained from ducks and geese is of course eggs. Geese are not particularly good egg producers as they do not produce many eggs per laying season, they are highly seasonal when they do lay, and they are highly defensive of their eggs (Crawford 1984: 345). In contrast to this ducks are naturally excellent egg producers (Clayton 1984: 335). Before the intensive selective breeding of chickens to produce eggs in large numbers year-round, domestic ducks may have been the preferred animal for farmers wishing to produce eggs for market. Ducks naturally produce more eggs per day than chickens and before some infamous salmonella cases in the 1920s, duck eggs were very popular (De Rijke 2008: 81-82). Some have suggested that one of main reasons for duck breeding may not have been for their meat but rather for their eggs because they are such good natural producers (Hams 2000: 5). When conditions are favourable, egg shells can be preserved and then recovered from archaeological sites. Although the presence of eggs on an archaeological site is interesting for a number of reasons, it is difficult to know which species of duck or goose produced the eggs. Wild ducks and geese both lay their eggs on the ground and so people can collect their eggs relatively easily (Serjeantson 2009: 167). Therefore the presence of duck or goose eggs on site does not necessarily mean that domestic ducks and geese were present at the time of occupation. This is particularly true if an archaeological site is located near to wetland where ducks and geese nest in the wild. Another reason why the evidence of eggs on site is not reliable for identifying the presence of domestic animals is that wild ducks and geese can be kept in captivity and they will produce eggs, perhaps not as many as their domestic counterparts, but they have been known to do this (Cabot 2009: 29). Presently the distinction between eggs from wild and domestic birds cannot be made, meaning that eggs cannot be used as archaeological evidence for the keeping of domestic ducks and geese (Stewart *et al.* 2013: 1800).

## Foie gras

Another food product from ducks and geese is foie gras. Foie gras is made by excessively force feeding a duck or goose so that fatty deposits develop in the liver (Serjeantson 2002: 42). Once the liver is extracted it can then be cooked and turned into a pâté. Today this product is both a luxury and a controversial food item; the high cost of production involved makes it expensive and the process of force feeding the animal is seen by many as cruel as the animal lives in distress during the fattening process (De Rijke 2008: 87-90). In any case the practice has been undertaken for thousands of years in different parts of the world (Pliny, *Naturalis Historia* Book X, XXII [1<sup>st</sup> cent. AD]) (Crawford 1984: 346). The production of foie gras only makes changes in the soft tissue of the body and so there is no visible trace on the skeleton. This means that identifying the practice archaeologically is almost impossible. However, there are historical and pictographic sources of evidence that are available to us. For example, a panel in the tomb of Ti from the 5<sup>th</sup> dynasty in Egypt contains a number of geese that are being fed by hand which some have interpreted as force feeding (Kear 2005: 6). Whilst this does not necessarily mean that the animals are being fattened for the production of foie gras, it does show that the practice of force feeding occurred, which is an inherent part of foie gras production. Foie gras may not have been the main reason for domesticating ducks and geese but once domestication had happened the product may have been seen as much more of a luxury item in the past as it is today. When investigating the role of ducks and geese in the past it is worth considering the social implications of serving luxury food such as foie gras. Being able to serve such a luxury dish may well have demonstrated a person's wealth and therefore reinforced, or even heightened, that person's social status in the past (Albarella and Thomas 2002: 26-27).

## Feathers

Arguably one of the most important products from ducks and geese is their feathers and there are many uses for duck and goose feathers due to their unique properties. Goose and duck feather stuffed mattresses and quilts are regarded as specialist items today but there are historical and art examples of down being an important and valuable commodity in the past (Crawford 1984: 347). Geese can be plucked alive a number of times per year starting from when they are around 12 or 15 weeks old, the feathers growing back as they naturally moult and regrow them each year (Serjeantson 2002: 40). Max Liebermann's "Plucking geese" (1870-1871) is an oil on canvas work that shows exactly this activity and demonstrates that it is not an easy task to pluck a live goose. Goose down was thought to be a particularly valuable commodity in Britain during the medieval period (Serjeantson 2002: 44) but it is unlikely that there will ever be any direct archaeological evidence for this specific activity. Unlike skinning an animal, plucking a bird (whether alive or dead) leaves no evidence on the bone. However, there may be indirect evidence for the importance of down production during the medieval period from assemblages that have a relatively high proportion of adult geese (Albarella 1997: 27). By interpreting these assemblages from a utilitarian perspective, the main product that can be harvested from live adult geese is their feathers as they are not particularly good egg producers.

Although there are no accounts of Roman writing quills, they have been used in Britain since at least the 6<sup>th</sup> century AD and were once a very important product (Serjeantson 2002: 43). Duck feathers are not generally considered sturdy enough for this task but the primary feathers of geese are excellent for it (Kear 1990: 48). There are a number of sources on the production and use of quills in the past and some of these sources are very particular about the feathers that make the best quills. For example Rees (1819 *cited* in Serjeantson 2002) suggested that the best feathers are the second and third primaries from the left wing

for right handed people. There has been a suggestion that specific cut marks on the carpometacarpus of geese and an uneven ratio of left to right wing bones is indicative of quill production (Serjeantson 2002: 50-51). If this is a reliable method of identifying quill production archaeologically then this is certainly a feature to look for when examining anatid assemblages, though it is not expected that this project will find any Roman evidence of quill production as they appear to have been a later development.

The last feather product discussed here are fletchings. Fletchings, or flights as they are also known, are feathers that are attached to the shaft of an arrow to make the arrow spin and stabilise during flight (Sossinka 1982: 377). It is not known when fletchings were first used or which bird's feathers started the practice as most of the evidence for the early use of bow and arrows comes from arrowheads of the upper Palaeolithic (Kear 1990: 49). However, wooden arrows recovered from bogs in Denmark dating to the Iron Age have impressions of thread where the fletchings were attached, suggesting that the technology was well established by at least this period (Clark 1948: 127). Both duck and goose wing feathers can be used for fletchings but goose feathers seem to have been particularly suited to the task (Kear 1990: 49). Goose feathers were preferred by several archers for fletchings in the medieval period and indeed modern archers involved in battle re-enactments attest to their efficacy (Von Meissen 2001: 5). Archers played pivotal roles in many battles in the past and so the role of goose feathers as part of a devastating weapon cannot be underestimated.

## Culture, religion and symbolism

There are many world religions and cultures that use birds as symbols and representatives of deities and ducks and geese have not been excluded from this use. Not only are there a number of instances from the classical civilisations where geese or ducks play a part in myths and fables (one example from ancient Greece is the association between Aphrodite and geese as shown in a drawing of an attic red figure on white ground ware, 4th century BC (Kear 1990: 231)), but there are many examples from other religions and cultures.

Ducks feature in some creation myths by being the creators of the cosmic egg and by diving for mud and sand to make humans in other religions (De Rijke 2008: 10). In some myths they feature as mystical animals that disappear for the winter and return bringing the spring and renewed life with them (Serjeantson 2009: 338). In the medieval period in Ireland some regarded waterfowl as animals of both the land and the sea. This dual existence was used by some Christians at the time to justify eating meat during lent. In Catholicism meat is forbidden during the fasting period before Easter but fish can be eaten and by labelling geese as creatures of the sea they could also be eaten (De Rijke 2008: 7). Within Christianity there are a number of saints that are strongly associated with either ducks or geese. For example St. Cuthbert is associated with the Eider ducks he protected near his home, geese are associated with St. Martin and are traditionally eaten on his feast day and St. Werburgh is often depicted with a goose as it was believed that she returned a goose to life after it was cooked (Kear 1990: 228-229). Many churches bear images of these saints and the ducks and geese they are associated with. This means that these animals were not just part of the economic lives of people in the past but also part of their spiritual life and had higher meaning than merely food and feathers.

## **Ducks and geese in the Roman Empire: Historical evidence**

### Geese

Ducks and geese were used for different reasons throughout the Roman Empire and there are various historical accounts of the use and attitude towards both groups of animals. Based upon historical sources, geese were arguably much more important than ducks in the Roman Empire from both an economic and a cultural perspective (Serjeantson 2009: 293-294). As discussed above, the economy of domestic geese was very important to many different cultures in the past and the Romans were no exception. A number of authors discuss the use of geese from various different parts of Europe and at different times during the Roman period. Varro discussed white geese being more productive and easier to keep than their wild counterparts in the first century BC and suggested that goslings should start to be fattened from when they are one and half months old (*Rerum Rusticarum* Book III, X [1<sup>st</sup> cent. BC]). Columella, writing in the 1<sup>st</sup> Century AD, mentions domestic geese that could lay eggs three times a year compared to wild geese that naturally only lay once a year, and also mentions a German variety of goose that was particularly good for feather production (*De Re Rustica* Book VIII, XIV [1<sup>st</sup> cent. AD]). Pliny the Elder discussed the use of goose down and also mentions the fattening of geese to produce a fatty liver (*Naturalis Historia* Book X, XXII [1<sup>st</sup> cent. AD]) and the use of goose meat is referenced in a first century book of recipes (Apicius, *De Re Coquinaria* Book VI, VIII [1<sup>st</sup> cent. AD]). The variety of uses discussed by these authors suggests that although geese may not have been the most important bird in the Roman world (Albarella 2005: 249), they may have been familiar and well-used by a number of different people in the Roman period in Europe.

Another characteristic of geese that may have made them particularly useful in the past is that they are relatively easy to transport. Geese are capable of walking great distances without greatly diminishing their condition (Serjeantson 2009: 298-299). This allows a goose

farmer to transport their product to market without the need for expensive cages, wagons and traction animals. Pliny the Elder gave an account of geese being walked to Rome from Gaul (*Naturalis Historia* Book X, XXII [1<sup>st</sup> cent. AD], Toynbee 1973: 262). This journey would have taken a considerable amount of time and so must have been worth the effort financially for the goose herders. Although it is unclear how often geese were transported to Rome from Gaul, or indeed whether there were many other places that they were transported from in this way, it does show that geese were an important enough animal in Rome to warrant the journey.

Very little is known about the use of wild geese in the Roman Empire as they are rarely discussed in historical sources and there is very little archaeological evidence for them (Parker 1988: 203). It is likely that there were a number of wild species of geese in Europe at the time and the distribution and range of those species must have varied across Europe much as it does today. Varro hints at the use of wild geese but only in that he said that a white variety of goose (*i.e.* probably domestic) should be bred rather than a grey variety as they are much better for meat production (*Rerum Rusticarum* Book III, X [1<sup>st</sup> cent. BC]). It may be the case that the grey variety Varro referred to were also domesticated but the lower meat production capability suggests that they could be a captive wild variety, or at least a domestic variety that has not been as highly developed as the white variety. It is possible that wild geese were caught and eaten as well, perhaps as a seasonal resource, but there are no known accounts of this happening.

Aside from their economic significance, the cultural role played by geese in the Roman Empire must also be discussed. Geese were strongly associated with the goddess Juno and there are historical references to white geese being kept at her temple in Rome (Toynbee 1973: 263). These geese were not only a symbol of purity and the virtues attributed to Juno, but also became virtuous animals in their own right for their natural territorial behaviour. One

famous account discusses Juno's geese that saved Rome in 390BC from a Gaulish sneak attack (Crawford 1984: 347). The guard dogs remained asleep but the geese woke and made such a noise that they roused the Roman soldiers and the attackers were repelled. Although this is a fairly romantic tale it does show that geese may have been regarded highly throughout the Roman Empire following this event, not only as important animals economically, but also because of their association with Juno and as the saviours of Rome.

### Ducks

Historical accounts of ducks during the Roman period suggest that they were not thought of as highly as geese and perhaps may have been negatively regarded in a number of contexts. There are a few accounts of ducks being used for food and when they are discussed some authors suggested that only certain parts are good to eat and that perhaps they are food for the lower classes (Toynbee 1973: 273). It is unlikely that ducks have changed much in their palatability since the Roman period so this perception that some parts of ducks are bad to eat is more likely due to cultural attitudes rather than ducks being poor sources of meat. However, in some parts of the Roman Empire ducks may have been an important seasonal resource. Roman depictions of winter sometimes feature ducks and it has been suggested that this association means that it was an important resource to at least some people at this time (Toynbee 1973: 273). One example showing the connection between ducks and winter is on the Parabiago patera from Milan, where the hooded figure for winter is carrying two ducks (Elsner 1998: 207). Perhaps ducks may not have been considered as high class food but in a lean season they may well have been a valuable resource to those who used them.

Although ducks may not have been considered as wholesome food within the Roman Empire, there is one attribute that some species of wild ducks have that was desirable. Some duck species have very ornate and brightly coloured plumage and Varro discussed how to

build shelters for captive ducks so that his guests could enjoy them (Toynbee 1973: 264). Although it does not appear that keeping ducks in this way was common, and as yet archaeological evidence for such structures is lacking, it does show that the beauty of these birds may have been reason enough for them to be present on Roman sites. Further evidence that ducks may have been kept for their appearance are the mosaics that were created during this period. There are a number of examples where ducks feature prominently and the quality of these mosaics suggests that ducks were thought of highly, at least on occasion, for their aesthetic qualities (Toynbee 1973: 273). A good example of this is the threshold mosaic from the House of the Faun in Pompeii where ducks feature prominently and are rendered with great skill. Although ducks are no by no means the most popular birds to be included in mosaics from this period, there must have been at least some people with sufficient wealth to afford mosaics that appreciated them.

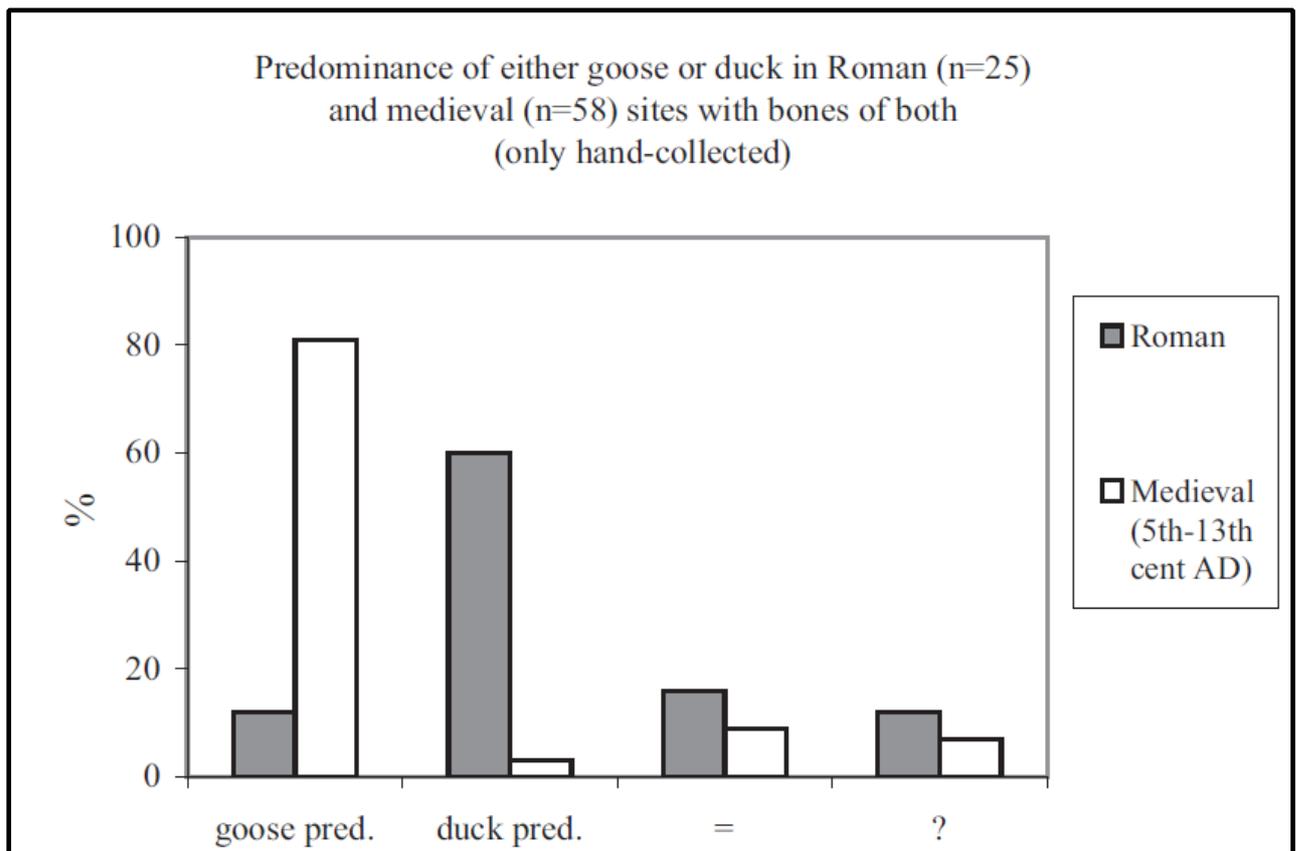
Unlike geese there are no specific accounts of domestic ducks or even a description of white ducks (white colouration tends to denote a domestic bird, although not always) in Roman literature. This does not mean that there were no domestic ducks during this period, but it is a strong indication that if they did exist in Europe then they were not as common as the domestic goose. It is possible, as some have suggested, that there were no domestic ducks in Britain until the medieval period and even then they may not have been particularly common (Clayton 1984: 335-336).

To summarise this section, there are some inferences that can be made about the general attitude of people towards ducks and geese during the Roman period in Europe based upon historical and pictographic evidence. Firstly geese were significant animals economically, both for their meat and for their feathers, and domestic geese were available in the Roman world from a relatively early date. Geese were sacred and associated with Juno, whilst wild geese had a very minor role both economically and culturally during the Roman

period in Europe. Ducks conversely were not thought of as highly as geese and there is little evidence that domestic ducks were available in the Roman Empire. Although duck meat was available seasonally, and would have been an excellent source of protein and fat, it may have been regarded as food for the lower classes and did not feature in high class cuisine (Apicius, *De Re Coquinaria* Book VI, II [1<sup>st</sup> cent. AD]). Wild ducks may have been kept on occasion for their aesthetic qualities as suggested by remaining mosaics and the detailed instructions we have been left on building duck nurseries, but this does not appear to have been a common practice.

## **Ducks and geese in Roman Britain: The archaeological evidence so far**

Now that the use of ducks and geese in the Roman Empire has been discussed in a very general sense from a historical perspective we can review the available zooarchaeological evidence in Britain. If we apply our knowledge of Roman attitudes to ducks and geese from the historical sources we may assume that: domestic geese would be present, geese would be much more important than ducks and that there would be very few wild anatids present on occupation sites (Zeiler 2014: 379). However looking at the evidence currently available from the British sites that do have ducks and/or geese it seems to be the case that their use in Roman Britain is very different from what we would expect from a Roman assemblage on the basis of the Mediterranean tradition. The first thing to note is that there is little evidence for the use of domestic geese and domestic ducks in Britain, both from a historical and archaeological perspective. Some have argued that domestic individuals have been identified due to the large size of some specimens (Serjeantson 2009: 74) or that the leg bones are relatively thick compared to their length (Yalden and Albarella 2009: 103). Although these are traits of domestic ducks and geese, they are not necessarily enough to identify domestic birds in their own right due to the overlap in size range between the wild and domestic forms (demonstrated in chapters 4 and 5). Secondly, figure 1.1 shows that there are a number of sites in Britain that have many more duck bones than goose bones, and in some cases goose bones are completely absent when duck bones have been recovered (Albarella 2005: 250-251). As duck bones are generally smaller and less robust than goose bones we cannot explain the higher amounts of duck bones than goose bones because of preservation or recovery bias (Payne 1973: 283-284).



**Figure 1.1.** Bar chart showing the percentage of Roman and medieval sites with assemblages comprised of predominantly goose bones, predominantly duck bones, equal occurrence or unknown relative frequency (Albarella 2005: 251). From historical sources geese seem to have been more important than ducks in the Roman Empire but most assemblages from these sites from Britain are dominated by duck bones.

Given that there is little evidence of the duck being domesticated by the Roman period, and there are many more ducks than geese on some sites, it is possible that most duck and goose bones from Roman sites in Britain are from wild birds (Yalden and Albarella 2009: 103-105). It may even be the case that many different species of duck and goose were used in the past rather than the few we use today.

With a few exceptions, duck and goose bones are not particularly numerous on any one site though they are regularly recovered and there are many sites throughout Britain that they are present at. Table 1.1 summarises the different types of Roman sites in Britain that duck and goose remains have been recovered from and how many of each site type there are.

Due to the time constraints of this project it is not possible to analyse the assemblages from all of these sites and there has to be a degree of selection on which sites are analysed. The sites analysed in this study have been selected because they have sufficiently sized assemblages to allow for meaningful discussion on the use of ducks and geese at the site, because they fit in with the chronological scope of this project, and lastly because they will allow for discussion on the variation between different types of sites. For example there are a number of urban sites and a number of coastal sites that are contemporary with each other that should show differences in the use of wild resources if there are any. If there is significant variation between the two types of site then it is necessary to discuss the possible causes of the variation including environmental and anthropogenic influences. The selection of sites for analysis is discussed in detail in chapter 6.

**Table 1.1.** Table showing type and frequency of Roman sites in Britain that duck and/or goose bones have been recovered from Parker 1988 and Albarella and Pirnie 2008.

<b>Site type</b>	<b>Number of sites</b>
Enclosure	4
Fortress	14
Industrial	1
Roadside settlement	2
Rural	16
Temple	4
Urban	45
Villa	19
<b>Total</b>	<b>105</b>

Given that the use of ducks and geese in Britain during the Roman period seems to be different from the expected use based on historical data, there are a number of questions that need to be answered in order for us to understand the way these birds were used in the past.

Below is a summary of the archaeological questions that this project seeks to answer:

- 1. Were domestic geese used in Britain during the Roman period?**
- 2. Were domestic ducks used in Britain during the Roman period?**
- 3. To what extent were wild species used in Roman Britain compared to their domestic counterparts?**
- 4. Were there any differences in the species that were used between different types of site?**

Before any of these questions can be explored there has to be a reliable, cost effective, and time effective method of distinguishing between the different duck and goose taxa recovered from archaeological sites. At this time no such satisfactory method has been published, although a number of possible methods have been partially explored (discussed below). As a suitable method of identification for all of the taxa in question has not yet been developed, a large part of this project is to ascertain reliable criteria for the identification of duck and goose remains from archaeological sites. As such there will only be opportunity to analyse a sample of Roman assemblages in order to address the above questions. However, any inferences that can be made about the use of ducks and geese in this period will impact on our understanding of the economy and society of Roman Britain and how it compares to the rest of the Empire and the periods before and after the Roman occupation.

## **Identifying ducks and geese from archaeological sites: Previous work**

Although there are many questions about the use of ducks and geese in Roman Britain that require an answer, relatively little work has been done on the topic. This is not because there is an absence of archaeological material but rather because the identification of anatid osteological remains is difficult, even to the genus level (Barnes *et al.* 1998: 280, Albarella 2005: 249, Bocheński and Tomek 2009: 7, Gál and Kunst 2014:341-342). Identification to the species level is rarely attempted in animal bone reports, and even when it is, there is little discussion of how reliable the identifications are, meaning that further work is very limited (Albarella 2005: 250). Without a reliable method of identification some authors have neglected to discuss duck and goose remains at all, or worse, have made unjustified assumptions about which species are present. There are a number of methods of identification that have been developed for the main domestic mammal species that have a relatively high degree of accuracy but they are lacking for ducks and geese, or they have not been attempted at all yet.

The first method of identifying ducks and geese from their bones that could work for this project is traditional morphometrics. This method works on the basis that bones are different in sizes and/or shapes in different taxa (Blackith and Reyment 1971: 9-10). For example, the greatest length of the femur may always be longer in one species compared to another and so the two species can be separated into two statistically significant groups based on femur length. There are many examples of this method being successfully used for the study of mammals from archaeological sites such as the difference between domestic and wild pigs (Albarella *et al.* 2005) and the difference between complete and castrated male sheep (Davis 2000). Although this method of identification has not been fully developed for ducks and geese, some work has been done that can be used as a basis for further research. In the 1960s many measurements of ducks and geese were taken and some general trends were

identified in the difference between the various anatid species (Bacher 1967, Woelfle 1967). However, these works only used one or two measurements in each analysis, and only discussed average differences between taxa in very general terms, and so it is very difficult to use this approach to identify an individual bone to the species, or even genus, level. There is a lot of overlap in size between many species meaning that analyses using only one measurement are often insufficient for identification purposes. For example a large Pintail (*Anas acuta*) may have a femur that is longer than a small Mallard's (*Anas platyrhynchos*), as the ranges of their femur lengths overlap (see chapter 4). Depending on the bone in question it is possible to rule out some taxa using the measurements from this work but more often than not we are left with a range of possible species (or even genera) and so cannot begin to discuss archaeological questions in any meaningful detail (Parker 1988: 201). Some authors have suggested that you can differentiate between wild and domestic geese by comparing the lengths of the leg bones relative to their breadths (Reichstein and Pieper 1986: 95-96). This relies on the principle that domestic geese are larger and heavier than wild geese and so their leg bones will have become thicker relative to their length to cope with the added weight in a biomechanical sense (Yalden and Albarella 2009: 103). This method has been used on a number of different sites from a range of periods to discuss the use of domestic geese, for example Hutton MacDonald *et al.* (1993), O'Connor (2000), and Gál and Kunst (2014). Although all of these authors use the method, they all agree that it may not be reliable. There are a range of reasons for this; large robust wild geese fall within the range of the domestic geese (demonstrated in chapter 5), the effect of malnutrition on domestic geese and their bone morphology is unclear at this time which may cause them to be smaller and less robust (Sossinka 1982: 381), and it is not known if there is any sexual dimorphism within domestic geese, for example two observed groups could actually be male and female of the same species rather than domestic and wild. Whilst there is a general trend for the leg bones of

domestic geese to be larger and thicker than wild geese, there is a large degree of overlap and so the method cannot be relied upon entirely.

Traditional morphometrics as a method of identifying archaeological ducks and geese has not yet been fully explored and has the potential to be a very useful identification tool. One major advantage of using traditional morphometrics for identification is that the method is already widely employed by zooarchaeologists for other species. This means further training is not necessary and it is relatively inexpensive compared to some other methods of identification as the only equipment that is required is a set of callipers. Another benefit of using traditional morphometrics is that the method is non-destructive. Unlike genetic and mass spectrometry analyses, no samples are required to be taken from the bone as the measurements are only taken on the external surface.

Geometric morphometrics is a similar method to traditional morphometrics in that it relies on the shapes of bones to be more variable between taxa than within; consequently it can be used for distinguishing between taxa (Rohlf 2000: 464). However, unlike traditional morphometrics, size is not used in the analysis (Bignon *et al.* 2005: 389). The method works by assigning landmarks, or loci, on bones which are in roughly the same position for each taxon, and then analysing the variation in the exact position of those landmarks (*e.g.* geometric morphometric analysis of horse metapodials by Bignon *et al.* 2005: 379). Landmark co-ordinates are used rather than linear measurements between points to study shape and to remove size, scaling, and rotational effects (Zelditch *et al.* 2004: 11). Once the co-ordinates have been recorded for an individual they can be entered into a database and traditional statistical analyses can be applied to look at the variation between discrete groups such as species (Cucchi *et al.* 2011: 12). The centre points, or centroids, of the co-ordinates can also be calculated, which uses all the landmarks in one analysis. Taxa that have significantly different shapes will have statistically different centroid locations (Zelditch *et*

*al.* 2004: 13). Although this method has the potential to be highly accurate, there have only been a handful of zooarchaeological applications so far. This may be because it requires specialist software, equipment and training that is not common amongst zooarchaeologists at present. For these reasons this project will not focus on geometric morphometrics as it may have limited archaeological application until the method is more widely used and understood. Another aspect of geometric morphometrics to consider is how much time is required to record each specimen compared to how accurate an identification method it is. Setting up the equipment and software for each specimen is relatively time-consuming compared to the straight forward recording system used in traditional morphometrics and so it would not be possible to record as many specimens using geometric morphometrics. It is unclear at this time if geometric morphometrics will be more accurate for taxon identification than traditional morphometrics when applied to archaeological ducks and geese. Therefore the reduction in the amount of specimens that could be analysed in this project means that geometric morphometrics will not be the best method of identification to attempt for this project. However, it is worth pointing out that it is a method that could be tested in the future and it would be very interesting to compare the results of the two methods using the same specimens.

Another way of distinguishing between taxa that could be explored is through the analysis of their genetics. Using the concept that taxa will vary from each other in their genetic makeup, if genetic sequences can be identified that are specific to one taxon then that taxon can be identified (Beebee and Rowe 2004). In the study of mammals there are a number of examples of this approach being successfully used to determine the presence or absence of domestic species and to identify their wild progenitors (Reitz and Wing 1999: 280). There has been some application of this method to the identification of geese which was successful in distinguishing between different *Branta* species (Barnes *et al.* 1998) and

between the pink footed goose (*Anser brachyrhynchus*) and the domestic goose (*Anser anser domesticus*) (Barnes *et al.* 2000). In these cases genetic analysis was employed to answer very specific questions about the use of the species at the sites discussed. Although the method of identification was successful, and likely highly accurate in these instances, it has not been employed in many studies since. The reason for this is it has only been developed for distinguishing between particular species of geese. Using it to discuss other anatids would require a lot more work to identify specific genetic sequences which can be used in an archaeological context. This process would be very time consuming and expensive given the procedures involved. Without a swift method of development this will not be happening for the foreseeable future (O'Connor 2000: 47, Barnes *et al.* 2000: 90). Although genetic analysis could be a highly accurate identification method, its future application to archaeological questions is limited simply because of the cost and equipment that is required.

One recently developed and exciting method of identifying animal remains is zooarchaeology by mass spectrometry (ZooMS). Different animals have different peptide sequences within the protein they produce which can be preserved in their bones. The relative mass of those peptides is more variable between taxa than it is between individuals within a taxon and so by measuring the mass of the peptides from a bone we can identify which taxon the bone came from (Buckley *et al.* 2009: 3843). This is a particularly effective identification method when a bone is fragmented as identification based upon morphology is impossible. There are some examples of this being applied to archaeological research when it is difficult to determine which mammal a bone fragment come from, but so far the only application of this method for birds has been to identify which species an egg shell came from (Stewart *et al.* 2013). This method has the potential for being highly accurate in the future but at the moment it has only been tested on a small number of bird species and as yet there is no evidence that closely related species can be distinguished. Certainly domestic and wild geese

and ducks cannot be distinguished at this time (Stewart *et al.* 2013: 1800). Although ZooMS could be useful for identifying duck and goose bones in the future, particularly when they are fragmented, there are a number of reasons why the method may not be the best to attempt for this project. Firstly, although identification by ZooMS is not as expensive as genetics to develop and use (Buckley *et al.* 2009: 3843), it is relatively much more expensive than morphometry. Secondly, no criteria for distinguishing between wild and domestic species have been established and there is no guarantee that further work on the method would produce such criteria. Lastly, similar to genetic identification, the method is not generally available to zooarchaeologists so the application of it will be limited for the foreseeable future.

Despite the work conducted in the past, no reliable method for identifying the different taxa of ducks and geese has been developed. Given that traditional morphometrics is a method of identification that has had success with other species and been widely applied to zooarchaeological questions in the past, this is the method that will be further developed and employed in this thesis. Although there may be some limitations to the method, such as some species being similar in shape and/or size, or it may not work for highly fragmented assemblages, there are many advantages to using this approach. Firstly, it is a very cost effective method of identification in that no specialist equipment or materials are required. Secondly, it is a technique that is already widely employed by zooarchaeologists for the identification of other species so it can be easily adopted once identification criteria have been established. Lastly, the method is not destructive meaning that assemblages are not damaged in any way for future study. In order to identify different duck and goose taxa from archaeological contexts, identification criteria will be developed by taking measurements from modern reference specimens of known species. The measurements will be assessed using a range of statistical tests to see which measurements, or combination of measurements,

can be used to distinguish between the different taxa. Once the efficacy and reliability of the measurements has been established using the modern reference material the same measurements can be taken from the archaeological material and tested to see which taxa they likely to belong to. This will work by process of elimination rather than on a best fit basis.

## **Summary**

Ducks and geese have been used for many different reasons in many parts of the world for thousands of years. They have been used not only for their meat and eggs but also to produce luxury goods such as foie gras and feather mattresses. Their feathers have been used as tools to write some of the most important works ever written and have been used as flights on arrows in key battles in history. They feature in many myths and folk stories and have been associated with numerous deities and saints. Despite all this their importance in the past is often underestimated due to the current importance of chickens and the development of modern synthetic materials that have replaced the products we once relied on ducks and geese for.

The role of ducks and geese in Roman Britain is poorly understood in particular and rarely discussed, despite the regular recovery of their bones from archaeological sites. The reason that they are rarely discussed is that it is difficult to distinguish between the different genera, let alone different species, based on their bone morphology. This has meant that answering some key questions such as the presence or absence of the domestic forms, the use of the various wild species, changes in use through time and the variation of use between different types of sites has hardly been attempted. Understanding the attitude, to and use of, ducks and geese during the Roman period could add to our understanding of how Roman Britain developed and changed from the Iron Age until the Anglo-Saxon period and the economic and social implications of those changes.

In order to investigate the use of ducks and geese in the past this project demonstrates how traditional morphometrics and multivariate statistics can be used to identify twenty species of duck and seven species of goose which are likely to have been indigenous to Britain during the Roman period. New and reliable identification criteria have been developed using modern reference material of known species and then applied to

archaeological assemblages to discuss key questions about the use of ducks and geese in Roman Britain. Topics discussed include the presence or absence of domestic species, variation between different types of sites, variation between different areas of Britain and lastly variation in the use of ducks and geese through time.

There are many further applications of the identification method developed as part of this project and the identification criteria could be applied to countless other research questions. A reliable method of identification that can be used by any zooarchaeologist allows us to start analysing how humans have utilised and developed ducks and geese in the past and lets us explore how these animals have influenced people and how they lived their lives in much greater detail.

## **Chapter 2~** **Modern reference sample selection and recording protocol**

### **Modern reference material sample selection**

There are many species of ducks and geese that could be included in this study but the range of species is restricted for a number of reasons. Firstly, as this project is analysing faunal remains from Roman Britain the species that are included in the modern reference material analysis are native to Britain. For example, species such as the Canada goose (*Branta canadensis*) are not included as they were introduced to Britain a long time after the Roman period (Yalden and Albarella 2009: 204). The second reason the list of species for analysis is restricted is because some species are very rare in modern reference collections. Some species are relatively rare in the wild now; they are protected, or have not been subject to much scientific analysis in the past, and are absent from most reference collections. This means that there are not enough individuals of each species to allow for statistically meaningful analysis in this project (e.g. *Anas querquedula*). Table 2.1 lists the species that have been analysed as part of this project in order to develop identification criteria for them along with counts for each genus. Species names follow Svensson *et al.* (2009).

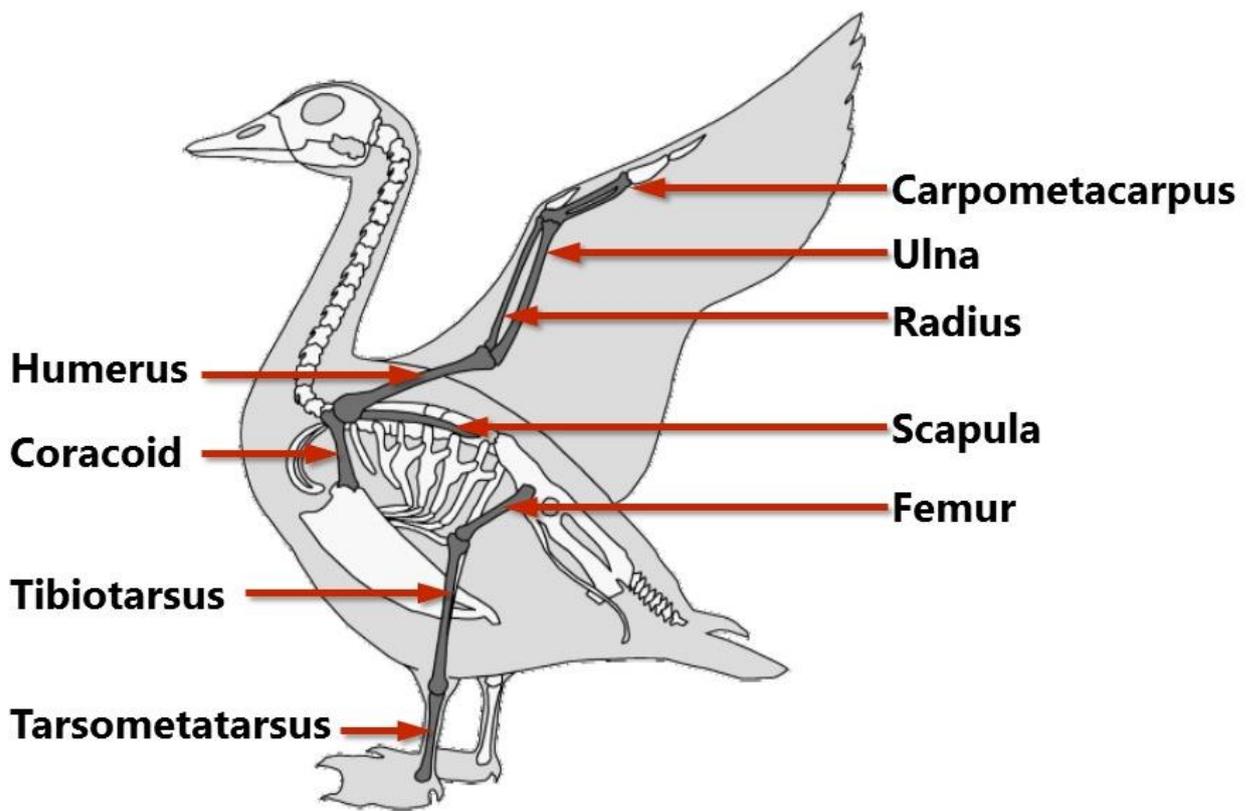
**Table 2.1.** Table showing the counts of modern reference skeletons included in this thesis for ducks and geese, genera and species.

Duck or goose	Count	Genus	Count	Species	Count
Ducks	538	<i>Anas</i>	239	<i>Anas acuta</i> (Pintail)	15
				<i>Anas clypeata</i> (Shoveler)	25
				<i>Anas crecca</i> (Teal)	27
				<i>Anas penelope</i> (Wigeon)	32
				<i>Anas platyrhynchos</i> (Mallard)	71
				<i>Anas platyrhynchos (dom)</i> (Domestic duck)	42
				<i>Anas querquedula</i> (Garganey)	10
				<i>Anas strepera</i> (Gadwall)	17
		<i>Aythya</i>	79	<i>Aythya ferina</i> (Pochard)	25
				<i>Aythya fuligula</i> (Tufted duck)	36
				<i>Aythya marila</i> (Scaup)	18
		<i>Bucephala</i>	28	<i>Bucephala clangula</i> (Goldeneye)	28
		<i>Clangula</i>	24	<i>Clangula hyemalis</i> (Long-tailed duck)	24
		<i>Melanitta</i>	45	<i>Melanitta fusca</i> (Velvet scoter)	16
				<i>Melanitta nigra</i> (Common scoter)	29
		<i>Mergus</i>	64	<i>Mergus albellus</i> (Smew)	9
				<i>Mergus merganser</i> (Common merganser)	27
<i>Mergus serrator</i> (Red-breasted merganser)	28				
<i>Somateria</i>	37	<i>Somateria mollissima</i> (Eider)	37		
<i>Tadorna</i>	22	<i>Tadorna tadorna</i> (Shelduck)	22		
Geese	219	<i>Anser</i>	166	<i>Anser albifrons</i> (Greater white-fronted goose)	25
				<i>Anser anser</i> (Greylag)	43
				<i>Anser anser (dom)</i> (Domestic goose)	50
				<i>Anser brachyrhynchus</i> (Pink-footed goose)	19
				<i>Anser fabalis</i> (Bean goose)	29
		<i>Branta</i>	53	<i>Branta bernicla</i> (Brent goose)	25
				<i>Branta leucopsis</i> (Barnacle goose)	28
<b>Total</b>					<b>757</b>

One important point to make about this project is that it involves so many wild species. Previous research projects on identification have tended to focus on domestic animals and the species that are closely related to them. This has only produced some

applicable, if unreliable, results (discussed above). However, there are several wild species that overlap in size or shape with the main domesticates and so a broader approach is required in order to understand the use of these animals in the past as fully as possible. This project focuses on the distinction between as many different taxa as possible, including, but not exclusively, between wild and domestic taxa. Specimens from wild species form the bulk of the modern reference individuals in this project.

Along with a restriction on which species to analyse there is also a restriction on which bones to analyse. Some elements of the avian skeleton are very rarely recovered from archaeological sites, some bones preserve poorly and some bones are relatively easy to identify to species compared to other bones. For these reasons the bones that have been analysed in this study are restricted to the coracoid, scapula, humerus, ulna, radius, carpometacarpus, femur, tibiotarsus and the tarsometatarsus (figure 2.1). These bones are regularly recovered from archaeological sites and are difficult to identify to the species or even genus level by eye (Serjeantson 2009: 155-164). The cranium has not been selected for analysis as they are much easier to identify to species and they do not often survive intact in an archaeological context (Serjeantson 2009: 107-114). The vertebrae, ribs, phalanges and other smaller bones will not be included as they are not regularly recovered from archaeological sites without sieving, or even wet sieving, and they are so numerous within an individual that analysing each and deciding on taxon specific identification criteria would take too long.



**Figure 2.1.** The bones of the skeleton recorded and analysed in this project.

Following data collection from a number of modern reference collections in Britain and Poland a very large database has been produced and includes information from 757 birds. Table 2.2 lists the different reference collections that have been used and a summary of how many birds were measured from each collection. At this point it must be acknowledged that some of the information in the database was collected by Tessa Pirnie who started a similar project a number of years ago but was unfortunately unable to complete the project. Tessa has given permission for the use of the data she collected, which are here presented for the first time.

**Table 2.2.** Table showing the number of specimens recorded from each reference collection used in this thesis.

<b>Reference collection</b>	<b>No. of specimens recorded</b>
Historic England	122
Institute of Systematics and Evolution, Polish Academy of Sciences	257
Manchester Museum	23
National Museums Scotland	66
Natural History Museum	163
University of Leicester	15
University of Sheffield	39
University of York	58
World Museum Liverpool	14
<b>Total</b>	<b>757</b>

### **Recording protocol**

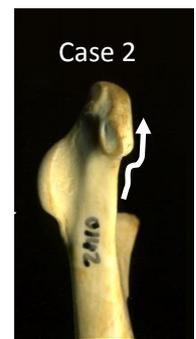
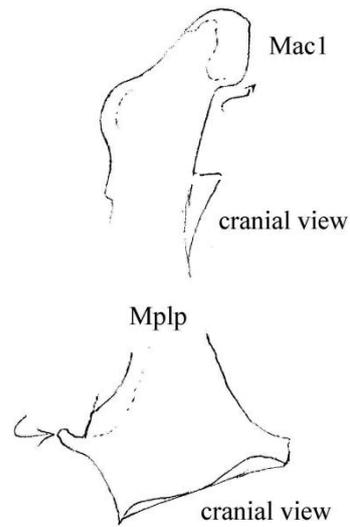
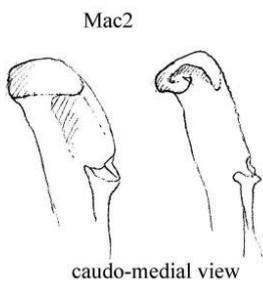
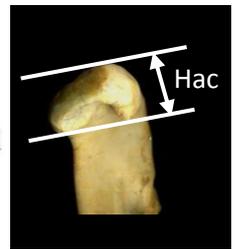
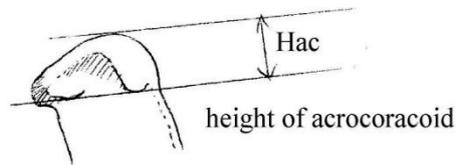
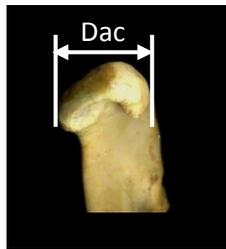
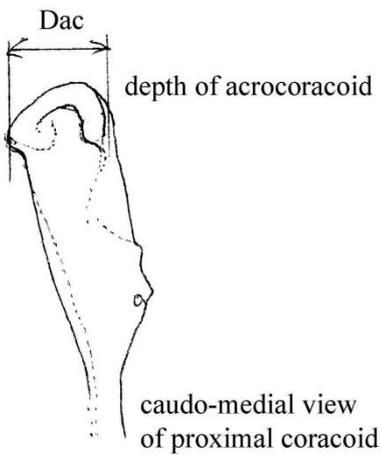
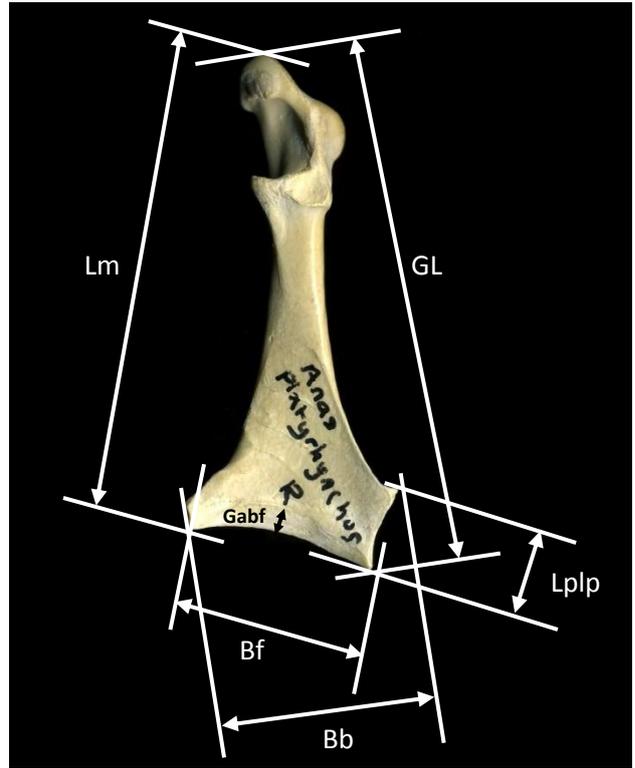
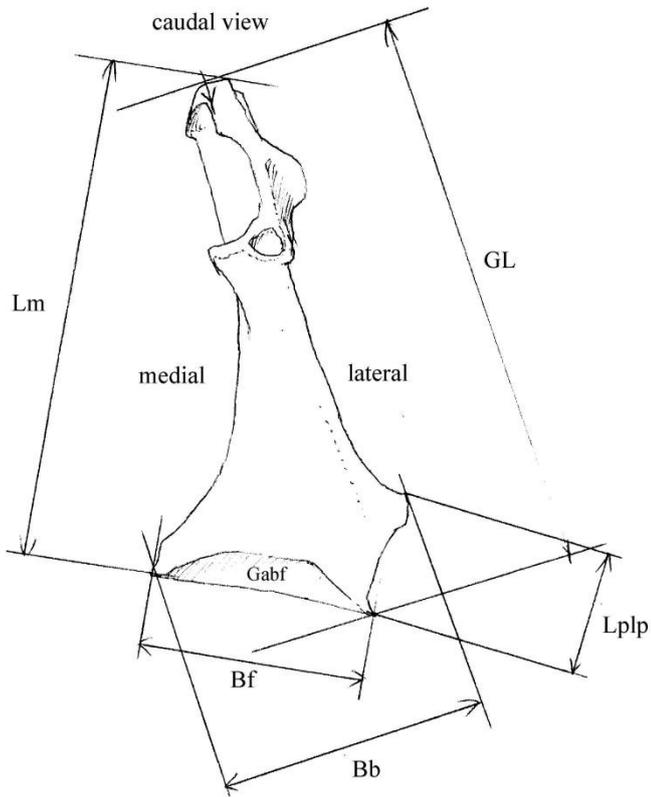
The measurements taken for each bone are based upon a combination of those suggested by Bacher (1967), Woelfle (1967), Von Den Driesch (1976), and Tessa Pirnie (pers. comm.). All bones were recorded using digital calipers to an accuracy of 0.01mm. Only complete bones were included for the analysis of identification criteria, and all bones showing evidence of a pathological condition were excluded as pathologies can affect the size and shape of a bone (Gál 2013: 217-218). Below is a description of each measurement and morphological trait, and how to record them.

### **Note:**

M = morphology, and refers to Case 1/Case 2 characters  
vdD = measurements taken directly from von den Driesch (1976)

## **Coracoid**

GL: (vdD)	Greatest diagonal length
Lm: (vdD)	Medial length
Bb: (vdD)	Greatest basal breadth (including the processus lateralis)
Bf: (vdD)	Breadth of basal articular surface (or 'sternal width')
Lpl:	(cf. Woelfle 1967) Length of processus lateralis anterioris-posterioris (taken with tips of the calipers. Note, this is hard to define in geese)
Gabf:	Maximum (greatest) arch of basal facet (taken from caudal side)
Dac:	Depth of acrocoracoid (taken from caudo-medial side)
Hac:	Height of acrocoracoid (taken from caudo-medial side)
Mac1:	Shape of head of joint (in cranial aspect): Case 1: Acrocoracoid is not clearly set out from the shaft Case 2: It is hook-shaped or bulges outwards markedly
Mac2:	Morphology of acrocoracoid (in caudo-medial aspect): Case 1: The depression is shallow with an ill-defined edge Case 2: It is semi-circular, sub-rectangular or 'cross-shaped'
Mpl:	Protruberance of the processus lateralis posterioris (in cranial aspect): Case 1: It projects in a point or hook above the sterno-coracoid process Case 2: The corner is angular, but is not protruding
Mscp:	Shape of sterno-coracoid process seen in cranial aspect: Case 1: Straight Case 2: Concave



## **Scapula**

GL: (vdD)      Greatest length

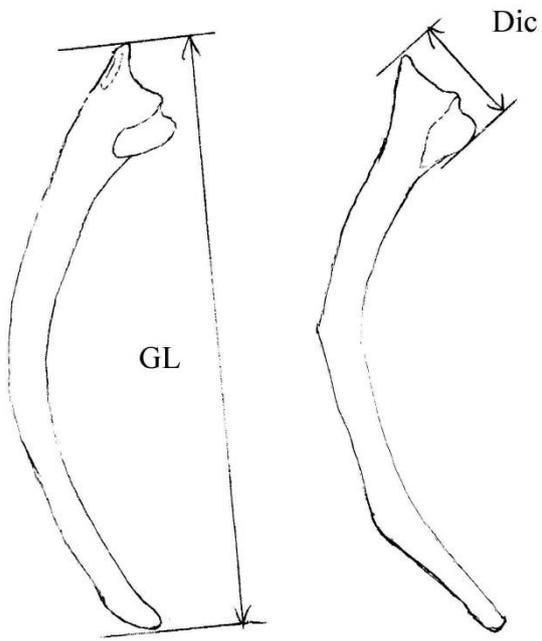
Dic: (vdD)      Greatest cranial diagonal ('BP' in Woelfle 1967)

Md:              Shape of distal end is:  
                    Case 1: Pointed  
                    Case 2: Blunt or rounded (or with a flat end, as with mallard in Woelfle 1967)

Ms:              Outside contour of shaft (seen from dorsal side):  
                    Case 1: Is smoothly curved  
                    Case 2: Has one or two angles or protruberances in the edge of the blade

Mds:             The outside contour of the distal end of the blade:  
                    Case 1: Is a convex curve  
                    Case 2: Is concave (whereas the rest of the blade is more or less convex)

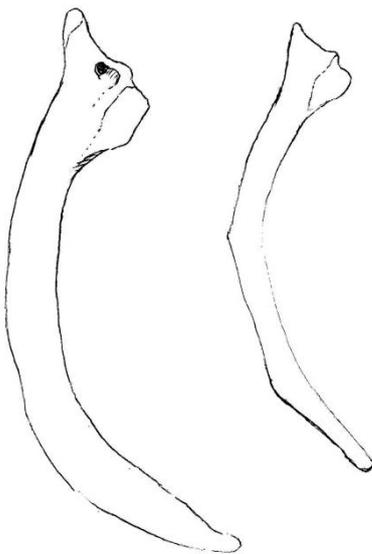
dorsal view



Ms

Case 1

Case 2



Mds

Case 1

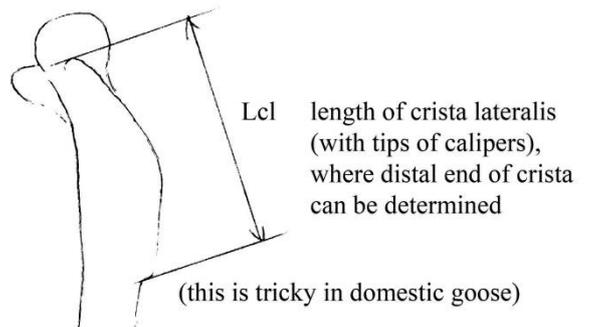
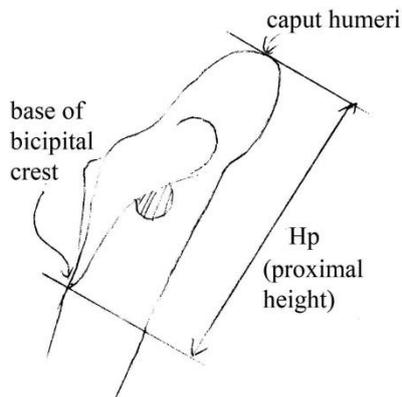
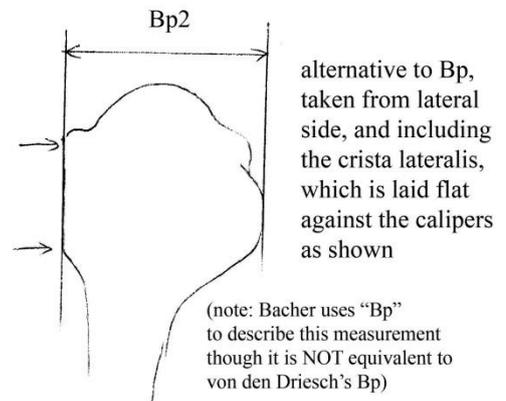
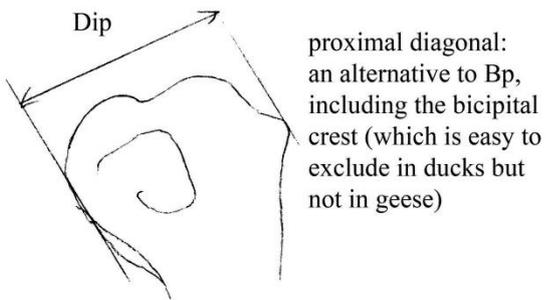
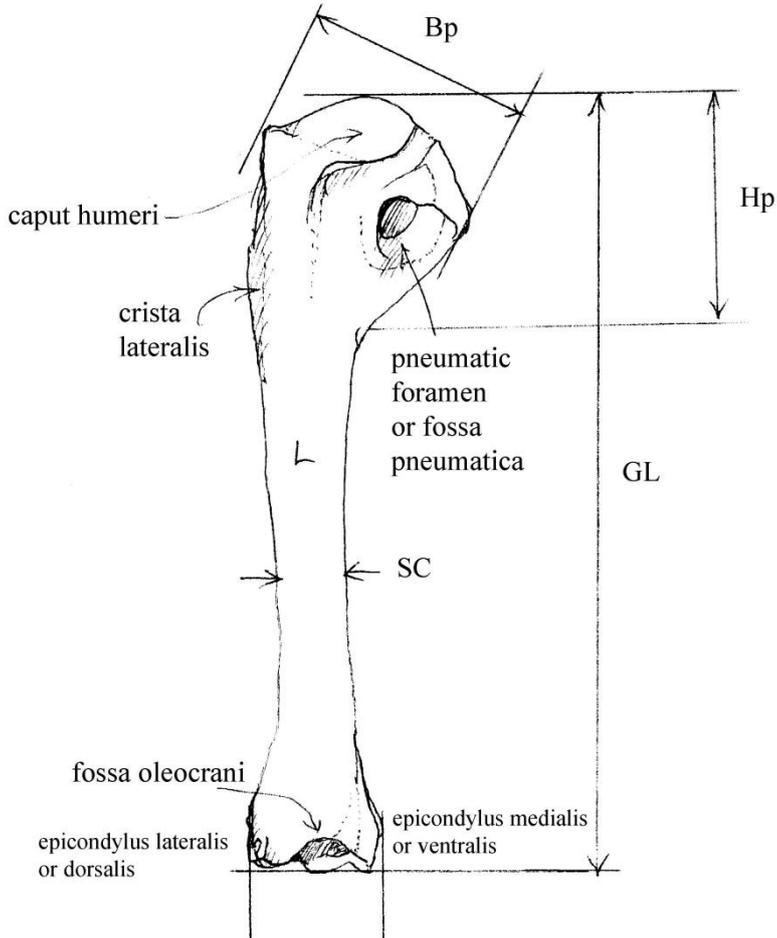
Case 2



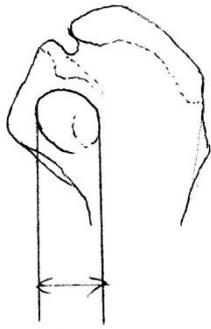
## **Humerus**

GL: (vdD)	Greatest length
SC: (vdD)	Smallest breadth of the corpus or shaft (taken in the plane illustrated)
SC2:	Smallest breadth of the corpus (taken in the plane shown, which has been variously called caudal-cranial, or antero-postero, or medio-lateral)
Hp:	Proximal height, from base of bicipital crest to the top of the caput humeri, taken with the calipers at right angles to the shaft (where base of bicip. crest can be determined)
Bp: (vdD)	Greatest breadth of proximal end
Bp2:	Greatest breadth of proximal end, taken from lateral side, perpendicular to shaft (note: this is equivalent to Bacher's BP (1967))
Dip:	Alternative to Bp (for geese) where bicipital crest is included in the measurement
Gpf:	Greatest width of pneumatic foramen
Dch:	Greatest depth of caput humeri (taken from proximal end)
Lcl:	Length of crista lateralis (as shown), where the distal edge of the crista lateralis can be determined
Bd: (vdD)	Greatest breadth of distal end
Dd:	Depth of distal end, taken with the calipers laid flat against the lateral portion of both condyles
Hcr:	Height of condylus radialis (the largest one at the distal end, on the lateral side)
Hnf:	Position of nutrient foramen, taken in line with the shaft, from base of condyle ulnaris to base of foramen
Mpf:	Morphology of the pneumatic foramen (look upwards into it from the distal end): Case 1: The margin spirals into the foramen, with a trabecular lattice of bone visible inside Case 2: The margin continues down the shaft or merges into the foramen (no trabecular bone is visible inside it)
Mcl:	The crista lateralis is (seen from lateral aspect): Case 1: Angled Case 2: Rounded

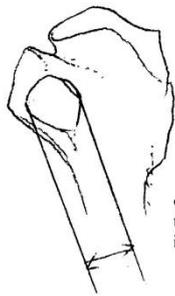
medial or ventral view of humerus



Gpf: greatest width of pneumatic foramen

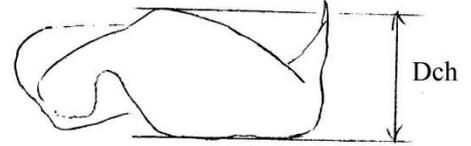


Anas platyrhynchos

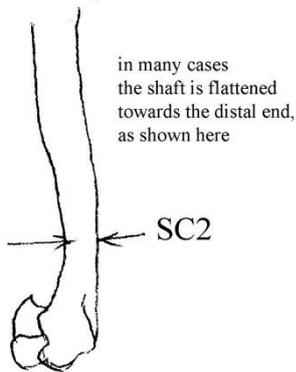


Clangula hyemalis

calipers may need to be tilted to achieve maximum width, in Bucephala and Clangula

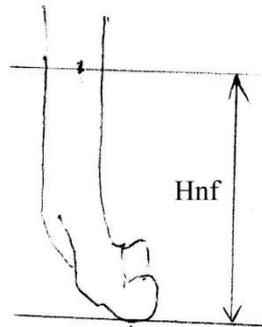


SC2: alternative smallest breadth of the corpus



in many cases the shaft is flattened towards the distal end, as shown here

SC2

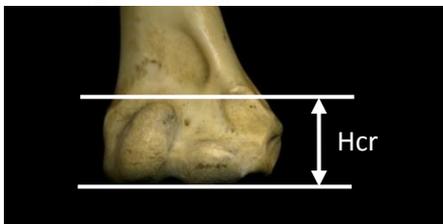


Hnf

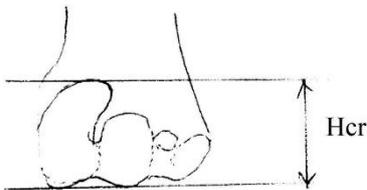
position of nutrient foramen: taken in line with shaft, from base of foramen to base of condyle ulnaris

base of condyle ulnaris

height of condylus radialis



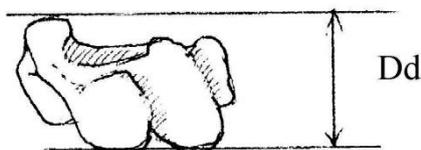
Hcr



Hcr

lateral or dorsal view, distal end

distal view



Dd

Mcl: shape of crista lateralis (in lateral aspect)

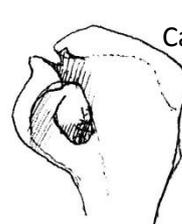


Case 1

Case 2

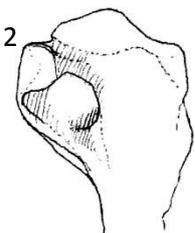


Mpf: morphology of pneumatic foramen



Case 1

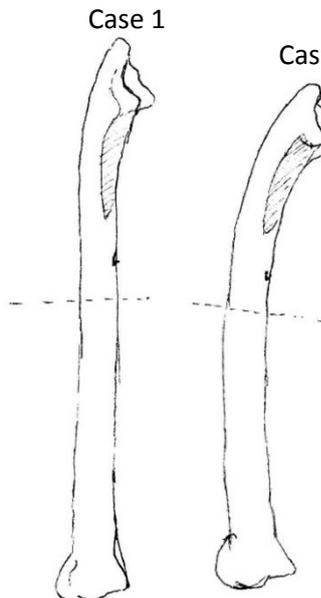
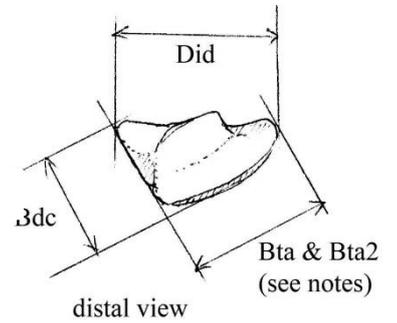
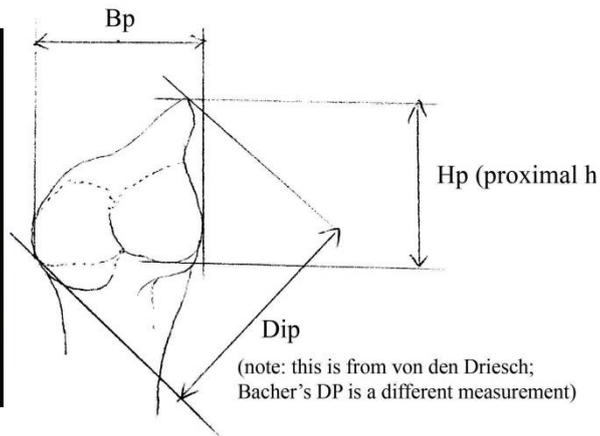
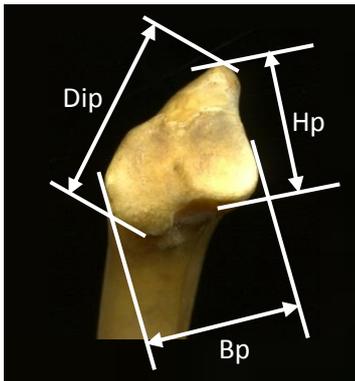
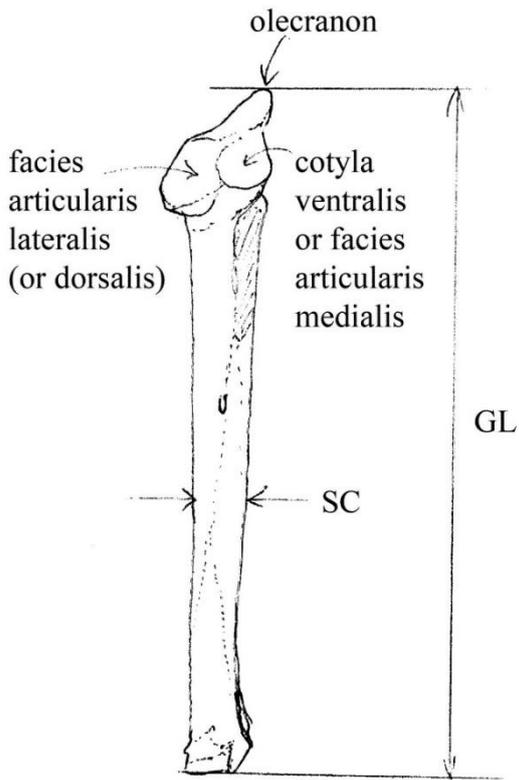
tilt the bone so as to look up into the pneumatic foramen



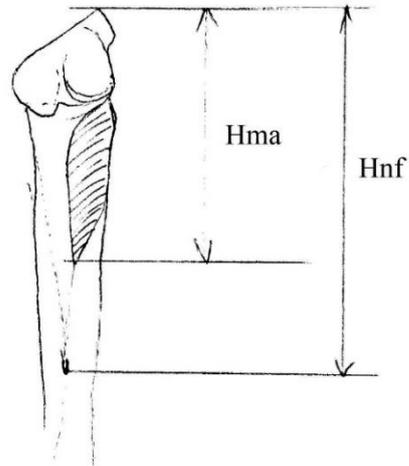
Case 2

## Ulna

GL: (vdD)	Greatest length
SC: (vdD)	Smallest breadth of the corpus (strictly from the cranial view)
Bp: (vdD)	Greatest breadth of the proximal end (taken from cranial aspect), in this instance taken with the calipers parallel to the shaft of the bone
Hp:	Proximal width (or height of proximal end), taken with calipers perpendicular to the shaft of the bone, but angled cranio-caudally as required.
Dip: (vdD)	Greatest diagonal of the proximal end from the caudal (or medial) border of the olecranon to the cranial (or lateral) border of the facies articularis lateralis or dorsalis (Note: this is not the same as Bacher's DP or 'TP' (1967))
Did: (vdD)	Greatest diagonal of the distal end
Bta:	Maximum breadth of distal condyle/trochlea articularis (with calipers parallel to the axis of the condyle)
Bta2:	Alternative width of distal condyle: here the calipers are laid along the edge as shown (this measurement is less tricky to take than 'b' in ducks)
Hma:	Distance from tip of olecranon to base of muscle attachment (several cases apply: see diagrams). This is measured in conjunction with 'e' and compared with 'GL'.
Hnf:	Distance from tip of olecranon to nutrient foramen (see notes for 'd'/Hma)
Ms:	Curvature of shaft (seen in the cranial aspect): Case 1: The shaft is straight in the bottom half (generally up to the nutrient foramen) Case 2: The shaft begins to curve in its distal half



Ms:  
curvature of the shaft:



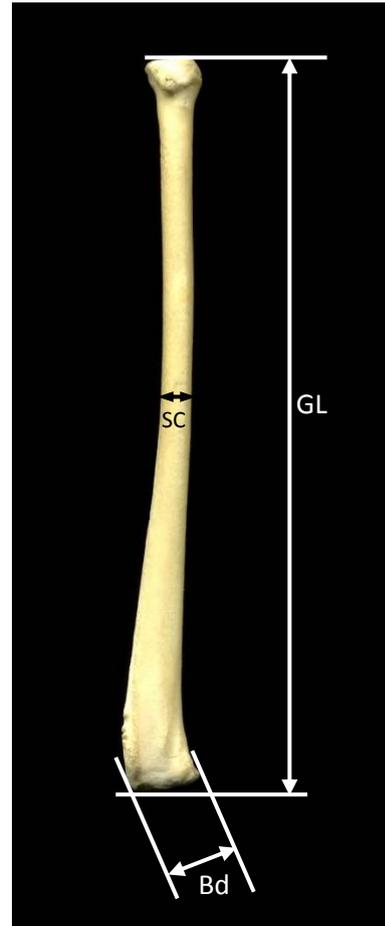
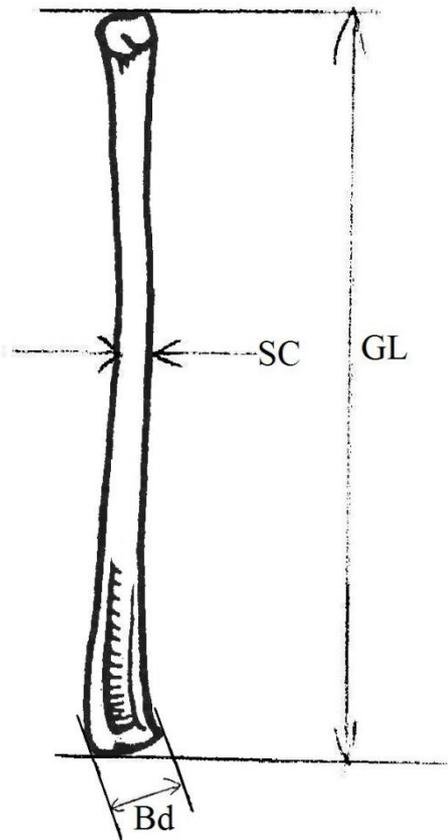
positioning of muscle-attachment point (from tip of olecranon, taken in line with the shaft), and position of nutrient foramen

## Radius

GL: (vdD)    Greatest length

SC: (vdD)    Smallest breadth of the corpus

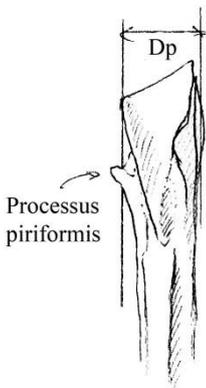
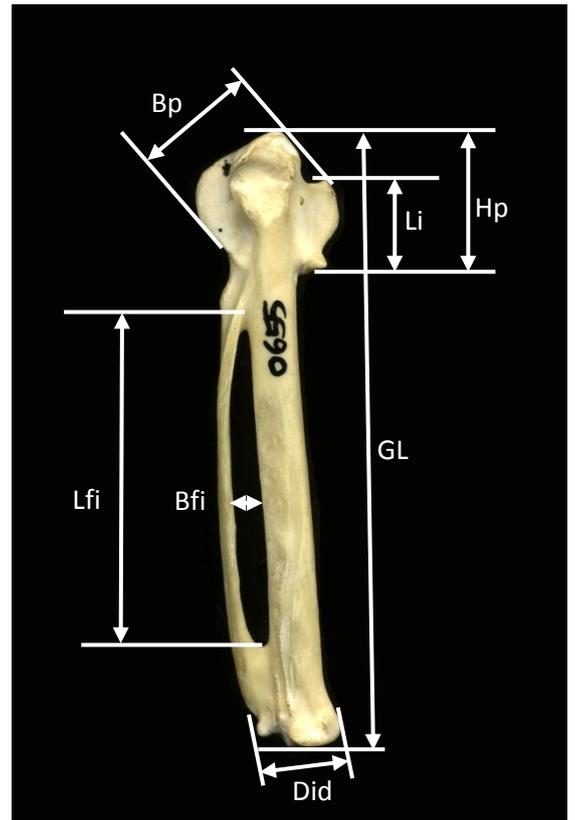
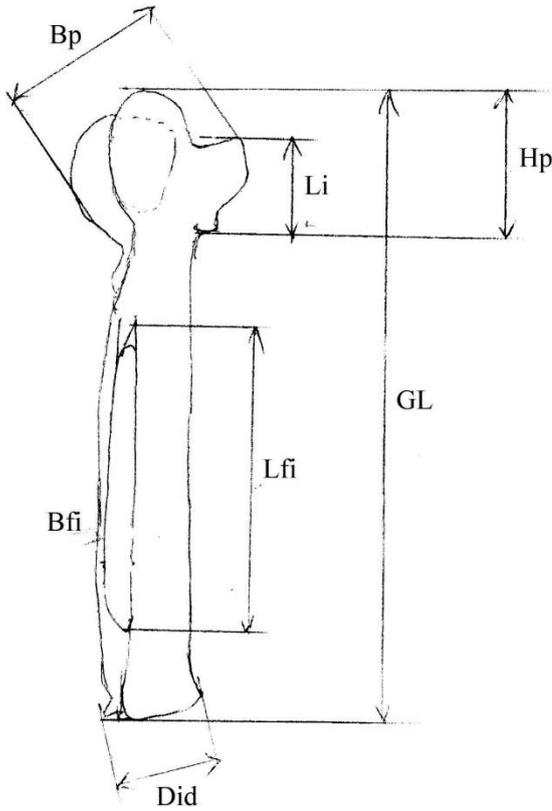
Bd: (vdD)    Greatest breadth of the distal end



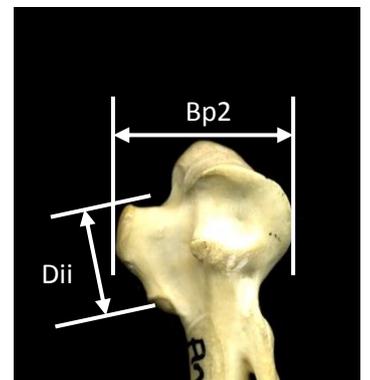
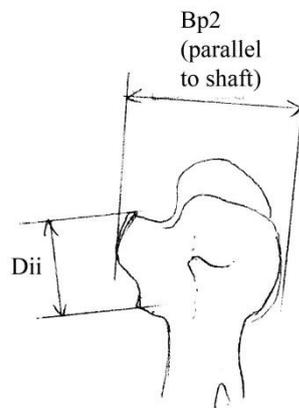
## Carpometcarpus

GL: (vdD)	Greatest length
Bp: (vdD)	Greatest breadth of proximal extremity (in this instance the Bp will usually be somewhat diagonal to the longitudinal axis of the bone, rather than being at right angles to it)
Bp2:	Breadth of proximal extremity, taken strictly in line with the shaft
Dp:	Proximal depth (must not include the Processus piriformis: it is possible to swivel the calipers slightly behind this)
Hp:	Height of proximal end (from lateral side, depending on terminology: not the side with the processus piriformis - settle the lower edge of the calipers on the small ledge at the base of the Os metacarpale I)
Li:	Vertical length of Os metacarpale I (best taken from ventral aspect - terminology variable, <i>i.e.</i> viewing it in line with the shaft)
Di1:	Height of Os metacarpale I from tuberculum dorsale to base (this achieves diagonal height: compare with Li, which measure the vertical height)
Mi1:	From the lateral side, the shape of the distal part of the Os metacarpale I is: Case 1: Distinctly undercut and/or angled Case 2: Gently curved
Mi2:	From the lateral side, the shape of the proximal part of the Os metacarpale I is: Case 1: Straight/horizontal (as for all geese) Case 2: Tilted/curved upwards (Note: this may not be suitable for the smallest specimens, which are very hard to judge)
Bfi:	Greatest gap between Os metacarpale II and III (in other words, the greatest width of the spatium intermetacarpale or fissura metacarpi) taken from the ventral (or medial) side
Lfi:	Greatest length of the fissura metacarpi (see above) taken from ventral side
Did: (vdD)	Diagonal of the distal end (in this instance taken at right angles to the longitudinal axis of the bone)

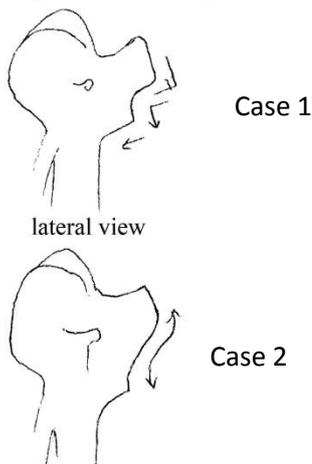
medial or ventral view



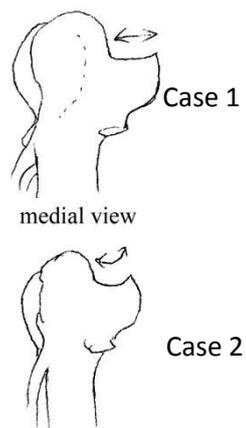
proximal depth, taken behind the processus piriformis, where this protrudes



Mi1: shape of Os metacarpale I:

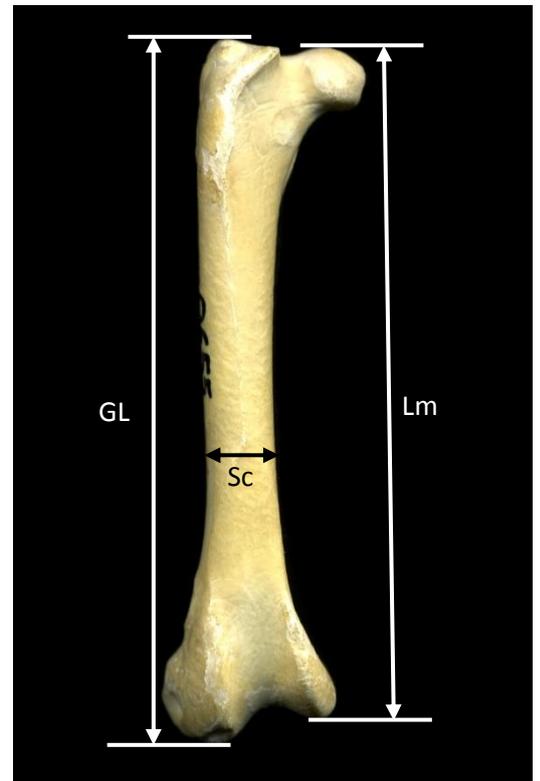
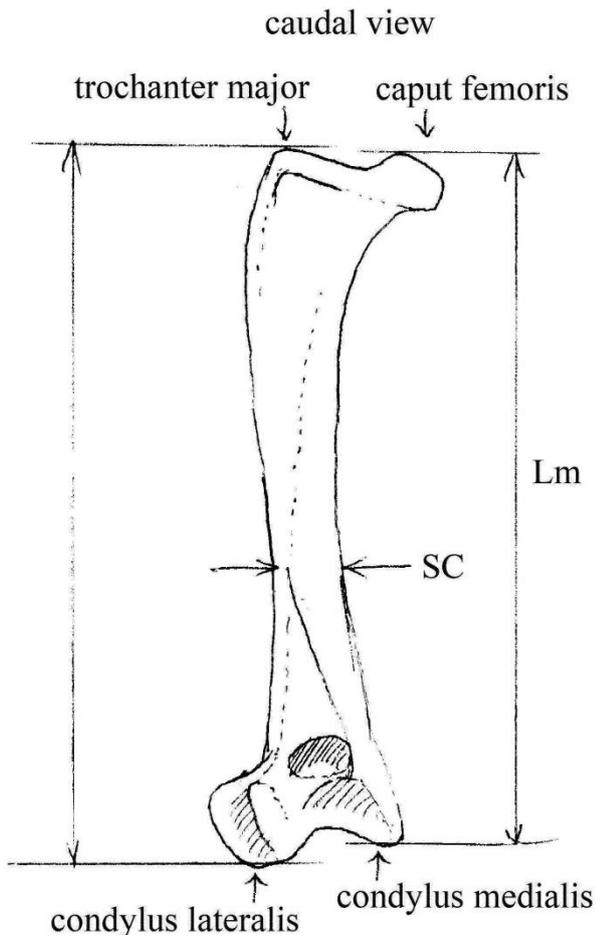


Mi2: shape of Os metacarpale I:

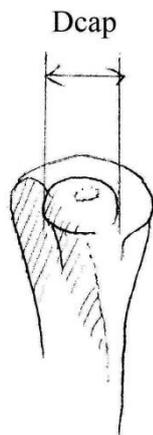
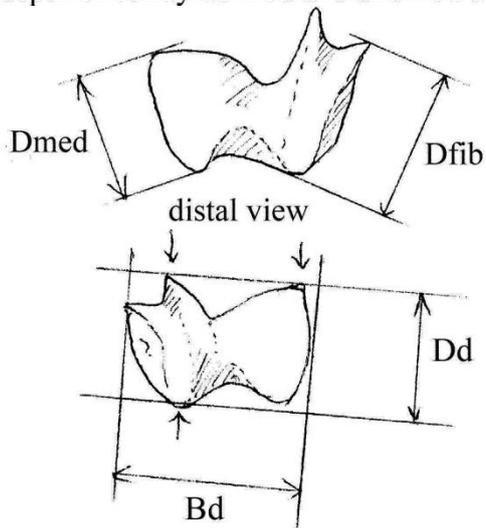


## **Femur**

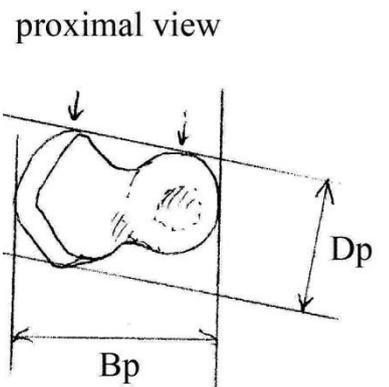
GL: (vdD)	Greatest length
Lm: (vdD)	Medial length
SC: (vdD)	Smallest breadth of the corpus (taken strictly in the aspect shown)
Bp: (vdD)	Greatest breadth of proximal end (at right angles to the Dp)
Dp: (vdD)	Depth of proximal end (from cranial points on the caput femoris and on the trochanter major)
Dcap:	Diameter (depth) of the caput femoris (taken from medial aspect, <i>i.e.</i> 'head on', and with calipers in line with the shaft)
Bd: (vdD)	Greatest breadth of distal end (taken from the distal aspect, and at right angles to the measurement Dd)
Dd: (vdD)	Greatest depth of distal end, taken from the distal aspect, with one edge of the calipers resting on both the condyles on the cranial side
Dfib:	Greatest depth of the condylus fibularis
Dmed:	Greatest depth of condylus medialis
Mtr:	The depression under the trochanter major is: Case 1: Rounded (often very shallow) Case 2: Pointed
Mpop:	The shape of the popliteal fossa is: Case 1: Deep (as if drilled from the front) or even undercut Case 2: A shallow depression (even if its edges are rounded and clearly defined)



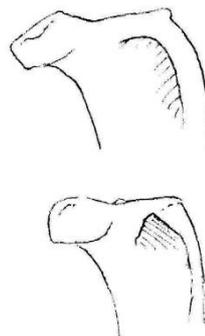
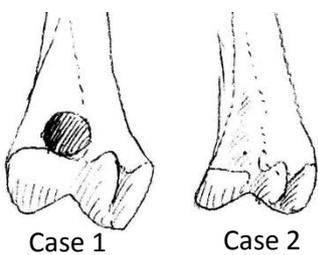
depth of condylus medialis and fibularis



diameter of  
Caput femoris



Mpop:  
shape of popliteal fossa:



Case 1

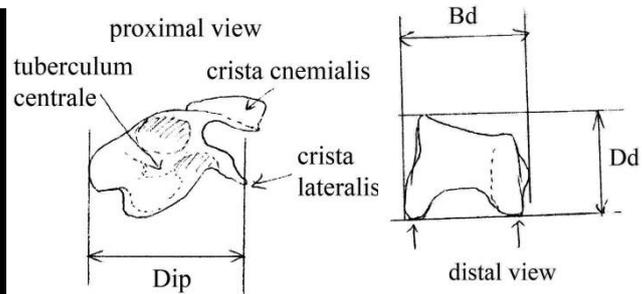
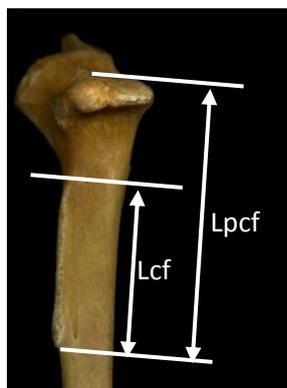
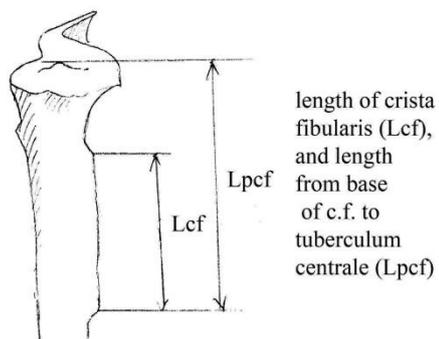
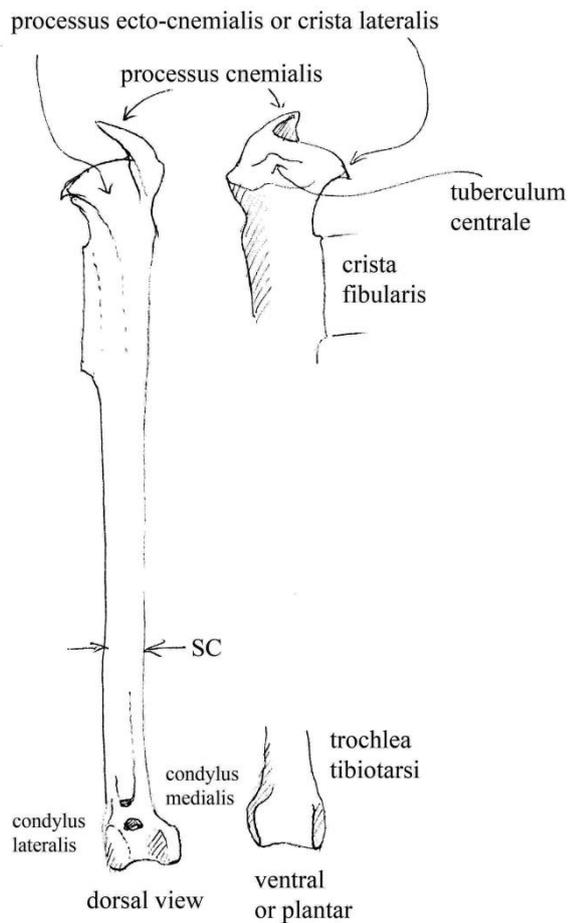
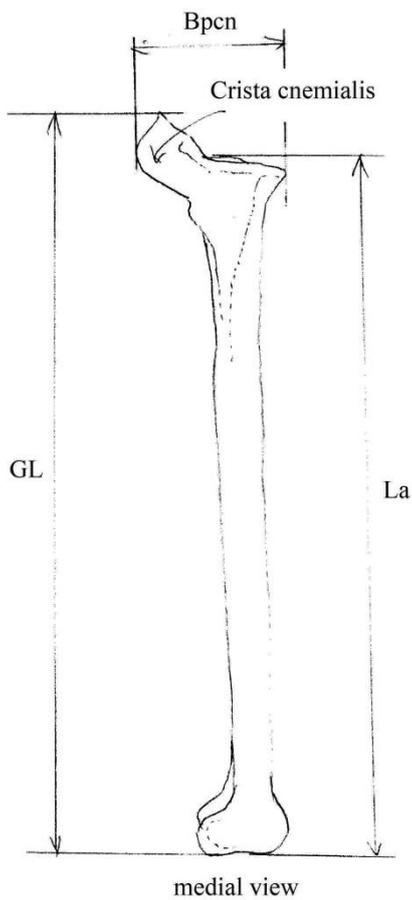
Mtr:  
contour of the depression  
on the trochanter major  
(cranial side):

Case 2

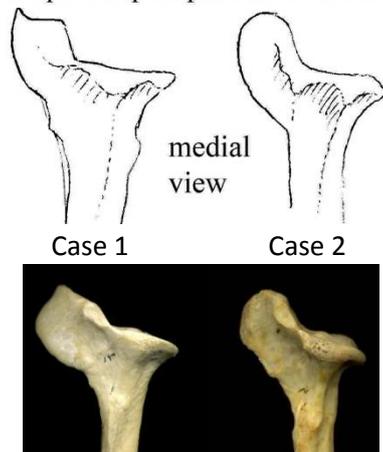


## **Tibiotarsus**

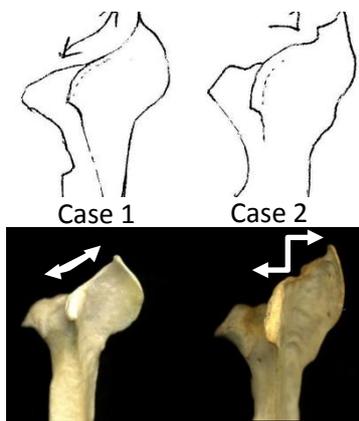
- GL: (vdD)      Greatest length (in ducks, easiest to take from the dorsal side, with the calipers at right angles to the shaft)
- La: (vdD)      Axial length, from tuberculum centrale to the distal border of the trochlea tibiotarsis (easiest to take from the plantar side)
- SC: (vdD)      Smallest breadth of corpus (in plantar or dorsal aspect)
- Dip: (vdD)      Greatest diagonal of the proximal end (see vdD notes)
- Bpcn:            Greatest width of proximal end, including the crista/processus cnemialis (from medial side, with calipers in line with shaft. This can generally be taken even when tip of the crista is broken off)
- Lcf:             Length of crista fibularis (or labium fibulare) (in caudal aspect) if this can be clearly defined
- Lpcf:            Length from tuberculum centrale (at proximal end) to base of the crista fibularis (in caudal aspect), with calipers in line with the shaft
- Bd: (vdD)      Breadth of the distal end
- Dd: (vdD)      Depth of the distal end, with the caudal points of the condyles resting on one side of the calipers
- Mcn1:            In the medial view, the processus cnemialis is:  
Case 1: Pointed  
Case 2: Blunt or rounded
- Mcn2:            In the dorsal view, the conjunction of the processus cnemialis and ecto-cnemiali is:  
Case 1: Angled (see diagram)  
Case 2: Gradual or gently curved
- Mcn3:            The upper contour of the processus cnemialis (in the medial view):  
Case 1: Curves upwards (even if then ends in a point)  
Case 2: Has an upwardly protruding angle



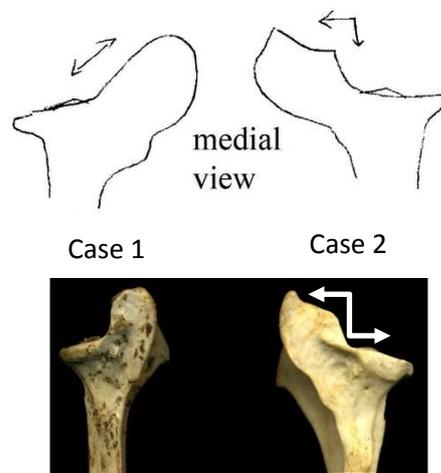
Mc1:  
shape of tip of processus cnemialis



Mc2:  
(dorso-lateral view)

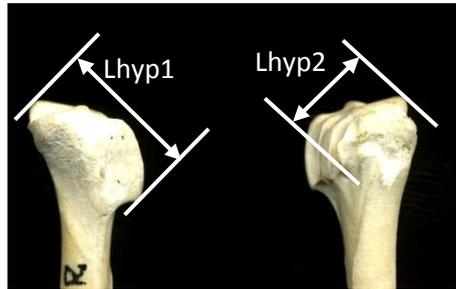
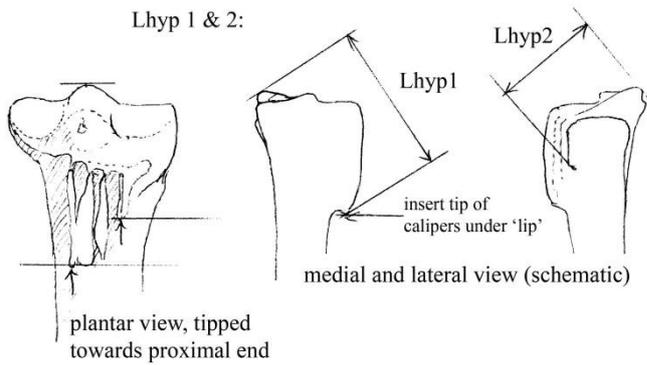
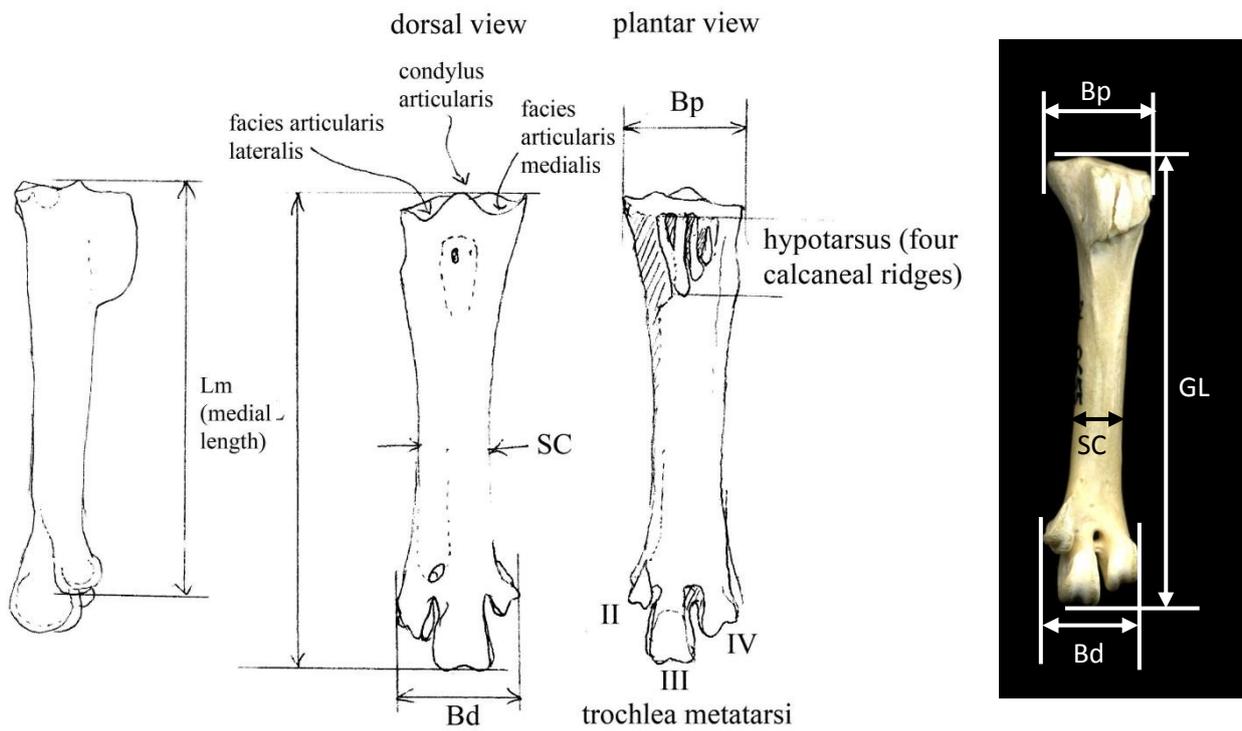


Mc3:

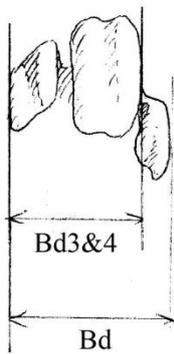
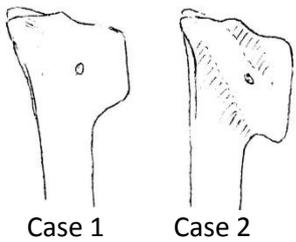


## Tarsometatarsus

GL: (vdD)	Greatest length
Lm:	Medial length, as shown, to base of trochlea metatarsus II (take with the tips of calipers in smaller ducks, to avoid 'clipping' the highest dorsal proximal point)
SC: (vdD)	Smallest breadth of the corpus, taken as shown, from the dorsal aspect ( <i>i.e.</i> from medial to lateral)
Bp: (vdD)	Greatest breadth of proximal end (measured in line with the shaft)
Lhyp1:	Distance from the tip of the condylus articularis to the base of the medial (longest) calcaneal ridge of the hypotarsus, where it joins the shaft
Lhyp2:	Distance from the tip of the condylus articularis to the base of the lateral (shortest) calcaneal ridge of the hypotarsus
Bd: (vdD)	Greatest breadth of distal end (measured in line with the shaft)
Bd3&4:	Greatest breadth of trochlea metatarsi III and IV (viewed from distal end) (Note: this is one measurement not two)
Mhyp1:	The medial side of the medial calcaneal ridge is: Case 1: Flat, with a smooth vertical depression between it and the shaft Case 2: Irregular (see diagram), with a raised diagonal portion separating it from the distal part of the shaft (cf. <i>Melanitta fusca</i> )
Mhyp2:	The distal edge of the medial (longest) calcaneal ridge: Case 1: Overhangs strongly ( <i>Aythya ferina</i> , <i>Bucephala clangula</i> , <i>Clangula hyemalis</i> , <i>Melanitta nigra</i> and <i>Mergus merganser</i> ) Case 2: Sticks out horizontally, or merges into the shaft in a shallow curve or angle ( <i>Anas</i> sp., <i>Somateria mollissima</i> , <i>Tadorna tadorna</i> , and geese)
Ms:	The shape of the dorsal edge of the shaft from medial side is: Case 1: Straight Case 2: Slightly concave

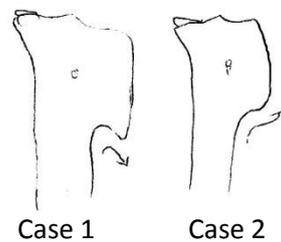


Mhyp1:  
 medial side of proximal end:



Bd3&4:  
 greatest breadth  
 of trochlea metatarsi  
 III and IV  
 distal view

Mhyp2:  
 medial calcaneal ridge:

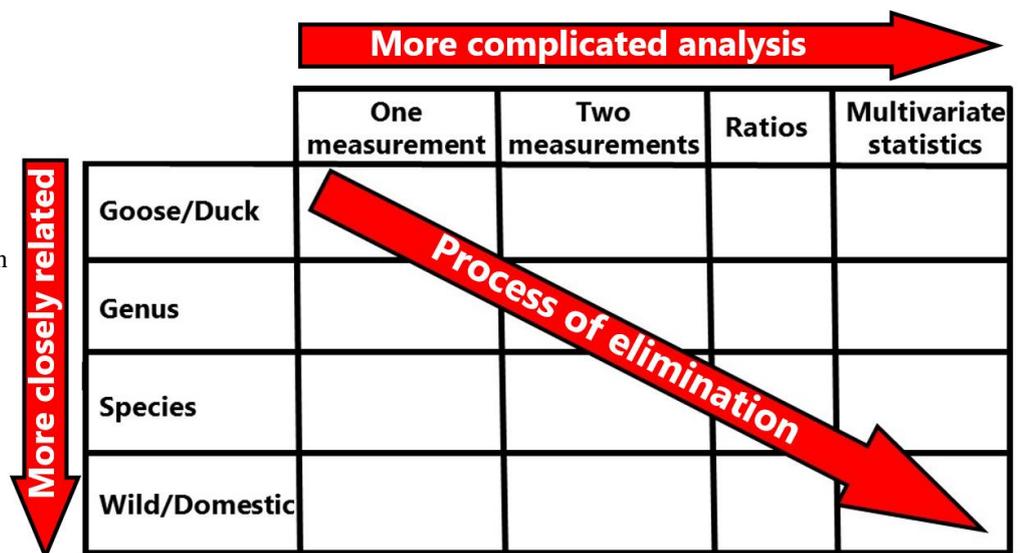


## **Statistical analysis**

The order of statistical analyses used to ascertain reliable identification criteria runs from the simple to the complicated (figure 2.2). The first stage is to determine if there is a morphological trait that can reliably separate two taxa. If there is no reliable morphological trait then the next stage is to use the analysis of linear measurements. Analyses using single linear measurements (*e.g.* greatest length, distal breadth, shortest width of the shaft, *etc.*) were tried first to see if reliable differences could be observed between the various taxa. Then analyses using two measurements, such as scatter plots, were used to see if different taxa could be separated. Next ratios of measurements were used combining up to four measurements in a single analysis (*e.g.* greatest length divided by distal breadth plotted against proximal breadth divided by the shortest width of the shaft). Finally multiple measurements were used simultaneously in discriminant function analysis which can be used to assign a bone to a particular group, such as genus or species, based upon the analysis of particular variables. It can then be calculated how many specimens were accurately put into the correct group, in this case the correct taxon (Lachenbruch and Mickey 1968).

The first distinctions that were made were between ducks and geese, then between the different genera within those two groups, then between species within the genera, and finally between the domestic and wild forms. This methodology is designed to go from the simplest method of distinguishing between the most different groups to the most complicated method of distinguishing between the most closely related groups. This is so that the easiest reliable analysis is used for each stage of identification to avoid an unnecessarily complicated protocol. There is no benefit to using complicated methodology if a more simple method reliably works. All data was recorded in Microsoft Excel and then imported into IBM SPSS Statistics 21 for all of the statistical analyses. The Shapiro-Wilk test of normality was used to check that the data was normally distributed within each group before further analysis, with a

significance of 0.05 or better being accepted. Chi-squared tests were used to check that observed differences in the analysis of the morphological characteristics were likely due to real differences and not due to chance, with a significance of 0.05 or better being accepted. Box plots were made to show that the measurement ranges of two taxa did not overlap for each measurement presented in chapters 3-5, and two tailed t-tests were made to check that the overserved differences were not likely due to chance, with a significance of at least 0.05 being accepted. The ratios of measurements were calculated in Microsoft Excel prior to importing into SPSS. The measurements and ratios were plotted in simple scatter plots to see if two taxa clustered in different areas of the graph. Discriminant function analysis was used to classify taxa using multiple measurements in one analysis. Computation was made from group sizes and did not assume that all groups were equal. Missing values were not replaced with the mean of that taxon. Box's M and Wilks' Lambda tests were carried out to test for the equality of covariance matrices and how well each function discriminated between the classes, a significance of 0.05 or better was required for both tests. Generally, discriminant function analysis was deemed to be reliable as a classification tool if it could accurately classify taxa in 90% of cases. However, some results with an accuracy of 85% are presented in this thesis as they can still be useful for making an identification in conjunction with other sources of information, such as box plots and scatter plots (discussed where relevant in chapters 3-5).



**Figure 2.2.** Diagram showing the order of analyses tested during the process of elimination for producing identification criteria. The order runs from the simplest analysis to the most complicated.

## **Chapter 3~** **Distinguishing between ducks (*Anatinae*) and geese (*Anserinae*)**

The purpose of the next three chapters is to demonstrate the measurements and analyses that can be used to distinguish between the different taxa assessed in this project. These criteria can then be applied to archaeological bones of unknown taxa in order to identify them, or at the very least rule out taxa the bones could be from. The three chapters are organised with sub sections for the different levels of identification for each bone:

3. Duck and goose distinctions - Figures in appendix 3
4. Duck distinctions - Figures in appendix 4:
  - Genus
  - Species
  - Wild and domestic forms
5. Goose distinctions - Figures in appendix 5:
  - Genus
  - Species
  - Wild and domestic forms

Each section outlines the simplest reliable method for making an identification. For example, as duck and goose ulnae can be distinguished using just the UIngl measurement, or two measurements at the articular ends (see below), there is no need to use a method such as discriminant function analysis as it is more complicated than necessary. Discriminant function analysis does work for this purpose, but it is redundant if a simpler method is reliable. Each sub section is divided by bone and the order of the bones runs from the anterior to the posterior, and along each limb.

All figures discussed in these chapters are in appendices 3-5 of this thesis and indicated by figure number. A full results table of the measurements taken, and

morphological characteristic recorded, for each modern reference bone can be found in appendix 1.

One of the main objectives of this thesis is to present criteria for the identification of the various duck and goose taxa thought to be native to Britain during the Roman period. The first stage is to distinguish between the main anatid groups, namely between swans, geese, and ducks. It is very unlikely that a researcher can confuse a duck bone for a swan bone purely based on the size difference, but there is some overlap in size between the larger geese and the smaller swans native to Britain (Cohen and Serjeantson 1996). However, as this will only apply to a very small number of specimens it is also unlikely that there will be an incorrect identification. As an archaeological bone is unlikely to be misidentified as a goose or duck when it should be a swan, the identification criteria discussed in these next three chapters do not cover swans. In any case, this project's application of the criteria outlined below is to investigate the use of ducks and geese during the Roman period, and so there is no need to discuss the identification of swan bones other than to say that they can confidently be excluded from the analyses of the assemblages in the vast majority of cases.

The method of identification used in this thesis is traditional morphometry combined with various statistical tests to see if taxa can be differentiated using the presence/absence of a morphological characteristic, one measurement, two measurements, up to four measurements in ratio plots, or many measurements in a multivariate statistical test. The first stage of identification is to decide whether an unknown archaeological bone belongs to a duck or a goose. There are a number of publications that discuss this and a lot of the time identification is possible due to their size difference and/or certain morphological characteristics (see Serjeantson 2002, Serjeantson 2009, and Yalden and Albarella 2009). However, there are some instances when duck and goose bones overlap in size, or distinct morphological characteristics are missing (*e.g.* Tmtmhyp2), and so it is not that easy to

identify a bone to the correct taxon. Presented below are identification criteria that are reliable for the distinction between ducks and geese. In most cases it is not necessary to use more than two measurements for identifying whether a bone belonged to a duck or a goose, apart from the leg bones where there is a greater overlap in the size ranges. For these bones it is therefore necessary to use multivariate statistics to identify an unknown bone if it plots in the overlap area of a bi-plot.

### **Coracoid**

The coracoid is an example of a bone for which ducks and geese overlap in size significantly and so using single measurements for the purpose of identification is not reliable. However, by plotting two measurements, or ratios of measurements, it is possible to distinguish between the two taxa reliably. Figures 3.1 - 3.7 show that ducks and geese separate out well into distinct clusters and so if an unknown bone plots in one of those groups you can be confident that it belongs to that taxon.

Morphological characteristics that can be used for the distinction between ducks and geese are discussed in a number of places (*e.g.* Woelfle 1967 and Cohen and Serjeantson 1996) and there is no need to repeat that in this thesis. The one morphological characteristic of the coracoid that was tested in this project, and did show some ability to distinguish between ducks and geese, was the Cormac2 characteristic (Figure 3.8). However, this is not entirely reliable as Case 1 was present in nearly 30% of ducks and Case 2 was present in around 20% of geese. This identification criteria should not be used in isolation but can be combined with the measurements discussed above to allow a researcher to be more confident in an identification.

## **Scapula**

There is a lot of overlap in size between duck and goose scapulae so it is often necessary to plot two measurements together to make a reliable identification. Figures 3.9 - 3.11 show that even when only two measurements are used it is possible to separate ducks and geese into two distinct clusters.

Of the three morphological characteristics assessed in this thesis, only one allowed for the distinction between duck and goose scapulae to be made with confidence. Figure 3.12 shows that just under 80% of goose scapulae were Case 1 and just over 90% of duck scapulae were Case 2.

## **Humerus**

The humerus is the bone with the most measurements and morphological characteristics recorded for it in this thesis, and so there is a lot of potential for developing taxon identification criteria. Figures 3.13 - 3.14 show that there is almost no overlap between ducks and geese for the Humgl and Humlcl measurements. This means that if an unidentified archaeological bone plotted in one of the size ranges, a researcher could be confident it belonged to that taxon.

However, it may be the case that it is not possible to take the measurements discussed above (for example, due to breakage in an archaeological bone) and so other measurements are necessary to distinguish between ducks and geese. Figures 3.15 - 3.21 show that ducks and geese can be separated using just two measurements, and usefully it is not necessary for the bone to be complete. Measurements taken at the proximal and distal ends of the bone can be used for identification purposes.

As there is some overlap in the size of duck and goose humeri, it may be necessary to take the identification process to the next stage and plot ratios of measurements to see if there

is a clearer separation between the two taxa. Figures 3.22 - 3.24 show that there is relatively little overlap between the clusters just by plotting ratios of measurements. The interesting thing about ratios is that by plotting one measurement divided by another we can see that these two taxa are not only different in their size, but also their shape. Figure 3.22 shows that the relative width of the shaft compared to the greatest length of the bone is not that variable between ducks and geese, but the Humlcl is much longer in geese compared to ducks and so the value for the Humgl/Humlcl is much lower in geese allowing for the two taxa to be separated on a scatter plot.

None of the morphological characteristics assessed in this thesis showed a reliable difference between ducks and geese. Ducks are much more variable morphologically than geese and so some traits that were always present in geese were also often present in ducks, meaning that they cannot be used to reliably separate ducks and geese.

## **Ulna**

There is no overlap in the ranges of the greatest lengths of duck and goose ulnae. This measurement can be used to make a reliable identification in isolation if it is possible to take it on an archaeological bone. Figure 3.25 shows that goose ulnae are much longer than duck ulnae for British species.

If the bone is not complete then it can still be identified as belonging to a duck or a goose by plotting two measurements. Figure 3.26 shows that there is almost no overlap in ducks and geese for the Ulnahnf and Ulnhma measurements taken on the proximal end of the bone and, although there is some overlap, Figure 3.27 shows that ducks and geese can largely be separated through measurements of the distal end.

There were no morphological characteristics that reliably distinguished between duck and goose ulnae identified in this project.

## **Radius**

The radius is similar to the ulna in that the ranges of the greatest length of duck and goose radii do not overlap and so it is possible to reliably identify a bone if it is possible to take this measurement (Figure 3.28).

It is not possible to reliably identify a bone if the Radgl and Radbd measurements cannot be taken and the Radsc plots in the overlap area between the taxa. However, if the Radbd and Radsc measurements can be taken then it is possible to identify most bones (Figure 3.29).

## **Carpometacarpus**

There is no single measurement that the ranges of ducks and geese do not overlap considerably for the carpometacarpus. However, it is possible to separate the two taxa by plotting two measurements on a scatter plot. Figures 3.30 - 3.34 show that the two groups separate out with only minimal overlap. In the case of Figure 3.30 and Figure 3.32 we can see that ducks and geese not only cluster in different parts of the graph, but they also have different regression lines, suggesting that they have different shapes as well as sizes.

Although it is not always necessary to take the identification process to the next stage, it may be useful to plot ratios of measurements in case an archaeological bone plots in the overlap area of the two measurement scatter plots. Figures 3.35 - 3.37 show that ducks and geese generally plot in different areas of the graph. Although a number of ducks plot in the same area as the geese, there is a large cluster of ducks in each plot that contains no geese. If an unknown bone plots in this area then it can be confidently identified as belonging to a duck.

The morphological characteristic Cmcmi2 may also be useful for distinguishing between duck and goose carpometacarpi. Although over 60% of ducks were Case 1 for this

characteristics, 100% of geese were Case 1 for the Cmcmi2 (Figure 3.38). This means that if an unknown archaeological bone is Case 1, it cannot be identified using this criterion, but if it is Case 2 then it can be reliably identified as belonging to a duck.

In the cases where an archaeological bone plots in the overlap of the bi-plots and ratio plots, it may be necessary to take the analysis to the next stage and use discriminant function analysis. Figure 3.39 shows that duck and goose carpometacarpi can be distinguished readily by analysing several measurements simultaneously. In this case, duck carpometacarpi were accurately classified into the correct group 98.3% of the time meaning that it is a very reliable method of separating the two taxa.

### **Femur**

There is a large degree of overlap between ducks and geese in the measurements of the leg bones and no single measurement in isolation is particularly useful for identification purposes. Figures 3.40 - 3.46 show that although the goose and duck clusters overlap, there is a significant amount of space where they do not when two measurements are plotted. It is possible to identify an archaeological bone if it plots in one of the areas where there is no overlap.

Ducks and geese almost completely overlap in the ratio plots and so this is not a reliable method of distinguishing between the two taxa. However, it is still possible to identify an unknown archaeological bone, even if it plots in the overlap of the bi-plots discussed above, by using discriminant function analysis. Figure 3.47 shows that the two groups can be reliably classified.

None of the morphological characteristics assessed in this thesis showed a reliable difference between ducks and geese femora.

## **Tibiotarsus**

The analysis of the tibiotarsus shows similar results to the femur in that there is a lot of overlap between ducks and geese when only a single measurement is used and when the ratios of measurements are plotted. As such these are not useful for identification purposes. There are differences between ducks and geese when two measurements are plotted in a bi-plot and so it is possible to reliably identify most unknown bones. Figures 3.48 - 3.53 show that geese and ducks plot in different areas of the graph when two measurements are plotted.

Discriminant function analysis can be used to reliably identify any unknown bone that plots in the overlap area of the bi-plots discussed above. Figure 3.54 shows that ducks and geese can be readily classified using several measurements in a single analysis.

None of the morphological characteristics assessed in this thesis showed a reliable difference between ducks and geese for the tibiotarsus.

## **Tarsometatarsus**

The last bone analysed in this project is the tarsometatarsus, and like the femur and tibiotarsus, ducks and geese overlap in size and shape significantly meaning that comparing single measurements and ratios of measurements is not reliable for identification purposes. Plotting two measurements together shows that ducks and geese plot in different areas (with some overlap) and so the identification of an unknown bone can be achieved in most cases (Figures 3.55 - 3.61).

Only one of the morphological characteristics assessed in this thesis can be used to separate ducks and geese with any confidence. Figure 3.62 shows that just over 87% of duck tarsometatarsi were Case 1 and just under 84% of goose tarsometatarsi were Case 2. The risk of misidentification is still pretty high though, which means that these morphological criteria should be integrated with biometric analysis.

Discriminant function analysis can be used to identify an unknown bone that plots in the overlap areas of the bi-plots discussed above. Figure 3.63 shows that ducks and geese can be separated reliably using the measurements detailed in the caption.

## **Chapter 4~** **Duck genus and species distinctions**

This chapter follows the same structure as the previous chapter in the order the bones are discussed, but the structure differs in that identification criteria follows alphabetically for genus, then species, then wild/domestic distinctions within each bone sub section. Figures referred to in this chapter can be found in appendix 4 of this thesis.

### **Coracoid**

#### **Genus**

##### **Anas/Aythya**

No single measurement can be used in isolation for reliable identifications, but bi-plots can be used as long as the unknown bone does not plot in the overlap area (Figures 4.1-4.3). Plotting ratios of measurements helps to separate these genera (Figures 4.4-4.6), but it may be necessary to take the identification to the last stage and use discriminant function analysis if an unknown bone continues to plot in an overlap area in the scatter plots (Figure 4.7).

##### **Anas/Bucephala**

*Anas* and *Bucephala* coracoids can be readily separated using bi-plots or ratios plots with little overlap in most cases (Figures 4.8-4.15). However, if further confirmation of an identification is needed then discriminant function analysis can be used (Figure 4.16).

##### **Anas/Clangula**

In most cases these genera can be separated using just two measurements or by plotting ratios of measurements (Figures 4.17-4.22), but two morphological characteristics

can also be used to indicate the correct genus. Figures 4.23-4.24 show that the Cormac2 and Cormplp characteristics are usually different in these genera, and although not 100% reliable, they can be used to add confidence in an identification. If it is necessary to carry on with the identification and take it to the next stage, discriminant function analysis can be used reliably to classify these genera (Figure 4.25).

#### *Anas/Melanitta*

Similar to the *Anas/Clangula* distinctions, *Anas* and *Melanitta* can generally be distinguished by plotting two measurements or ratios of measurements (Figures 4.26-4.30). The Cormac2 morphological characteristic is also useful for telling these genera apart, as over 80% of *Anas* coracoids have a case 2 shape and around 80% of the *Melanitta* coracoids have a case 1 shape (Figure 4.31). If it is really necessary to take the identification further than discriminant function analysis can be used as demonstrated in Figure 4.32.

#### *Anas/Mergus*

*Anas* and *Mergus* can be readily separated using just a few measurements and plotting them in bi-plots or ratio plots (Figures 4.33-4.40). Usefully there is little or no overlap in the clusters for these genera and so they can very confidently be distinguished without the need for multivariate statistics.

#### *Anas/Somateria*

The size range of the *Somateria* coracoids overlaps with the larger *Anas* individuals and so they cannot be separated easily using bi-plots or ratio plots. Figures 4.41-4.46 are presented to show the range of the *Somateria* coracoids and so if an unknown bone plots outside of this range a researcher can be confident that the bone does not belong to

*Somateria*. Discriminant function analysis is needed if an archaeological bone does plot in the overlap areas of the bi-plots and ratio plots. Figure 4.47 shows these genera can still be separated provided enough measurements can be taken on an archaeological bone.

#### *Anas/Tadorna*

Similar to the *Anas/Somateria* distinctions, *Tadorna* coracoids overlap with *Anas* coracoids in terms of their overall size and so it is usually necessary to take the identification process to the next stage and plot ratios or use discriminant function analysis. Figures 4.48-4.51 show that *Tadorna* coracoids are generally a different shape to the *Anas* coracoids, but that there is still some degree of overlap. Figure 4.52 shows that these two genera can be separated out reliably using discriminant function analysis provided enough measurements can be taken.

#### *Aythya/Bucephala*

*Aythya* and *Bucephala* differ in size for the measurements of the distal end of the coracoid, and there is very little, if any, overlap when these measurements are plotted in bi-plots or ratio plots (Figures 4.53-4.58). Discriminant function analysis is not necessary to distinguish the coracoids of these genera as the measurements needed for the analysis can be used in the scatter plots discussed above to make a reliable identification.

#### *Aythya/Clangula*

The coracoids of these genera differ in both size and shape and there is minimal overlap in the bi-plots and ratio plots featured in Figures 4.59-4.65. The Cormac2 morphological characteristic can also be useful for distinguishing between them with around 90% of *Aythya* coracoids being case 2 and around 80% of *Clangula* coracoids being case 1

(Figure 4.66). Further confidence in separating these genera can be achieved using discriminant function analysis, provided that enough measurements can be taken on an archaeological bone (Figure 4.67).

#### *Aythya/Melanitta*

*Aythya/Melanitta* distinctions are very similar to *Aythya/Clangula* distinctions for the bi-plots, ratio plots, the identification of the Cormac2 characteristic, and the discriminant function analysis result (Figures 4.68-4.74).

#### *Aythya/Mergus*

The distal ends of these genera differ greatly in both size and shape and so can be readily separated with a bi-plot or ratio plot (Figures 4.75-4.78). Discriminant function analysis can also be used to reliably separate them as demonstrated in Figure 4.79.

#### *Aythya/Somateria*

There is no overlap in the size ranges of *Aythya* and *Somateria* coracoids for most measurements and so it is possible to reliably separate them using any single measurement with the exception of the Corhac measurement (Figures 4.80-4.85).

#### *Aythya/Tadorna*

Although there is an overlap in the size ranges of these genera, they plot on different regression lines in bi-plots, and plot in different areas of the graph for one ratio plot, albeit with some overlap (Figures 4.86-4.90). The Cormplp characteristic is very useful for identifications as over 90% of *Aythya* coracoids are case 2 and over 90% of *Tadorna*

coracoids are case 1 (Figure 4.91). Discriminant function analysis reliably separates these taxa if enough measurements can be taken on an archaeological bone (Figure 4.92).

#### *Bucephala/Clangula*

There is little, or no, overlap in the clusters when measurements of the coracoids of these genera are plotted in bi-plots and ratio plots (Figures 4.93-4.99) and so they can usually be distinguished readily. Cormac2 can be a useful morphological characteristic to differentiate between *Bucephala* and *Clangula* coracoids, but is not completely reliable in isolation (Figure 4.100). The coracoids of these genera can be separated using discriminant function analysis if it is not possible using the measurements discussed above, although it is not as reliable as some other discriminant function analyses discussed in this chapter (Figure 4.101).

#### *Bucephala/Melanitta*

*Bucephala* and *Melanitta* coracoids overlap in terms of overall size, but the bi-plots and ratio plots show that there is no overlap in the clusters when certain measurements are plotted (Figures 4.102-4.106). The Cormac2 characteristic can also be indicative of genus, but not in isolation as it is not 100% reliable (Figure 4.107).

#### *Bucephala/Mergus*

The coracoids of these genera overlap in size significantly and so it is only by plotting ratios of measurements can they start to be separated (Figures 4.108-4.109). Discriminant function analysis is reliable for separating them if enough measurements can be taken on an unknown bone, although this will not be needed if the ratio plots work (Figure 4.110).

### *Bucephala/Somateria*

There is almost no overlap in the size ranges of *Bucephala* and *Somateria* coracoids for many measurements and usually they can be separated using a single measurement (Figures 4.111-4.115).

### *Bucephala/Tadorna*

*Bucephala* and *Tadorna* coracoids overlap in size, but plot on different regression lines in bi-plots (Figures 4.116-4.118). Figure 4.119 shows that these genera can be separated by plotting two sets of ratios, and Figure 4.120 shows that discriminant function analysis is a reliable method for differentiation.

### *Clangula/Melanitta*

*Clangula* and *Melanitta* coracoids differ in size considerably at the proximal end and plot on different regression lines for measurements on the distal end (Figures 4.121-4.122). If an unknown bone plots in the small overlap areas of the bi-plots then discriminant function analysis can be used, provided that enough measurements can be taken (Figure 4.123).

### *Clangula/Mergus*

There is a significant amount of overlap between the coracoids of these genera apart from when the Corgl and Corbb, and Corbb and Corlplp measurements are plotted in a bi-plot (Figures 4.124-4.125). These species can also be reliably classified using discriminant function analysis (Figure 4.126).

### Clangula/Somateria

There is no overlap in the size ranges between *Clangula* and *Somateria* coracoids for most measurements and so the two genera can be distinguished using a single measurement in most cases (Figures 4.127-4.132). The Cormac2 morphological characteristic can also be indicative of genus as around 80% of *Clangula* coracoids are case 1 and around 95% of *Somateria* coracoids are case 2 (Figure 4.133).

### Clangula/Tadorna

*Clangula* and *Tadorna* coracoids overlap in terms of overall size, but there is no overlap in the clusters when certain measurements are plotted on bi-plots and ratio plots (Figures 4.134-4.136). The Cormac2 characteristic may also be useful for identification, but not in isolation, as around 80% of *Clangula* coracoids are case 1 and around 80% of *Tadorna* coracoids are case 2 (Figure 4.137).

### Melanitta/Mergus

*Melanitta* and *Mergus* coracoids overlap in size, but vary greatly in shape as demonstrated by different regression lines in bi-plots and clusters appearing in different parts of the graph in ratio plots (Figures 4.138-4.143).

### Melanitta/Somateria

There is a very small amount of overlap in terms of size of these genera and so they can be readily separated using bi-plots (Figures 4.144-4.148). As with other genera discussed above, the Cormac2 morphological characteristic can be used to separate these genera as *Melanitta* is case 1 around 80% of the time and *Somateria* is case 2 around 95% of the time (Figure 4.149).

### Melanitta/Tadorna

There is a significant amount of overlap in the size of the coracoids of these genera and the only bi-plot that reliably separates them is when the Cordac and Corhac measurements are plotted (Figure 4.150). However, when ratios of measurements are plotted these genera can be separated out readily (Figures 4.151-4.154), and the Cormac2 characteristic can be used to assist in the identification. *Melanitta* coracoids are case 1 around 80% of the time and *Tadorna* coracoids are case 2 around 80% of the time (Figure 4.155).

### Mergus/Somateria

There is only one measurement for which the coracoids of these genera do not overlap, which is the Corbf measurement. This can be used in isolation for distinguishing between the genera if it can be taken (Figure 4.156). If this measurement cannot be taken, then there are a number of combinations of measurements that can be used in bi-plots to readily differentiate between *Mergus* and *Somateria* coracoids (Figures 4.157-4.160).

### Mergus/Tadorna

The coracoids of these genera overlap in their size ranges, but they can be separated readily by using bi-plots or by plotting ratios of measurements without the need to take the identification process to the next level and use multivariate statistics (Figures 4.161-4.166).

### Somateria/Tadorna

*Somateria* and *Tadorna* coracoids do not overlap in their size ranges for two measurements; the Corlm and the Corlplp (Figures 4.167-4.168) and so can be separated using a single measurement if these can be taken. Bi-plots can also be used for identification

(Figures 4.169-4.171) and there is no need to plot ratios of measurements or use multivariate statistics.

### **Species**

#### *Anas acuta/Anas clypeata*

These species can be distinguished using a single measurement if the Corgl or Cordac measurements can be taken, and can be separated using measurements of the distal end of the coracoid in bi-plots (Figures 4.172-4.176).

#### *Anas acuta/Anas crecca*

*Anas acuta* is much larger than *Anas crecca* and so they can be reliably differentiated using any measurement in isolation (Figures 4.177-4.182).

#### *Anas acuta/Anas penelope*

These species overlap in terms of overall size, but can be separated using bi-plots or by plotting ratios of measurements, particularly for the distal end of the coracoid (Figures 4.183-4.187).

#### *Anas acuta/Anas platyrhynchos* (wild and domestic form)

*Anas acuta* and *Anas platyrhynchos* overlap completely in their size ranges. Figures 4.188-4.193 show the range of *Anas acuta* compared to *Anas platyrhynchos* in bi-plots and a ratio plot. If an unknown bone plots outside of the *Anas acuta* area, then we can confidently say that it does not belong to this species. However, if a bone plots in the overlap area it is necessary to use discriminant function analysis to attempt a separation of the two species

(Figures 4.194). To produce an unambiguous identification it may be best to combine the methods discussed above.

*Anas acuta/Anas querquedula*

As with *Anas crecca*, the size range of *Anas querquedula* does not overlap with *Anas acuta* and so any single measurement can be used to reliably distinguish between these species (Figures 4.195-4.202).

*Anas acuta/Anas strepera*

A bi-plot and a ratio plot can be used to differentiate between these species, but if an unknown bone plots in an overlap area it is necessary to take the identification process to the last stage and use discriminant function analysis, provided that enough measurements can be taken on the unknown bone (Figures 4.203-4.205).

*Anas clypeata/Anas crecca*

There is no overlap in the size ranges of these species for a number of measurements so a single measurement is all that is needed in most cases (Figures 4.206-4.211).

*Anas clypeata/Anas penelope*

*Anas clypeata* and *Anas penelope* coracoids are very similar in both size and shape meaning they are difficult to separate. Although there is some overlap, a bi-plot using the Corbb and Corlplp measurements and a ratio plot using the Corbb, Corlplp, and Corgabf measurements can be used to make an identification (Figures 4.212-4.213). Discriminant function analysis can be used to separate these species if an unknown bone plots in the overlap areas of the above plots (Figure 4.214).

*Anas clypeata*/*Anas platyrhynchos* (wild and domestic form)

There is little, or no, overlap in the size ranges for the coracoids of these species for three measurements meaning they can be used in isolation for identification if they can be taken on an unknown bone (Figures 4.215-4.217). Bi-plots can also be used to reliably distinguish between *Anas clypeata* and *Anas platyrhynchos* (Figures 4.218-4.219).

*Anas clypeata*/*Anas querquedula*

The only measurement that there is no overlap in the size ranges of the coracoids of these species is the Cordac which can be used reliably in isolation for identification if it can be taken on an archaeological bone (Figure 4.220). Some bi-plots show a degree of separation between the species and it is possible to make an identification if an unknown bone does not plot in the overlap areas of the clusters (Figures 4.221-4.224). However, it is necessary to use discriminant function analysis for any bone that does plot in overlap areas of the bi-plots discussed above (Figures 4.225).

*Anas clypeata*/*Anas strepera*

*Anas clypeata* and *Anas strepera* can be separated with little, or no, overlap in their clusters using bi-plots and ratios plots for a range of different measurements (Figures 4.226-4.229). If an unknown bone plots in the overlap areas of the scatter plots discussed above, then discriminant function analysis can be used reliably classify the bone (Figure 4.230).

*Anas crecca*/*Anas penelope*

There is no overlap in the size ranges for most measurements of the coracoid for these species and so they can usually be separated using a single measurement (Figures 4.231-4.235).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

*Anas crecca* is much smaller than *Anas platyrhynchos* and so their coracoids can be distinguished using any one of the measurements assessed in this thesis (Figures 4.236-4.241).

*Anas crecca/Anas querquedula*

Of all the *Anas* species analysed in this thesis, *Anas crecca* is most similar to *Anas querquedula* in both size and shape. Bi-plots can be used to separate them in most cases, although there is some overlap in their clusters (Figures 4.242-4.246). Ratio plots do not separate the species and on this occasion discriminant function analysis did not produce a significant result. This may be due to the small sample size for *Anas querquedula*.

*Anas crecca/Anas strepera*

*Anas crecca* and *Anas strepera* do not overlap in their size ranges for any measurement assessed in this thesis and so any measurement can be used in isolation to distinguish between these two species (Figures 4.247-4.252).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

These species overlap in terms of their overall size and there is no bi-plot that there is no overlap in their clusters. However, it is useful to plot the range of *Anas penelope* compared to *Anas platyrhynchos* so that if an unknown archaeological bone plots outside the range of *Anas penelope* we can rule out that species from the identification (Figures 4.253-4.258). Discriminant function analysis can be used if a bone does plot in the overlap area to make a reliable identification (Figure 4.259).

*Anas penelope*/*Anas querquedula*

The Corbf measurement can be used in isolation to separate these species, but if that cannot be taken then there are a number of bi-plots that show that they can be differentiated using just two measurements (Figures 4.260-4.264).

*Anas penelope*/*Anas strepera*

*Anas penelope* and *Anas strepera* coracoids are very similar in size and shape and can only really be separated using discriminant function analysis. The plot of the first discriminant function suggests that there is a lot of overlap and they cannot reliably be classified (Figure 4.265). However, the classification results suggest that this method is still relatively reliable despite the similarity in size and shape for the two species with 88.2% of bones being correctly classified.

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

There is no overlap in the size ranges for most measurements of the coracoids of these two species and so they can be separated readily using a single measurement in most cases (Figures 4.266-4.270).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

The size ranges of these species overlap completely and so it is necessary to use discriminant function analysis to reliably distinguish between them if an unknown bone plots in the overlap area (Figure 4.271). In this case, it is best to go straight to the discriminant function analysis if enough measurements can be taken as that produces the most reliable results. However, here are presented some bi-plots and ratio plots to show the range of *Anas*

*strepera* and *Anas platyrhynchos*, and if a bone plots outside of the *Anas strepera* area we can be confident that it does not belong to that species (Figures 4.272-4.275).

*Anas querquedula/Anas strepera*

There are several measurements on the coracoid that the size ranges of these two species do not overlap and so they can be reliably distinguished using a single measurement in most cases (Figures 4.276-4.279).

*Aythya ferina/Aythya fuligula*

*Aythya ferina* and *Aythya fuligula* coracoids overlap considerably in terms of overall size but generally plot in different areas of the graph in bi-plots and ratio plots, albeit with some overlap in their clusters (Figures 4.280-4.284). Discriminant function analysis can be used if it is not possible to confidently identify an unknown bone using the plots discussed above (Figure 4.285).

*Aythya ferina/Aythya marila*

Bi-plots and ratio plots can be used to reliably separate these two species even though there is some overlap in the size of their coracoids (Figures 4.286-4.289). Discriminant function analysis may be a useful tool for differentiating between the two species but unfortunately the results of Box's M test was not significant meaning the classification results may not be reliable. This is likely due to the small sample size that was available to this project.

*Aythya fuligula/Aythya marila*

These species are generally different sizes and can reliably be distinguished using two measurements in bi-plots (Figures 4.290-4.293).

*Melanitta fusca/Melanitta nigra*

There is some overlap in the overall size of the coracoids of these species and so only a couple of bi-plots and ratio plots can be used to distinguish between them (Figures 4.294-4.299). If necessary, discriminant function analysis can also be used to make a reliable classification (Figure 4.300).

*Mergus albellus/Mergus merganser*

There is no overlap in the size ranges of the coracoids of these species for most measurements and almost every measurement included in this thesis can be used to differentiate them in isolation (Figures 4.301-4.306).

*Mergus albellus/Mergus serrator*

As with the *Mergus albellus/Mergus merganser* differences, there is no overlap in the size ranges of *Mergus albellus* and *Mergus serrator* for most measurements of the coracoid. Most measurements can be used in isolation to make an identification (Figures 4.307-4.312).

*Mergus merganser/Mergus serrator*

These two *Mergus* species overlap in terms of size and shape so single measurements cannot be used to separate them in all cases. Only one bi-plot and one ratio plot (with some overlap) can be used to distinguish them, and so it is necessary to use discriminant function analysis to make an identification in many cases (Figures 4.313-4.315).

### **Wild compared to domestic (*Anas platyrhynchos*)**

Although there is some overlap in terms of overall size, the coracoids of modern domestic ducks and the wild Mallard (*Anas platyrhynchos*) can be separated reliably using a range of bi-plots (Figures 4.316-4.321). Discriminant function analysis can also be used as these taxa separate out readily when a number of measurements are used in a single analysis (Figure 4.322). It is worth pointing out at this point that Domestic Ducks in the present and the past may have been morphologically different, and that Domestic Ducks during the Roman period (if there were any) may have been more similar to Mallards than modern Domestic Ducks. If Mallard can be ruled out for an identification, and the archaeological bone is morphologically consistent with a modern Domestic Duck, then we can be confident that the bone came from a Domestic Duck as wild ducks are less likely to have been morphologically variable through time than Domestic Ducks due to selective breeding within the domestic populations. If an archaeological bone plots in the overlap areas of the wild and domestic ducks then it is impossible to say with confidence if the bone belonged to a wild or a domestic individual and so the frequency of these bones must be taken into consideration when interpreting the results of an assemblage analysis (chapter 8).

## **Scapula**

### **Genus**

#### **Anas/Aythya**

Size ranges of both measurements for *Aythya* scapulae are completely within that of *Anas* ranges and so they cannot be separated using a single measurement. A bi-plot and ratio plots show that although there is overlap between the *Anas* and *Aythya* clusters, it is possible to rule out a genus if an unknown bone plots outside of the overlap areas (Figures 4.323-4.325). There are no significant discriminant function analysis results for the scapula as too few measurements can be taken for this type of analysis to be viable.

#### **Anas/Bucephala**

As with *Aythya*, *Bucephala* scapulae measurements fall within the ranges of the *Anas* measurements, and the *Bucephala* clusters of the bi-plot and ratio plots overlap with the *Anas* clusters (Figures 4.326-4.328). Again, a genus can be ruled out if an unknown bone does not plot in the overlap area. The Scapmd morphological characteristic may also be useful for identification purposes as over 95% of *Bucephala* scapulae are case 2 meaning a scapula with a case 1 Scapmd is very unlikely to be *Bucephala* (Figure 4.329).

#### **Anas/Clangula**

As with the previous two genera, it is not possible to distinguish between *Anas* and *Clangula* using measurements if an unknown bone plots in the overlap area. Figures 4.330-4.332 show the range of the *Clangula* clusters compared to *Anas*. The Scapmd characteristic may also be useful here with around 90% of *Clangula* scapula being case 2 it is unlikely that a scapula with a case 1 Scapmd belongs to the *Clangula* genus (Figure 4.333).

### *Anas/Melanitta*

The spread of the *Anas* clusters in the bi-plot and ratio plots completely overlaps with the *Melanitta* clusters and so it is not possible to rule out a genus if an archaeological bone plots in the overlap area (Figures 4.334-4.336). There is no reliable difference between the scapulae of these genera for the morphological characteristics assessed in this thesis.

### *Anas/Mergus*

The *Mergus* clusters in the bi-plot and ratio plots for the scapula measurements overlap with the *Anas* clusters even more than the genera discussed above meaning that it is impossible to rule out *Mergus* if an unknown bone plots in the overlap area (Figures 4.337-4.339). It is only possible to rule this genus out if a bone plots at the extremities of the *Anas* clusters.

### *Anas/Somateria*

The overlap in the clusters of *Anas* and *Somateria* scapula measurements is less than the genera discussed above, but there is still an overlap meaning that it is not possible to distinguish between them if an unknown bone plots in the overlap area of scatter plots (Figures 4.340-4.342). As 100% of the *Somateria* scapulae were case 2 for the Scapmd characteristic, it means that any case 1 scapula could not have come from a bird belong to *Somateria* (Figure 4.343).

### *Anas/Tadorna*

As with *Somateria*, the overlap between *Anas* and *Tadorna* is relatively little meaning that there is a good chance that a positive identification can be made if an unknown bone does not plot in the overlap area of the scatter plots (Figures 4.344-4.346). However, unlike

*Somateria*, there is no morphological characteristic that can be used to reliably separate the scapulae of these two genera.

#### *Aythya/Bucephala*

The size ranges of *Aythya* and *Bucephala* overlap for both measurements on the scapula so no single measurement can be used for identification purposes. However, the bi-plot and ratio plots show that there is a good degree of separation meaning that often a positive identification can be made (Figures 4.347-4.349). There is no morphological characteristic that can be used to distinguish between these genera.

#### *Aythya/Clangula*

These two genera have very similar scapulae in terms of size and shape and so it is difficult to separate them. There is a significant amount of overlap in their clusters in the bi-plot and ratio plots meaning that it is not possible to distinguish between them if an unknown bone plots in the overlap areas (Figures 4.350-4.352). Although not completely reliable, the Scapmds characteristic may be useful for identification purposes as around 80% of *Aythya* scapulae were case 1 and around 90% of *Clangula* scapulae were case 2 (Figure 4.353).

#### *Aythya/Melanitta*

Although there is some overlap in terms of their overall size, these genera separate out well in the bi-plot and particularly in the ratio plots with very little overlap (Figures 4.354-4.356).

### *Aythya/Mergus*

*Aythya* and *Mergus* scapulae plot on different regression lines on the bi-plot and generally plot in different areas in the ratio plots (Figures 4.357-4.359). There is some overlap, but a positive identification can be made in most cases. There is no morphological characteristic that can be reliably used to distinguish between the scapulae of these genera.

### *Aythya/Somateria*

There is no overlap in either measurement assessed in this thesis and so these genera can be separated using a single measurement (Figures 4.360-4.361).

### *Aythya/Tadorna*

There is no overlap in the size ranges of the ranges of these two genera for the Scapdic measurement meaning that it can be used in isolation to distinguish between these genera (Figure 4.362-4.363). As you cannot make a bi-plot or ratio plot without this measurement for the scapula, there is no need to plot them to distinguish between these genera.

### *Bucephala/Clangula*

*Bucephala* and *Clangula* scapulae are very similar in both size and shape meaning that it is difficult to separate them. Although they generally plot in different areas of the graph for the bi-plot and ratio plots, it is not possible to distinguish between them if an unknown plots in the overlap area (Figures 4.364-4.366). There is no morphological characteristic that can be reliably used to distinguish between these genera.

### *Bucephala/Melanitta*

The scapulae of these genera can be separated out reasonably well using a bi-plot, and to some extent using the ratio plots, albeit with some overlap (Figures 4.367-4.369). There is no morphological characteristic that can be used to reliably distinguish between them.

### *Bucephala/Mergus*

There is a significant amount of overlap in the clusters of these two genera when the measurements of their scapulae are plotted meaning that it is very difficult to identify an unknown bone unless it plots at the extremities of the clusters (Figures 4.370-4.372). There is no reliable morphological characteristic for distinguishing between these genera.

### *Bucephala/Somateria*

There is no overlap in the ranges of *Bucephala* and *Somateria* for either measurement taken for the scapula meaning that both measurements can be used in isolation for identification purposes (Figures 4.373-4.374).

### *Bucephala/Tadorna*

There is very little overlap in the size ranges of these genera meaning that in some cases a single measurement can be used to make an identification (Figures 4.375-4.376). If that does not work then the bi-plot or ratio plots can be used (Figures 4.377-4.378).

### *Clangula/Melanitta*

*Clangula* and *Melanitta* scapulae plot with very little overlap in the bi-plot and ratio plots meaning they can be separated out with a high degree of confidence (Figures 4.379-4.381).

### *Clangula/Mergus*

The bi-plot is not useful separating these genera as their size ranges overlap significantly (unless an unknown bone plots in the extremities and not in the overlap area) (Figure 4.382). However, the ratio plots show that they separate out relatively well with little overlap (Figures 4.383-4.384).

### *Clangula/Somateria*

There is no overlap in the size ranges either of the measurements of the scapula for these genera so both measurements can be used in isolation for identification purposes (Figures 4.385-4.386).

### *Clangula/Tadorna*

There is a small amount of overlap in the size ranges of *Clangula* and *Tadorna* scapulae, but in most cases they can be distinguished using a single measurement (Figures 4.387-4.388). The bi-plot and the ratio plots can also be used for any scapula that plots in the overlap area (Figures 4.389-4.390).

### *Melanitta/Mergus*

The size ranges of the scapulae of these genera almost completely overlap meaning it is difficult to separate them (Figures 4.391-393). The range of *Mergus* scapulae start at a smaller size so it is possible to separate these genera if an unknown bone plots in that area, but not in the overlap area of the bi-plot and ratio plots. There is no morphological character that can be used to reliably differentiate between the scapulae of these genera.

### Melanitta/Somateria

There is very little overlap between the clusters of these genera in the bi-plot and ratio plots meaning that an unknown bone can be reliably identified in most cases (Figures 4.394-4.396).

### Melanitta/Tadorna

These genera can be separated using ratio plots with only a small amount of overlap in their clusters, but the bi-plot is not particularly useful for identification as there is too much overlap (Figures 4.397-4.398).

### Mergus/Somateria

There is almost no overlap in the clusters of these genera in the bi-plot and ratio plots meaning it is very unlikely that an unknown bone would be incorrectly identified (Figures 4.399-4.401).

### Mergus/Tadorna

*Mergus* and *Tadorna* scapulae plot on different regression lines on the bi-plot and in separate clusters on the ratio plot meaning these genera can be distinguished in most cases (Figures 4.402-4.404).

### Somateria/Tadorna

*Somateria* and *Tadorna* scapulae plot in completely different areas of the bi-plot and ratio plots meaning they can be differentiated with a high degree of confidence (Figures 4.405-4.407).

## Species

### *Anas acuta/Anas clypeata*

There is no overlap in the Scapgl ranges of these species meaning this measurement can be used in isolation to distinguish between them (Figure 4.408). There is some overlap in the Scapdic measurement but the bi-plot and ratio plots separate these species out reliably (Figures 4.409-4.411).

### *Anas acuta/Anas crecca*

There is no overlap in the size ranges of *Anas acuta* and *Anas crecca* scapulae so both measurements can be used in isolation to distinguish between them (Figures 4.412-4.413).

### *Anas acuta/Anas penelope*

*Anas acuta* scapulae tend to be larger than *Anas penelope* scapulae so their clusters do separate out to some extent in the bi-plot and ratio plots (Figures 4.414-4.416). However, there is a certain amount of overlap so it is not possible to identify a bone that plots in the overlap areas of these plots.

### *Anas acuta/Anas platyrhynchos* (wild and domestic form)

These species plot in different areas of the graph for the bi-plot and ratio plots meaning that it is unlikely that an unknown bone is incorrectly identified (Figures 4.417-4.419). *Anas platyrhynchos* tend to have longer Scapdic relative to the Scapgl than *Anas acuta*, which means that they can be separated on more than just size.

*Anas acuta/Anas querquedula*

Both measurements on the scapula can be used in isolation for separating these species as there is no overlap in their size ranges (Figures 4.420-4.421).

*Anas acuta/Anas strepera*

There is very little difference in the size and shape of the scapulae of these species. There is some separation in the ratio plots but there is a large degree of overlap in the clusters of these species (Figures 4.422-4.424). Unless an unknown bone plots in the extremities of the clusters, it is not possible to say which of these two species it belongs to.

*Anas clypeata/Anas crecca*

There is no overlap in the ranges of these species for the Scapgl measurement so they can be reliably distinguished if that measurement can be taken (Figure 4.425). There is some overlap with the Scapdic measurement, but the bi-plot and ratio plots show that they completely separate out into different areas of the graph (Figures 4.426-4.427).

*Anas clypeata/Anas penelope*

Although there is some overlap in the overall size ranges of the scapulae of these species, they separate out relatively well in the bi-plot and ratio plots (Figures 4.428-4.430). An unknown bone can be identified with confidence if it does not plot in the overlap area of these species' clusters.

*Anas clypeata/Anas platyrhynchos (wild and domestic form)*

Both measurements taken on the scapula can be used in isolation to separate these species as there is no overlap in their size ranges (Figures 4.431-4.432).

*Anas clypeata/Anas querquedula*

There is some overlap in the ranges of the Scapgl measurement for these species, but the bi-plot and ratio plots show that they cluster in different parts of the graph (Figures 4.433-4.435). However, it is worth pointing out that the sample size for *Anas querquedula* is small and it is not clear how much variation there is within that species. It may be that the size range is larger than observed here and overlaps more with *Anas clypeata*. This is something that needs further investigation in the future.

*Anas clypeata/Anas strepera*

There is no overlap in the ranges of both measurements of the scapula for these two species and so both measurements can be used in isolation to make a reliable identification of an unknown bone (Figures 4.436-4.437).

*Anas crecca/Anas penelope*

*Anas crecca* scapulae are considerably smaller than *Anas penelope* scapulae and there is no overlap in their size ranges. This means that both measurements of the scapula can be used in isolation to make a reliable distinction between these species (Figures 4.438-4.439).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

There is no overlap in the size ranges of the scapulae of these species so either of the measurements will work for differentiating between the two (Figures 4.440-4.441).

*Anas crecca/Anas querquedula*

The size ranges of these two species overlap but they separate reasonably well in the bi-plot and the ratio plots (Figures 4.442-4.444). However, this may not be the case if the

sample size of *Anas querquedula* is increased. As only a small sample is assessed here, it is not possible to say what the full range of *Anas querquedula* is and if it extends more into the range of *Anas crecca*.

*Anas crecca/Anas strepera*

There is no overlap in the size ranges of the scapulae of these two species and both measurements can be used in isolation to distinguish between them (Figures 4.445-4.446).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

Plotting bi-plots and ratio plots show that there is very little overlap in the clusters of these two species and so it is likely that an unknown archaeological could be identified using just the two measurements of the scapula (Figures 4.447-4.449).

*Anas penelope/Anas querquedula*

*Anas penelope* scapulae are significantly larger than *Anas querquedula* scapulae and therefore it is possible to differentiate between these species using a single measurement (Figures 4.450-4.451). As *Anas penelope* is significantly larger, it is unlikely that the small sample size for *Anas querquedula* is an issue here.

*Anas penelope/Anas strepera*

The size range of *Anas strepera* scapulae falls completely within the range of *Anas penelope* and so it is impossible to distinguish between them if an unknown bone plots with the overlap areas on the bi-plot and ratio plots (Figures 4.452-4.453). However, there is a lot more variation in the size of *Anas penelope* and it is possible to rule out *Anas strepera* if an unknown bone plots outside of the overlap area.

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

There is no overlap in the size ranges of the scapulae of these species so they can be differentiated using a single measurement (Figures 4.454-4.455).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

Although there is an overlap in the overall size of these species, their clusters separate out in the bi-plot and ratio plots well so an identification can be made with confidence if both measurements can be taken (Figures 4.456-4.458).

*Anas querquedula*/*Anas strepera*

Both measurements of the scapula can be used in isolation to distinguish between these species as there is no overlap in their size ranges (Figures 4.459-4.460).

*Aythya ferina*/*Aythya fuligula*

There is a significant amount of overlap in the size ranges of these species meaning it is only really possible to make an identification of an unknown bone plots in the extremities of the clusters in the bi-plot and ratio plots (Figures 4.461-4.462).

*Aythya ferina*/*Aythya marila*

These species separate out with no overlap in the bi-plot and ratio plots meaning that an unknown archaeological bone can be identified with confidence (Figures 4.463-464).

*Aythya fuligula/Aythya marila*

As with *Aythya ferina*, there is no overlap in the clusters of *Aythya fuligula* and *Aythya marila* as *Aythya marila* is larger than the other two species and has a longer Scapdic relative to the Scapgl (Figures 4.465-4.466).

*Melanitta fusca/Melanitta nigra*

The scapulae of these two species can be differentiated readily as *Melanitta fusca* is significantly larger than *Melanitta nigra* (Figures 4.467-4.468).

*Mergus albellus/Mergus merganser*

*Mergus albellus* is the smallest of the three *Mergus* species assessed here and the size ranges of their scapulae do not overlap with *Mergus merganser* scapulae. This means single measurements can be used to make a reliable identification (Figures 4.469-4.470).

*Mergus albellus/Mergus serrator*

As with *Mergus merganser*, single measurements can be used to distinguish between *Mergus albellus* and *Mergus serrator* (Figures 4.471-4.472).

*Mergus merganser/Mergus serrator*

The size ranges of the scapulae of these species overlap, but *Mergus merganser* tends to be larger. An unknown archaeological bone can be identified as long as it does not plot in the overlap area of the bi-plot and ratio plots (Figures 4.473-4.474).

**Wild compared to domestic (*Anas platyrhynchos*)**

There is very little overlap in the bi-plot and ratio plots of modern wild and domestic *Anas platyrhynchos* scapulae meaning they can be distinguished reliably if both measurements can be taken (Figures 4.475-4.476).

## **Humerus**

### **Genus**

#### **Anas/Aythya**

The size range of *Anas* humeri encompasses the ranges of all other genera meaning that it is not possible to differentiate them from any other genus using a single measurement. *Anas* and *Aythya* humeri can be separated using two measurements in bi-plots and ratio plots with little or no overlap in their clusters (Figures 4.477-4.481). Discriminant function analysis can also be used to reliably differentiate between these genera if an unknown archaeological bone plots in the overlap area of the ratio plots (Figure 4.482).

#### **Anas/Bucephala**

The size range of *Bucephala* humeri falls completely within that of *Anas* so it is not possible to separate these genera using a single measurement, or a bi-plot, if an unknown bone plots in the overlap area. Figures 4.483-4.486 show the range of *Bucephala* compared to *Anas*. Ratio plots can be useful, but there is still a degree of overlap (Figures 4.487-4.489). If an unknown bone plots in the overlap areas of the bi-plots and ratio plots then discriminant function analysis is needed to make an identification (Figure 4.490).

#### **Anas/Clangula**

*Clangula* humeri have much less variation in their size and shape than *Anas* humeri and form concise clusters in bi-plots and ratio plots. Even though there is sometimes a large amount of overlap between the bi-plots and ratio plots, the tight clusters for *Clangula* mean that *Clangula* can be ruled out if an unknown bone plots outside of those clusters (Figures 4.491-4.496). *Anas* and *Clangula* humeri differ in shape the most at the distal end, as evidenced by the ratio plots (Figures 4.497-4.498). Discriminant function analysis can be

used if an unknown bone continuously plots in the overlap areas of the bi-plots and ratio plots and enough measurements can be taken on the bone (Figure 4.499).

#### *Anas/Melanitta*

These genera can be separated with little, or no, overlap in bi-plots and ratio plots without the need for discriminant function analysis (Figures 4.500-4.505). *Anas* humeri have thicker shafts relative to the rest of the bone compared to *Melanitta* so plotting the Humsc (or a ratio involving this measurement) with any other measurement can usually differentiate between the genera. As this is a measurement that can often be taken, even when one end of the bone is missing, it is a particularly useful measurement to take.

#### *Anas/Mergus*

Although there is some overlap, the humeri of these genera can largely be distinguished using bi-plots and ratio plots (Figures 4.506-4.509). However, it may be necessary to use discriminant function analysis which can classify these genera with a high degree of accuracy (Figure 4.510).

#### *Anas/Somateria*

*Somateria* humeri overlap in size with the larger *Anas* humeri so it is not possible differentiate between them using a single measurement. However, there are a number of bi-plots and ratio plots that can be used to reliably separate them (Figures 4.511-4.516). It is not necessary to take the identification process further and use discriminant function analysis to classify an unknown bone, especially if the bone is complete.

### Anas/Tadorna

Like *Somateria*, the size range of *Tadorna* humeri overlap in size with *Anas* humeri but can be separated using bi-plots and ratio plots without the need for discriminant function analysis (Figures 4.517-4.522).

### Aythya/Bucephala

The humeri of these genera are very similar in size and shape and their size ranges are almost identical for some of the measurements for the humerus. However, they plot on different regression lines for some bi-plots and in different areas in some ratio plots, albeit with some overlap (Figures 4.523-4.528). If an unknown bone plots in an overlap area then discriminant function analysis can be used, but it is not as accurate a method as for other duck genera distinctions (Figure 4.529).

### Aythya/Clangula

*Clangula* humeri tend to be smaller than *Aythya* humeri and can be separated by plotting two measurements, or ratios of measurements, with little or no overlap (Figures 4.530-4.536).

### Aythya/Melanitta

There is some overlap in the bi-plots and ratio plots of the humeri of these genera, but a positive identification can be made if an unknown bone does not plot in the overlap areas (Figures 4.537-4.542). If an unknown bone does, then discriminant function analysis can be used to make a reliable identification, provided enough measurements can be taken on the bone (Figure 4.543).

### *Aythya/Mergus*

The size ranges of *Aythya* humeri measurements fall completely within the size ranges of the *Mergus* humeri meaning it is not possible to distinguish them using a single measurement. There is a significant amount of overlap in the clusters of these genera in bi-plots, but it is possible to make an identification if an unknown bone plots outside of the overlap area (Figures 4.544-4.546). A ratio plot can be helpful for *Aythya/Mergus* humerus distinctions, even then there is a certain amount of overlap (Figures 4.547). Discriminant function analysis may be necessary to classify an unknown bone (Figure 4.548).

### *Aythya/Somateria*

There is no overlap in the size ranges of the humeri of these genera for many measurements so it is possible to distinguish between them using a single measurement in most cases (Figures 4.549-4.554).

### *Aythya/Tadorna*

As with *Somateria*, there is no overlap in the size ranges of the humeri of *Aythya* and *Tadorna* meaning that a single measurement is often sufficient to separate these two genera (Figures 4.555-4.560).

### *Bucephala/Clangula*

*Bucephala* and *Clangula* humeri overlap considerably in terms of overall size, but separate out well in bi-plots and ratio plots due to the differences in their shapes, particularly at the distal end of the humerus (Figures 4.561-4.565).

### *Bucephala/Melanitta*

There is little overlap in the ranges of some measurements for the humeri of these genera meaning that they can be differentiated using a simple bi-plot (Figures 4.566-4.571).

### *Bucephala/Mergus*

Although there is some overlap, *Bucephala* plots between the two *Mergus* clusters in bi-plots and to some extent separates out in ratio plots (Figures 4.572-4.576). Discriminant function analysis can help with identification, but is perhaps not as reliable as for other genera distinctions (Figure 4.578). The Hummel morphological characteristic may aid in identification as just under 90% of *Bucephala* humeri are case 2 and around 90% of *Mergus* humeri are case 1 (Figure 4.577).

### *Bucephala/Somateria*

There is no overlap in the size ranges of these two genera for many measurements of the humerus meaning that most measurements can be used in isolation to identify an unknown bone (Figures 4.579-585).

### *Bucephala/Tadorna*

*Bucephala* humeri are generally much smaller than *Tadorna* humeri and so in most cases a single measurement can be used to distinguish between the two genera (Figures 4.586-590).

### *Clangula/Melanitta*

There are several measurements of the humerus that the size ranges of *Clangula* and *Melanitta* do not overlap so they can be separated reliably using a single measurement

(Figures 4.591-4.594). However, they also separate out well in bi-plots without the need to plot ratios or use discriminant function analysis (Figures 4.595-4.596).

#### *Clangula/Mergus*

There is some overlap in the size ranges of these genera, particularly due to the smaller *Mergus* individuals, but *Clangula* plots between the *Mergus* clusters in bi-plots and they separate out with a small amount of overlap in ratio plots (Figures 4.597-4.602).

Discriminant function analysis is necessary for any unknown bones that plot in the overlap areas of the bi-plot and ratio plots, but is relatively reliable in this instance (Figure 4.603).

#### *Clangula/Somateria*

There is no overlap in the size ranges of all the measurements of the humerus for *Clangula* and *Somateria* meaning any measurement can be used in isolation to differentiate these genera (Figures 4.604-4.609).

#### *Clangula/Tadorna*

For most measurements, there is no overlap in the size ranges of *Clangula* and *Tadorna* humeri so there are a number of options to use a single measurement to separate these genera (Figures 4.610-4.615).

#### *Melanitta/Mergus*

*Melanitta* and *Mergus* humeri overlap in their size ranges almost completely for most measurements. Therefore, it is necessary to use bi-plots and ratio plots to separate them, even if there is some overlap (Figures 4.616-4.619). The Hummcl morphological characteristic can

also be useful for identifications as just under 90% of *Mergus humeri* are case 1 and around 95% of *Melanitta* are case 2 (Figure 4.620).

#### *Melanitta/Somateria*

These genera can be separated with bi-plots and ratio plots with little, or no, overlap in their clusters (Figures 4.622-4.626).

#### *Melanitta/Tadorna*

*Melanitta/Tadorna* distinctions are very similar to *Melanitta/Somateria* distinctions, although there is generally more overlap in their clusters on the scatter plots (Figures 4.627-4.631).

#### *Mergus/Somateria*

There is little, or no, overlap in the clusters of these genera in some bi-plots and ratio plots meaning identifications can be made without having to use discriminant function analysis (Figures 4.632-4.636).

#### *Mergus/Tadorna*

Similar to *Somateria*, there is very little overlap in the clusters of *Tadorna* and *Mergus* plots in some bi-plots and ratio plots meaning that an identification can be made without the need for discriminant function analysis (Figures 4.637-4.640). Hummcl can also be used for identification purposes as 100% of *Tadorna humeri* were case 2 and just under 90% of *Mergus humeri* were case 1 meaning this is a particularly accurate method of distinguishing these genera (Figure 4.640).

### Somateria/Tadorna

These genera overlap considerably in terms of overall size, but can be readily differentiated using bi-plots and a number of ratio plots meaning that a reliable identification can be made for an unknown bone that falls within their size ranges (Figures 4.642-4.646).

### **Species**

#### Anas acuta/Anas clypeata

There is no overlap in the size ranges of the humerus for a number of measurements for these species meaning that a number of single measurements can be used in isolation to make an identification (Figures 4.647-4.652).

#### Anas acuta/Anas crecca

*Anas acuta* humeri are considerably larger than *Anas crecca* humeri meaning that all measurements can be used in isolation to separate these species (Figures 4.653-4.658).

#### Anas acuta/Anas penelope

*Anas acuta* is generally larger than *Anas penelope* but most measurements' ranges overlap meaning that it is necessary to use bi-plots to distinguish between these species (Figures 4.659-4.660). There is little overlap in the clusters of these species in the bi-plots, but if an unknown bone plots in the overlap areas then discriminant function analysis can be used to make a reliable classification (Figure 4.661).

#### Anas acuta/Anas platyrhynchos (wild and domestic form)

The larger *Anas acuta* overlap in size with the smaller *Anas platyrhynchos* meaning it is not possible to distinguish them using a single measurement in most cases. Bi-plots of

measurements show the overlap area of these two species and it is possible to identify a bone if it does not plot in the overlap areas (Figures 4.662-4.663). Discriminant function analysis can be used to identify an unknown that plots in the overlap areas of the bi-plots discussed above (Figure 4.664).

#### *Anas acuta/Anas querquedula*

There is no overlap in the size ranges of the humeri of these species meaning that all measurements can be used in isolation to distinguish between them (Figures 4.665-4.670).

#### *Anas acuta/Anas strepera*

The humeri of these species are very similar in both size and shape meaning it is difficult to separate them. An unknown bone can only be identified if it plots in the extremes of the clusters in bi-plots, and not in the overlap areas (Figures 4.671-4.672). No significant result was obtained from a discriminant function analysis and so the only way to separate the humeri of these species is in the previously mentioned bi-plots.

#### *Anas clypeata/Anas crecca*

*Anas clypeata* and *Anas crecca* do not overlap in their size ranges for many measurements of the humerus meaning that these species can be separated using a single measurement in most cases (Figures 4.674-4.679).

#### *Anas clypeata/Anas penelope*

*Anas clypeata* humeri are generally smaller than *Anas penelope* humeri and so these species can be separated in bi-plots with little or no overlap in their clusters (Figures 4.680-4.684).

*Anas clypeata/Anas platyrhynchos* (wild and domestic form)

There is no overlap in the size ranges of humeri of these species meaning that a single measurement can be used to make an identification on most cases (Figures 4.686-4.691).

*Anas clypeata/Anas querquedula*

*Anas clypeata* humeri are larger than *Anas querquedula* humeri meaning most measurements can be used in isolation to distinguish between these species (Figures 4.692-4.696).

*Anas clypeata/Anas strepera*

There is some overlap in size ranges of the humeri of these species, but there is little or no overlap in their clusters when some measurements are plotted in bi-plots (Figures 4.697-4.702).

*Anas crecca/Anas penelope*

*Anas crecca* is much smaller than *Anas penelope* and so the humeri of these species can be distinguished using a single measurement in isolation in most cases (Figures 4.703-4.708).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

There is no overlap in the size ranges of these species so their humeri can be separated using any of the measurements assessed in this thesis (Figures 4.709-4.714).

*Anas crecca/Anas querquedula*

These two species are more similar to each other in terms of size and shape than they are to any of other *Anas* species. However, bi-plots show that they can be separated with a relatively little amount of overlap in their clusters (Figures 4.715-4.719).

*Anas crecca/Anas strepera*

There is no overlap in the size ranges of the humeri of these species meaning that an unknown bone can be reliably identified using any of the single measurements assessed in this thesis (Figures 4.721-726).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

The humeri of these species can be differentiated using bi-plots with little or no overlaps in their clusters meaning that only two measurements are needed to make an identification in most cases (Figures 4.727-4.731).

*Anas penelope/Anas querquedula*

A single measurement is all that is needed to distinguish between these species in most cases as there are many measurements of the humerus that these two species' size ranges do not overlap (Figures 4.733-4.738).

*Anas penelope/Anas strepera*

The size ranges of these two species' humeri overlap almost entirely for many measurements meaning that it is not possible to identify an unknown bone unless it plots in the extremities of the bi-plot clusters or enough measurements can be taken for a discriminant function analysis (Figures 4.739-4.744).

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

*Anas platyrhynchos* is much larger than *Anas querquedula* and so any other humerus measurements assessed in this thesis can be used in isolation to make a positive identification (Figures 4.744-4.749).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

There is a significant amount of overlap in the size ranges of the humerus for these species meaning that it is not possible to identify an unknown bone using bi-plots if it plots in the overlap area of these species' clusters. Figures 4.750-4.754 show the range of *Anas strepera* and this species can be ruled out if an unknown bone plots in outside of this species' cluster.

*Anas querquedula*/*Anas strepera*

There is no overlap in the size ranges of the humeri of these species and so they can be differentiated using any of single measurements assessed in this thesis (Figures 4.756-4.761).

*Aythya ferina*/*Aythya fuligula*

*Aythya ferina* and *Aythya fuligula* humeri overlap in size but can be separated with relatively little overlap in bi-plots (Figures 4.762-4.766). Discriminant function analysis can be used to reliably classify any archaeological bone that plots in the overlap area of these two species' clusters in the bi-plots discussed above (Figure 4.767).

*Aythya ferina/Aythya marila*

These two species are very similar in terms of their overall size and shape but can be distinguished using the Humdd and Humhcr measurements in a bi-plot (Figure 4.768). Discriminant function analysis can be used to make a positive classification provided that enough measurements can be taken on an archaeological bone (Figure 4.771).

*Aythya fuligula/Aythya marila*

*Aythya fuligula* humeri are considerably smaller than *Aythya marila* humeri meaning that they can be separated by some single measurements and bi-plots with no overlap (Figures 4.772-4.776).

*Melanitta fusca/Melanitta nigra*

The humeri of these species can be separated with little or no overlap in bi-plots, particularly for the measurements of the distal end of the humerus (Figures 4.777-4.781).

*Mergus albellus/Mergus merganser*

*Mergus albellus* humeri can be distinguished from *Mergus merganser* humeri using any measurement of the humerus in isolation (Figures 4.782-4.787).

*Mergus albellus/Mergus serrator*

Most measurements of the humerus can be used in isolation to separate these species so it is not necessary to use scatter plots to make an identification (Figures 4.788-4.792).

*Mergus merganser/Mergus serrator*

*Mergus merganser* humeri are generally larger than *Mergus serrator* humeri and the two species can be separated with little or no overlap in bi-plots, particularly when the measurements of the distal end of the humerus are plotted (Figures 4.793-4.797).

**Wild compared to domestic (*Anas platyrhynchos*)**

Modern wild *Anas platyrhynchos* and modern domestic *Anas platyrhynchos* humeri differ in both size and shape meaning that they can be differentiated between with a high degree of accuracy. Figures 4.798-4.803 show that there is little overlap between the wild and domestic clusters in bi-plots, and that the proximal end of the humerus is a different shape for both groups as evidenced in the ratio plot. It is unlikely that an unknown bone will plot in the overlap area of the bi-plot, but if it does then discriminant function analysis can be used to accurately classify the unknown bone as wild and domestic *Anas platyrhynchos* humeri separate reliably (Figure 4.804).

## **Ulna**

### **Genus**

#### **Anas/Aythya**

The size ranges of *Anas ulnae* completely encompass *Aythya ulnae*, so a single measurement is not useful for identification purposes. However, the two genera can be separated in bi-plots with no overlap, especially when the Ulngl measurement is used with another measurement (Figure 4.805-4.809). Discriminant function analysis can be used to make an identification (Figure 4.810), but it may be the case that if the Ulngl measurement cannot be taken, then there won't be enough measurements available for a significant discriminant function analysis.

#### **Anas/Bucephala**

There is some separation between the clusters of these genera in bi-plots and ratio plots, but with a significant amount of overlap (Figures 4.811-4.816). These scatter plots show the range of *Bucephala* compared to *Anas*, and if an unknown bone plots outside of this range, it cannot be from *Bucephala*. Discriminant function analysis can be used to reliably classify any bone that plots in the overlap areas of the scatter plots discussed above (Figure 4.817).

#### **Anas/Clangula**

*Anas/Clangula* ulna distinctions are similar to *Anas/Bucephala* ulna distinctions in that there is some separation in their clusters in bi-plots and ratio plots but there are overlaps (Figures 4.818-4.823). If an unknown bone plots in the overlap areas then discriminant function analysis is needed to accurately classify the bone (Figure 4.824).

### *Anas/Melanitta*

These genera can be reliably distinguished using bi-plots with little or no overlap, provided that the UIngl measurement can be taken (Figures 4.825-4.829). Discriminant function analysis can be used to identify an unknown bone if the UIngl measurement cannot be taken, but it does require sufficient measurements to be included to make it reliable (Figure 4.830).

### *Anas/Mergus*

There is some separation between these genera in bi-plots and ratio plots, and it is possible to make an identification if an unknown bone does not plot in the overlap area (Figures 4.831-4.835). However, discriminant function analysis is often necessary in order to make a reliable identification due to the similarity in size and shape between the ulnae of these genera (Figure 4.836).

### *Anas/Somateria*

The size ranges of the ulnae of these genera overlap but they can be distinguished in by plots and ratio plots with little, or no, overlap in their clusters (Figures 4.837-4.842). Discriminant function analysis is a reliable method of identification if it is necessary to take the identification to the last stage of the process (Figure 4.843).

### *Anas/Tadorna*

*Anas/Tadorna* ulnae distinctions are similar to *Anas/Somateria* distinctions for the bi-plots and ratio plots, except that there is a greater distance between the clusters in some cases (Figures 4.844-4.848). Again, discriminant function is a reliable identification option provided that enough measurements can be taken on an unknown bone (Figure 4.849).

### *Aythya/Bucephala*

*Aythya* and *Bucephala* ulnae size ranges overlap for all measurements but can be separated in bi-plots as they plot on different regression lines (Figures 4.850-4.853). Ratio plots also show that these genera have differently shaped ulnae as their clusters plot in different areas of the graph meaning that a reliable identification can be made (Figures 4.854-4.855).

### *Aythya/Clangula*

*Aythya* ulnae tend to have a smaller *Ulnsc* relative to the other measurements of the ulna compared to *Clangula* ulnae and so it is possible to distinguish them using this measurement combined with a number of different measurements in bi-plots (Figures 4.856-4.859). Ratio plots can also be used to reliably separate the ulnae of these genera (Figures 4.860-4.861).

### *Aythya/Melanitta*

*Aythya* ulnae tend to be smaller than *Melanitta* ulnae and the two genera can largely be separated using bi-plots with little overlap (Figures 4.862-4.867). The shape of the ulna for these genera is very similar so discriminant function analysis is needed if an unknown bone plots in the overlap areas of the bi-plots discussed above as they cannot be reliably separated with ratio plots (Figure 4.868).

### *Aythya/Mergus*

The ulnae of these genera plot on different regression lines in some bi-plots and cluster in different areas of the graph in ratio plots meaning that it is not necessary to use discriminant function analysis to make an identification in most cases (Figures 4.869-4.874).

If an unknown bone does plots in the overlap areas of the scatter plots discussed above, then discriminant function analysis works well for identification purposes (Figure 4.875).

#### *Aythya/Somateria*

There is no overlap in the size ranges of these genera for some measurements meaning that single measurements can be used in isolation to make a positive identification without the need for scatter plots and discriminant function analysis (Figures 4.876-4.880).

#### *Aythya/Tadorna*

Single measurements can be used in some cases to separate these genera as *Aythya* and *Tadorna* ulnae size ranges do not overlap for a number of measurements (Figures 4.881-4.884). However, if it is necessary to plot measurements then bi-plots can be used to reliably distinguish the ulnae of these genera (Figures 4.885-4.886).

#### *Bucephala/Clangula*

These genera can be separated with bi-plots and ratio plots, and in some cases their clusters do not overlap meaning that an identification can be made with confidence, provided that these measurements can be taken on an unknown bone (Figures 4.887-4.892).

#### *Bucephala/Melanitta*

*Melanitta* ulnae are generally larger than *Bucephala* ulnae and so the two genera can be reliably differentiated between using bi-plots and ratio plots (Figures 4.893-4.898).

### *Bucephala/Mergus*

Although *Bucephala* ulnae are generally smaller than *Mergus* ulnae, the smaller *Mergus* individuals can be smaller than *Bucephala* for some measurements meaning that single measurements cannot be used to reliably identify an unknown archaeological bone. There is a significant amount of overlap between the clusters of these genera in bi-plots and ratio plots and it is only really possible rule out one of them if an unknown bone plots in the extremities of the clusters (Figures 4.899-4.904). Discriminant function analysis can be used to classify an unknown bone, but it is not as reliable a method as it is for distinguishing the ulnae of other genera (Figure 4.905).

### *Bucephala/Somateria*

There are several measurements that the size ranges of these genera do not overlap and so it is possible to make a reliable identification using a single measurement in most cases (Figures 4.906-4.911).

### *Bucephala/Tadorna*

As with *Somateria*, there are a number of measurements that these genera do not overlap in their size ranges and so they can be distinguished using a single measurement in isolation (Figures 4.912-4.917).

### *Clangula/Melanitta*

There is no overlap in the size ranges of these genera for the UIngl measurement meaning they can be reliably separated if this measurement can be taken (Figure 4.918). Bi-plots can be used to confidently differentiate between the ulnae of these genera if the UIngl cannot be taken (Figures 4.919-4.922).

### *Clangula/Mergus*

The smaller *Mergus* ulnae overlap in size with *Clangula* ulnae, but they can be separated in bi-plots and ratio plots, albeit with some overlap between the clusters (Figures 4.923-4.928). Discriminant function analysis can be used to reliably separate these genera, provided that enough measurements can be taken on an unknown archaeological bone (Figure 4.929).

### *Clangula/Somateria*

*Clangula* ulnae are much smaller than *Somateria* ulnae and so almost any measurement of the ulna can be used in isolation to separate these genera (Figures 4.930-4.935).

### *Clangula/Tadorna*

Bi-plots can be used to distinguish between these genera, but in most cases this will not be necessary as there are a number of measurements of the ulna for which these genera do not overlap in their size ranges (Figures 4.936-4.941).

### *Melanitta/Mergus*

Although these genera overlap in terms of overall size, they can be reliably separated using bi-plots and ratio plots with little or no overlap in their clusters (Figures 4.942-4.947).

### *Melanitta/Somateria*

The ulnae of these genera can be separated out in bi-plots with little, or no, overlap in their clusters, particularly for the distal end of the bone (Figures 4.948-4.952).

### Melanitta/Tadorna

Like *Melanitta/Somateria* distinctions, *Melanitta* and *Tadorna* can be distinguished using bi-plots, although there is more overlap of their clusters for some measurements (Figures 4.953-4.956). Ratio plots can be used to identify any unknown bone that plots in the overlap areas of the bi-plots discussed above (Figures 4.957-4.958).

### Mergus/Somateria

There is no overlap in the size range of the Ulngl measurement for these genera meaning that this can be used on its own to make a reliable identification if it can be taken (Figure 4.960-4.965). Bi-plots also work for identification purposes if the Ulngl measurement cannot be taken (Figures 4.961-4.965).

### Mergus/Tadorna

As with *Somateria*, *Mergus* ulnae do not overlap in their size range with *Tadorna* ulnae for the Ulngl measurement meaning that this can be used in isolation to make an identification (Figure 4.966). Bi-plots can also be used make an identification but there is more overlap in the clusters for *Mergus/Tadorna* than *Mergus/Somateria* (Figures 4.967-4.971).

### Somateria/Tadorna

The ulnae of these genera are very similar to each other in terms of their size ranges and so it is necessary to plot them on bi-plots and ratio plots to separate them (Figures 4.973-4.978).

## Species

### *Anas acuta/Anas clypeata*

There is no overlap in the size ranges for some measurements of the ulna for these species and so it is possible to distinguish between them using a single measurement in most cases (Figures 4.980-4.985).

### *Anas acuta/Anas crecca*

*Anas crecca* ulnae are significantly smaller than *Anas acuta* ulnae and so they can be differentiated between using any of measurements of the ulna in isolation (Figures 4.986-4.991).

### *Anas acuta/Anas penelope*

The size ranges of the measurements of the ulnae overlap for these species significantly so it is necessary to separate them using bi-plots (Figures 4.992-4.996).

### *Anas acuta/Anas platyrhynchos* (wild and domestic form)

Although there is a significant amount of overlap in the size ranges of the ulnae of these species, *Anas platyrhynchos* tend to be wider relative to their length and so it is possible to separate them in bi-plots (Figures 4.998-4.1002). Discriminant function analysis is a reliable method of classifying an unknown bone if it plots in the overlap area of the bi-plots discussed above (Figure 4.1003).

*Anas acuta/Anas querquedula*

Any measurement of the ulna can be used to differentiate between the ulnae of these species as there is no overlap in their sizes ranges for every measurement (Figures 4.1004-4.1009).

*Anas acuta/Anas strepera*

*Anas acuta* ulnae tend to be larger than *Anas strepera* ulnae and so separate out relatively well in bi-plots, albeit with some overlap in some cases (Figures 4.1010-4.1013).

*Anas clypeata/Anas crecca*

There is no overlap in the size ranges of these species for many measurements of the ulna and so there are number of options for making a reliable identification using a single measurement (Figures 4.1015-4.1020).

*Anas clypeata/Anas penelope*

These species can largely be separated in bi-plots without the need for ratio plots or discriminant function analysis to identify an unknown bone (Figures 4.1021-4.1022).

*Anas clypeata/Anas platyrhynchos (wild and domestic form)*

There is no overlap in the size ranges of these species for a number of measurements of the ulna and so their ulnae can be distinguished using a single measurement in most cases (Figures 4.1026-4.1031).

*Anas clypeata/Anas querquedula*

*Anas querquedula* ulnae are smaller than *Anas clypeata* ulnae and so they can be differentiated between using a single measurement or bi-plots in all cases (Figures 4.1032-4.1036).

*Anas clypeata/Anas strepera*

In some cases a single measurement is all that is required to differentiate between these species, but bi-plots are necessary if only measurements that these species overlap in their size ranges for can be taken (Figures 4.1037-4.1041).

*Anas crecca/Anas penelope*

*Anas crecca* ulnae are much smaller than *Anas penelope* ulnae and so any measurement of the ulna can be used in isolation to distinguish between these species (Figures 4.1042-4.1047).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

There is a great difference in the size of the ulna for these species, with *Anas platyrhynchos* being much larger. This means that any measurement can be used in isolation to rule out one species or another (Figures 4.1048-4.1053).

*Anas crecca/Anas querquedula*

The ulnae of these species are more similar to each other than to another other species in *Anas*. However, *Anas querquedula* is larger and these species can be separated in bi-plots with little or no overlap (Figures 4.1054-4.1058). It is possible that discriminant function

analysis can also be used to make an identification, but as there is a relatively small sample size for *Anas querquedula* and so no reliable result was obtained.

*Anas crecca/Anas strepera*

*Anas crecca* ulnae are much smaller than *Anas strepera* ulnae and it is not possible to make an incorrect identification, even using a single measurement to differentiate between the two species (Figures 4.1060-4.1065).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

There is little overlap in the clusters of these species in bi-plots meaning that only two measurements are required to distinguish between their ulnae in most cases (Figures 4.1066-4.1071).

*Anas penelope/Anas querquedula*

There are a number of measurements for the ulna that these species do not overlap in their size ranges and so they can be separated using a single measurement in isolation (Figures 4.1072-4.1077).

*Anas penelope/Anas strepera*

The ulnae of these species are very similar in both size and shape meaning it is difficult to differentiate between them in bi-plots and ratio plots. It is only possible to rule out a species if an unknown bone does not plot in the overlap areas of their clusters (Figures 4.1078-4.1079). Discriminant function analysis may help in making a classification, but it is not as reliable for these species as it is for other species due to the similarity between them (Figure 4.1081).

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

*Anas platyrhynchos* ulnae are much larger than *Anas querquedula* and so any measurement of the ulna can be used to differentiate between these species in isolation (Figures 4.1082-4.1086).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

There is little or no overlap in the clusters of these species in bi-plots for many measurements of the ulna meaning that an unknown bone can be identified using just two measurements in most cases (Figures 4.1087-4.1091).

*Anas querquedula*/*Anas strepera*

There is no overlap in the size ranges of the ulna for these species and so any measurement can be used in isolation to differentiate between the two (Figures 4.1092-4.1097).

*Aythya ferina*/*Aythya fuligula*

*Aythya ferina* ulnae are larger than *Aythya fuligula* ulnae and these two species can be separated in bi-plots with little or no overlap (Figures 4.1098-4.1102).

*Aythya ferina*/*Aythya marila*

There is a relatively large amount of overlap in the clusters of these species in bi-plots and so there is a high chance of an unknown archaeological bone plotting in these overlap areas. Bi-plots can still be useful if an unknown bone plots at the extremities of the clusters (Figures 4.1103-4.1104), but it is likely that discriminant function analysis is needed to reliably classify an unknown bone (Figure 4.1105).

*Aythya fuligula/Aythya marila*

*Aythya fuligula* ulnae are much smaller than *Aythya marila* ulnae and so there are a number of options for differentiating between them using single measurements (Figures 4.1106-4.1110).

*Melanitta fusca/Melanitta nigra*

The Ulnidid measurement can be used in isolation to distinguish between the ulnae of these species as there is no overlap in their size ranges (Figure 4.1111). These species also separate out relatively well in bi-plots with *Melanitta fusca* ulnae generally being smaller than *Melanitta nigra* ulnae (Figures 4.1112-4.1114).

*Mergus albellus/Mergus merganser*

There is no overlap in the size ranges of the measurements of the ulna for these species and so any single measurement can be used in isolation to differentiate between the two (Figures 4.1115-4.1120).

*Mergus albellus/Mergus serrator*

*Mergus albellus* ulnae are significantly smaller than *Mergus serrator* ulnae and so the two species can be separated using only a single measurement in all cases (Figures 4.1121-4.1125).

*Mergus merganser/Mergus serrator*

The ulnae of these species can be separated with little, or no, overlap in their clusters in bi-plots meaning that only two measurements are required to make an identification in most cases (Figures 4.1126-4.1130).

### **Wild compared to domestic (*Anas platyrhynchos*)**

In many cases modern wild *Anas platyrhynchos* and modern domestic *Anas platyrhynchos* can be distinguished using only two measurements in bi-plots as there is little, or no, overlap in their clusters (Figures 4.1131-4.1134). The shape of the ulna for these taxa are also different as demonstrated in the ratio plots, with the domestic form tending to have wider articular ends relative to the length of the bone compared to the wild form (Figures 4.1136-4.1137). It may be the case that an unknown archaeological bone plots in the overlap areas of the scatter plots discussed above, and if this is the case then discriminant function analysis can be used to reliably classify the bone, provided that enough measurements can be taken on it (Figure 4.1138).

## **Radius**

### **Genus**

#### **Anas/Aythya**

As with the other bones assessed in this thesis, *Anas* radii overlaps in size with the radii of all other genera meaning it is necessary to take the identification process to at least the bi-plot stage. Figures 4.1139-4.1142 show that *Anas* and *Aythya* radii can be separated with little, or no, overlap in bi-plots and ratio plots making a reliable identification possible.

#### **Anas/Bucephala**

The *Bucephala* clusters in bi-plots and ratio plots fall completely within the *Anas* clusters meaning it is not possible to distinguish between these genera if an unknown bone plots within the overlap area. Figures 4.1143-4.1146 show the range of the *Bucephala* clusters and it is possible to rule this genus out if an unknown bone plots outside of this area. As there are only three measurements recorded for the radius, it is not possible to undertake a significant discriminant function analysis and see if the radii of these genera can be correctly classified.

#### **Anas/Clangula**

*Anas/Clangula* radii distinctions are similar to *Anas/Bucephala* radii distinctions in that the *Clangula* clusters all fall within the *Anas* clusters in scatter plots and it is only really possible to rule out *Clangula* if an unknown archaeological bone plots outside of the *Clangula* clusters (Figures 4.1147-4.1150).

### *Anas/Melanitta*

It is possible to differentiate between the radii of these genera in most cases as they plot on different regression lines in bi-plots and in different areas of the graph in ratio plots, albeit with some overlap (Figures 4.1151-4.1154).

### *Anas/Mergus*

It is very difficult to distinguish between the radii of these genera as their size ranges and clusters in scatter plots overlap almost completely. It is only possible to rule out *Mergus* if an unknown bone plots in the extremities of the *Anas* cluster in bi-plots (Figures 4.1155-4.1156).

### *Anas/Somateria*

*Anas* radii are wider in the shaft and at the articular ends relative to the length of the bone compared to *Somateria* radii and so it is possible to differentiate them in bi-plots (Figures 4.1157-4.1158).

### *Anas/Tadorna*

There is little, or no, overlap in the clusters of the radii of these genera in bi-plots meaning that it is possible to make an identification provided that these measurements can be taken (Figures 4.1159-4.1160).

### *Aythya/Bucephala*

The radii of these genera plot on different regression lines in bi-plots making it possible to differentiate them using only two measurements (Figures 4.1161-4.1162).

### *Aythya/Clangula*

*Clangula* radii are much wider at the articular end and in the shaft compared to the greatest length meaning that they plot in the different area of the graph to *Aythya* radii in bi-plots (Figures 4.1163-4.1164).

### *Aythya/Melanitta*

*Aythya* radii are smaller than *Melanitta* radii and so it is possible to distinguish between them in bi-plots with little overlap (Figures 4.1165-4.1166).

### *Aythya/Mergus*

*Mergus* radii are wider in the shaft and articular ends relative to the length compared to *Aythya* radii and so they plot on different regression lines in bi-plots (Figures 4.1167-4.1168).

### *Aythya/Somateria*

There is no overlap in the size ranges of these genera for the Radgl and Radbd measurements meaning that they can be used in isolation to make an identification (Figures 4.1169-4.1170).

### *Aythya/Tadorna*

As with *Somateria*, there is no overlap in the size ranges of the Radgl and Radbd measurements for *Aythya* and *Tadorna* meaning that making an identification is straightforward if one of these measurements can be taken (Figures 4.1171-4.1172).

### *Bucephala/Clangula*

*Clangula* radii are wider at the articular ends relative to the length of the bone compared to *Bucephala* meaning that they plot on different regression lines in bi-plots and in different areas of the graph in ratio plots (Figures 4.1173-4.1176).

### *Bucephala/Melanitta*

Although there is some overlap between the radii of these genera in terms of overall size, they plot in completely different areas of the graph in bi-plots and so it is straightforward to make a distinction between them (Figures 4.1177-4.1178).

### *Bucephala/Mergus*

The *Bucephala* radii clusters in bi-plots fall within the *Mergus* clusters meaning that it is only possible to rule *Bucephala* out if an unknown bone plots outside of the *Bucephala* cluster (Figures 4.1179-4.1180). Ratio plots do not separate these genera.

### *Bucephala/Somateria*

There is no overlap in the size ranges of the radius for these genera meaning that all that is required to differentiate between them is a single measurement (Figures 4.1181-4.1182).

### *Bucephala/Tadorna*

As with *Somateria*, there is no overlap in the size ranges of the radius for these genera making identifications straightforward (Figures 4.1183-4.1184).

### *Clangula/Melanitta*

There is no overlap in the size ranges of *Clangula* and *Melanitta* for the Radgl measurement so the two genera can be separated readily if this measurement can be taken (Figure 4.1185). There is some separation in the clusters of these genera when the Radsc and Radbd measurement are plotted in a bi-plot (Figure 4.1186), but this is not necessary if the Radgl measurement can be taken.

### *Clangula/Mergus*

The size range of *Mergus* radii completely encompasses the range of the *Clangula* radii, but *Clangula* radii are wider at the articular ends relative to the length of the bone meaning that the two genera plot on different regression lines on a bi-plot (Figure 4.1187-4.1188).

### *Clangula/Somateria*

There is no overlap in the size ranges of the radii of these genera for the Radgl and Radbd measurements meaning they can be reliably distinguished if these measurements can be taken (Figures 4.1189-4.1190).

### *Clangula/Tadorna*

As with *Somateria*, there is no overlap the ranges of the Radgl and Radsc measurements for *Clangula* and *Tadorna* allowing for a straightforward separation of these genera (Figures 4.1191-4.1192).

### *Melanitta/Mergus*

There is no overlap in the clusters of these genera in bi-plots meaning their radii can be distinguished readily using only two measurements (Figures 4.1193-4.1194).

### *Melanitta/Somateria*

The radii of these genera separate out in bi-plots, albeit with some overlap of their clusters (Figures 4.1195-4.1196). As it is not possible to undertake a significant discriminant function analysis using only the three measurements assessed in this thesis, it is not possible to identify an unknown bone that plots in the overlap areas of the previously mentioned scatter plots.

### *Melanitta/Tadorna*

*Melanitta/Tadorna* radius distinctions are very similar to *Melanitta/Somateria* radius distinctions in that they can be separated in bi-plots, but with some overlap in their clusters (Figures 4.1197-4.1198).

### *Mergus/Somateria*

There is no overlap in the ranges of these genera for the Radgl measurement, therefore this measurement can be used in isolation to distinguish between these genera (Figure 4.1199). These genera also separate in a bi-plot using the Radsc and Radbd with relatively little overlap (Figure 4.1200).

### Mergus/Tadorna

As with *Somateria*, there is no overlap in the ranges of *Mergus* and *Tadorna* for the Radgl measurement and the two genera separate out relatively well in a bi-plot using the Radsc and Radbd measurements (Figures 4.1201-4.1202).

### Somateria/Tadorna

The radii of these genera are more similar to each other in size and shape than they are to the radii of any other genera and so they are relatively difficult to distinguish. There is some separation in a bi-plot and a ratio plot and it is possible to make an identification if an unknown bone does not plot in the overlap areas of the scatter plots (Figures 4.1203-4.1204).

## **Species**

### Anas acuta/Anas clypeata

There is no overlap in the size ranges of these species for the Radgl and Radbd measurements meaning that they can be reliably separated using a single measurement (Figures 4.1205-4.1206).

### Anas acuta/Anas crecca

*Anas acuta* radii are much larger than *Anas crecca* radii and so there is no overlap in the size ranges of each measurement meaning that any measurement can be used to distinguish between them (Figures 4.1207-4.1208).

*Anas acuta/Anas penelope*

Although there is some overlap between the radii of these species in terms of overall size, they can be differentiated between using bi-plots with little overlap (Figures 4.1209-4.1210).

*Anas acuta/Anas platyrhynchos* (wild and domestic form)

These species can be differentiated between in bi-plots with little, or no, overlap because *Anas platyrhynchos* is wider at the articular ends relative to the length of the bone (Figures 4.1211-4.1212).

*Anas acuta/Anas querquedula*

There is no overlap in the size ranges of the radii of these genera meaning any of the measurements assessed in this thesis can be used in isolation for identification purposes (Figures 4.1213-4.1214).

*Anas acuta/Anas strepera*

These species overlap in overall size but can be separated in bi-plots with little, or no, overlap in their clusters meaning that an identification can be made with confidence (Figures 4.1215-4.1216).

*Anas clypeata/Anas crecca*

There is no overlap in the size ranges of the radii of these species for each measurement meaning they can be distinguished using any measurement in isolation (Figures 4.1217-4.1218).

*Anas clypeata/Anas penelope*

The radii of these species overlap in terms of overall size, but do separate out in a bi-plot and a ratio plot (Figures 4.1219-4.1220). An unknown archaeological bone can be identified to the species level provided that it does not plot in the overlap area of the scatter plots discussed above.

*Anas clypeata/Anas platyrhynchos (wild and domestic form)*

There is no overlap in the size ranges for the radius for these species and so they can be differentiated between using any of the measurements in isolation (Figures 4.1221-4.1222).

*Anas clypeata/Anas querquedula*

*Anas clypeata* radii are larger than *Anas querquedula* radii and the two can be separated in bi-plots with no overlaps (Figures 4.1223-4.1224).

*Anas clypeata/Anas strepera*

There is little, or no, overlaps in the clusters of these species in bi-plots meaning that they can be distinguished using only two measurements (Figures 4.1225-4.1226).

*Anas crecca/Anas penelope*

There is no overlap in the size ranges of the radius for these species for the Radgl and Radbd measurements meaning that an unknown bone can be identified using these measurements in isolation (Figures 4.1227-4.1228).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

*Anas crecca* radii are much smaller than *Anas platyrhynchos* radii and so any measurement can be used in isolation to distinguish between the radii of these species (Figures 4.1229-4.1230).

*Anas crecca/Anas querquedula*

The radii of these species can be separated in bi-plots with little, or no, overlap in their clusters as *Anas crecca* radii are smaller than *Anas querquedula* radii (Figures 4.1231-4.1232).

*Anas crecca/Anas strepera*

There is no overlap in the size ranges of the measurements of the radius for these species and so any measurement can be used in isolation to distinguish them (Figures 4.1233-4.1234).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

These radii of these species separate out in bi-plots, although there is some overlap in their clusters meaning that it is not possible to distinguish between them if an unknown bone plots in the overlap area (Figures 4.1235-4.1236).

*Anas penelope/Anas querquedula*

There is no overlap in the size ranges of the radii of these species for the Radgl and Radbd measurements meaning that they can be distinguished using a single measurement in isolation (Figures 4.1237-4.1238).

*Anas penelope*/*Anas strepera*

The radii of *Anas penelope* and *Anas strepera* are very similar in size and shape meaning that it is difficult to separate in bi-plots and ratio plots. Figures 4.1239-4.1240 show the overlap of the clusters of these species and it is only really possible to rule out a species if it plots in the extremities of the clusters.

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

There is no overlap in the size ranges of the radius for these species meaning any measurement can be used in isolation to distinguish between them (Figures 4.1241-4.1242).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

There is a significant amount of overlap in the clusters of these two species in bi-plots, but it is possible to make an identification for an unknown bone if it does not plot in the overlap areas (Figures 4.1243-4.1244).

*Anas querquedula*/*Anas strepera*

*Anas querquedula* radii are much smaller than *Anas strepera* radii and there is no overlap in the size ranges of each measurement meaning any measurement can be used in isolation to make an identification (Figures 4.1245-4.1246).

*Aythya ferina*/*Aythya fuligula*

*Aythya ferina* radii are larger than *Aythya fuligula* radii and the two species separate out in bi-plots with little, or no, overlap in their clusters (Figures 4.1247-4.1248).

*Aythya ferina/Aythya marila*

The radii of these species are very similar in size and shape and the only difference is that *Aythya marila* radii tend to be larger. Figures 4.1249-4.1250 show the extent of the clusters of these species and it is only possible to make an identification if an unknown bone plots at the extremities of the clusters.

*Aythya fuligula/Aythya marila*

These species can be separated using a single measurement as there is no overlap in their ranges for the Radgl and Radbd measurements (Figures 4.1251-4.1252).

*Melanitta fusca/Melanitta nigra*

There is no overlap in the clusters of these species in bi-plots meaning that a reliable identification can be made using only two measurements (Figures 4.1253-4.1254).

*Mergus albellus/Mergus merganser*

A single measurement is all that is required to distinguish between these species as there is no overlap in their ranges for each measurement (Figures 4.1255-4.1256).

*Mergus albellus/Mergus serrator*

There is no overlap in the size ranges of the measurement of the radius for these species meaning they can be distinguished with confidence using a single measurement (Figures 4.1257-4.1258).

*Mergus merganser/Mergus serrator*

There is some overlap in the size ranges of the radii of these species, but they separate out with no overlap in bi-plots meaning that a reliable identification can be made provided that the require measurements can be taken (Figures 4.1259-4.1260).

**Wild compared to domestic (*Anas platyrhynchos*)**

The modern wild and modern domestic *Anas platyrhynchos* radii can be differentiated between using bi-plots with only a small amount of overlap (Figures 4.1261-4.1263). It is not possible to take an identification further using ratio plots if an unknown bone plots in the overlap area as the clusters of both forms overlap almost completely. However, as the overlap areas of the bi-plots are relatively small, it is unlikely that an unknown bone will plot in that area.

## **Carpometacarpus**

### **Genus**

#### *Anas/Aythya*

The carpometacarpi of these genera overlap in their size ranges and so they cannot be distinguished if an unknown bone plots in the overlap areas of bi-plots and ratio plots, but can be identified if the bone plots outside of the overlap areas (Figures 4.1264-4.1268).

Discriminant function analysis did not produce a reliable result and so an unknown archaeological bone can only be identified using the scatter plots discussed above.

#### *Anas/Bucephala*

The size ranges of *Bucephala* carpometacarpi fall completely within the lower end of the *Anas* ranges. This means that it is not possible to reliably separate them if a bone plots in the overlap area of bi-plots and ratio plots. Figures 4.1270-4.1274 show the extent of the *Bucephala* clusters compared to *Anas* clusters and it is possible to rule out *Bucephala* if an unknown bone plots outside of the overlap area. In this case discriminant function analysis is not a reliable method of distinguishing between the carpometacarpi of these genera.

#### *Anas/Clangula*

It is possible to differentiate between the carpometacarpi of these genera in bi-plots and ratio plots, particularly when the Cmchp measurement is included as *Clangula* carpometacarpi have longer Cmchp measurements relative to the length of the bone (Figures 4.1275-4.1279).

### Anas/Melanitta

The measurements of the proximal end of the carpometacarpus are different relative to each other for *Melanitta* compared to *Anas* and so it is possible to separate them in bi-plots and ratio plots, albeit with some overlap in their clusters (Figures 4.1281-4.1285).

Discriminant function can be used to reliably classify any unknown bone that plots in the overlap areas of the scatter plots discussed above (Figure 4.1286).

### Anas/Mergus

The size ranges of *Mergus* carpometacarpi fall completely within the ranges of *Anas* and so it is difficult to separate them, even when multivariate statistics are used. There are some bi-plots that show that these genera plot on different regression lines, and therefore it is possible to make an identification, but other than that an unknown bone must fall outside of the overlap areas of bi-plots in order for an identification to be made (Figures 4.1287-4.1288).

### Anas/Somateria

*Somateria* carpometacarpi are generally larger than *Anas* carpometacarpi and only the largest *Anas* overlap with *Somateria*, meaning that it is possible to differentiate the two based on size in most cases (Figures 4.1289-4.1292).

### Anas/Tadorna

As with *Somateria*, only the largest *Anas* carpometacarpi overlap with *Tadorna* carpometacarpi and so the two genera can be differentiated between using size alone in many cases (Figures 4.1294-4.1297). The two genera differ in shape at the proximal end with *Anas*

being more robust, and they can be classified using discriminant function analysis (Figures 4.1298-4.1299).

#### *Aythya/Bucephala*

The carpometacarpi of these genera are very similar in size and shape and it is very difficult to separate them in bi-plots and ratio plots. The only way to rule out one of the genera is if an unknown bone does not plot in the overlap area of the scatter plots (Figures 4.1300-4.1301). Discriminant function analysis does not reliably classify the carpometacarpi of these genera meaning that it is not possible to identify an unknown to the genus level if it persistently plots in the overlap areas of the scatter plots discussed above.

#### *Aythya/Clangula*

These genera differ greatly in the shape of the proximal end of the carpometacarpus and so it is possible to reliably distinguish between them using bi-plots and ratio plots, if the relevant measurements can be taken (Figures 4.1302-4.1305).

#### *Aythya/Melanitta*

*Melanitta* carpometacarpi are generally larger than *Aythya* carpometacarpi and so the two genera can usually be separated in bi-plots without the need for multivariate statistics (Figures 4.1306-4.1310).

#### *Aythya/Mergus*

The size ranges of the *Aythya* carpometacarpi measurements fall within the ranges of the *Mergus* carpometacarpi meaning there is a significant amount of overlap in their clusters in bi-plots. An unknown bone can still be identified though if it does not plot in the overlap

are of the scatter plots (Figures 4.1311-4.1314). Discriminant function analysis can be used to make an identification for any bone that persistently plots in the overlap areas, but it is not as reliable as it is for classifying other genera (Figure 4.1315).

#### *Aythya/Somateria*

There is no overlap in the size ranges of the carpometacarpus for a number of measurements for these genera meaning an unknown bone could be identified using a single measurement in most cases (Figures 4.1316-4.1320).

#### *Aythya/Tadorna*

As with *Somateria*, there a number of options for differentiating between *Aythya* and *Tadorna* carpometacarpi using a single measurement in isolation (Figures 4.1321-4.1325).

#### *Bucephala/Clangula*

Bi-plots and ratio plots can be used to reliably differentiate between the carpometacarpi of these genera, particularly when the measurements of the proximal end are plotted (Figures 4.1326-4.1331).

#### *Bucephala/Melanitta*

*Melanitta* carpometacarpi are generally larger than *Bucephala* carpometacarpi and they two genera can be differentiated between using two measurements in bi-plots in most cases (Figures 4.1332-4.1337).

### *Bucephala/Mergus*

The size ranges of the carpometacarpi of these genera overlap, however there is some separation between them in bi-plots and ratio plots meaning an unknown bone can be identified, provided that it does not plot in the overlap area (Figures 4.1338-4.1343).

### *Bucephala/Somateria*

There is no overlap in the size ranges of these genera for a number of measurements of the carpometacarpus meaning they can be reliably distinguished using a single measurement in isolation (Figures 4.1344-4.1348).

### *Bucephala/Tadorna*

*Tadorna* carpometacarpi are much larger than *Bucephala* carpometacarpi and so there is a number of options for differentiating between them using only a single measurement (Figures 4.1349-4.1353).

### *Clangula/Melanitta*

The ranges of these genera do not overlap for the Cmcgl measurement and so can be separated using that alone if it can be taken (Figure 4.1351). These genera also separate out well in bi-plots if Cmcgl measurement cannot be taken (Figures 4.1352-4.1354).

### *Clangula/Mergus*

There is some overlap in the size ranges of these genera for the carpometacarpus, but they can be reliably separated in bi-plots as they differ in their shape, particularly for the proximal end of the bone (Figures 4.1355-4.1359).

### *Clangula/Somateria*

Single measurements can be used in isolation to differentiate between these genera as there is no overlap in their size ranges for the carpometacarpus (Figures 4.1360-4.1362).

### *Clangula/Tadorna*

*Clangula* carpometacarpi are much smaller than *Tadorna* carpometacarpi and so the two genera can be reliably distinguished using almost any single measurement in isolation (Figures 4.1363-4.1365).

### *Melanitta/Mergus*

There is a significant amount of overlap in the size ranges of the carpometacarpi of these genera, and although there is some separation in bi-plots and ratio plots, it is not possible to identify an unknown bone unless it plots outside of the overlap areas (Figures 4.1366-4.1371). Discriminant function analysis can be used to reliably classify any bone that plots in the overlap areas of the scatter plots discussed above (Figure 4.1372).

### *Melanitta/Somateria*

There is only a small amount of overlap in the size ranges of these genera for some measurements of the carpometacarpus and so the two can be distinguished using bi-plots and ratio plots with confidence (Figures 4.1373-4.1378).

### *Melanitta/Tadorna*

There is no overlap in the size ranges of these genera for the Cmc<sub>cbp</sub> measurement meaning this can be used in isolation to distinguish between them if it can be taken on an unknown bone (Figure 4.1379). If the Cmc<sub>cbp</sub> measurement cannot be taken, then there are a

number of options for bi-plots that can be used to reliably differentiate between the two genera (Figures 4.1380-4.1383).

#### *Mergus/Somateria*

*Mergus* and *Somateria* carpometacarpi can be differentiated between using bi-plots with little overlap meaning that an unknown bone can be identified using just two measurements in most cases (Figures 4.1384-4.1388).

#### *Mergus/Tadorna*

The Cmcbp measurement can be used in isolation to tell the difference between the carpometacarpi of these genera, and if that measurement cannot be taken, bi-plots work to reliably differentiate between the two (Figures 4.1389-4.1393).

#### *Somateria/Tadorna*

The carpometacarpi of these two genera are very similar to each other in terms of their overall size, but differ in their shape and so can be separated in bi-plots and ratio plots, particularly for the measurements of the proximal end of the bone (Figures 4.1394-4.1398).

### **Species**

#### *Anas acuta/Anas clypeata*

There are several measurements of the carpometacarpus that the ranges of these species do not overlap for meaning that an unknown bone can be identified using a single measurement in most cases (Figures 4.1399-4.1403).

*Anas acuta/Anas crecca*

*Anas acuta* carpometacarpi are much larger than *Anas crecca* carpometacarpi and so they can be reliably distinguished using a single measurement in isolation (Figures 4.1404-4.1409).

*Anas acuta/Anas penelope*

The carpometacarpi of these species are very similar in size and shape, and although there is some separation in bi-plots, an unknown bone can only be identified using this method if it does not plot in the overlap areas (Figures 4.1410-4.1414).

*Anas acuta/Anas platyrhynchos* (wild and domestic form)

There is some overlap in the clusters of these species in bi-plots, but an unknown archaeological bone can be identified if it plots outside of the overlap area (Figures 4.1415-4.1419).

*Anas acuta/Anas querquedula*

These species can be reliably differentiated between using any of the measurements of the carpometacarpus in isolation (Figures 4.1420-4.1424).

*Anas acuta/Anas strepera*

The carpometacarpi of these two species are more similar to each other in size and shape than to any other *Anas* species meaning they are particularly difficult to distinguish. There is some separation in bi-plots (Figures 4.1425-4.1426), but it is only possible make an identification for an unknown bone if it plots in the extremities of the clusters. Discriminant

function analysis may be a useful tool for classifying these species, but the results were not significant in this assessment, possibly due to sample size.

*Anas clypeata/Anas crecca*

*Anas clypeata* carpometacarpi are much larger than *Anas crecca* carpometacarpi and so there are a number of measurements that can be used in isolation to distinguish between the two species (Figures 4.1427-4.1430).

*Anas clypeata/Anas penelope*

The carpometacarpi of these species can be separated in bi-plots, albeit with some overlap, meaning that in most cases they can be differentiated between using only two measurements (Figures 4.1431-4.1434). Discriminant function analysis can be used to reliably classify any bone that plots in the overlap area of the bi-plots discussed above (Figure 4.1435).

*Anas clypeata/Anas platyrhynchos (wild and domestic form)*

There are a number of measurements of the carpometacarpus for which the size ranges of these species do not overlap and so the two can be differentiated between using single measurements in isolation (Figures 4.1436-4.1440).

*Anas clypeata/Anas querquedula*

*Anas clypeata* carpometacarpi are larger than *Anas querquedula* carpometacarpi and so the two can be distinguished using a number of single measurements without the need for scatter plots and multivariate statistics (Figures 4.1441-4.1444).

*Anas clypeata/Anas strepera*

These species can be readily differentiated between in bi-plots with *Anas strepera* carpometacarpi generally being larger than *Anas clypeata* (Figures 4.1445-4.1448). There is very little overlap in the bi-plots, but if an unknown bone happens to plot in the overlap areas then it can be classified accurately using discriminant function analysis (Figure 4.1449).

*Anas crecca/Anas penelope*

There is no overlap in the size ranges of these species meaning that any measurement of the carpometacarpus can be used in isolation to make a reliable identification (Figures 4.1450-4.1454).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

Any measurement can be used in isolation to differentiate between the carpometacarpi of these species as they are very different sizes (Figures 4.1455-4.1459).

*Anas crecca/Anas querquedula*

*Anas crecca* carpometacarpi and *Anas querquedula* carpometacarpi are more similar to each other in terms of size and shape than they are to any other *Anas* species meaning they can be difficult to differentiate between. Figures 4.1460-4.1464 show that there is some separation between the two in bi-plots and it is possible to make an identification if an unknown bone does not plot in the overlap area. The results of discriminant function analysis were not significant for classifying these species on this occasion, but this may be due to sample size and it is possible that this would be a useful method if the amount of *Anas querquedula* specimens was increased.

*Anas crecca/Anas strepera*

The carpometacarpi of these species are very different in their size ranges and so any measurement can be used in isolation to distinguish between the two (Figures 4.1465-4.1469).

*Anas penelope/Anas platyrhynchos (wild and domestic form)*

These species can be separated out in bi-plots with little overlap meaning that in most cases only two measurements are required to differentiate between their carpometacarpi (Figures 4.1470-4.1474). Discriminant function analysis can be used to reliably classify any unknown bone that plots in the overlap areas of the bi-plots discussed above, provided that enough measurements can be taken on the bone (Figure 4.1475).

*Anas penelope/Anas querquedula*

*Anas penelope* carpometacarpi are much larger than *Anas querquedula* carpometacarpi and so the two can be differentiated between using any measurement of the carpometacarpus in isolation (Figures 4.1476-4.1480).

*Anas penelope/Anas strepera*

The carpometacarpi of these species are very similar in size and shape and it is only really possible to identify an unknown bone it plots in the extremities of the clusters in bi-plots, with *Anas penelope* tending to be smaller than *Anas strepera* (Figures 4.1481-4.1485). Discriminant function analysis may be useful to classify the carpometacarpi of these species, but no significant results were produced in this assessment, possibly due to sample size.

Anas platyrhynchos (wild and domestic form)/Anas querquedula

There is no overlap in the size ranges of the measurements of the carpometacarpus for these species meaning that any measurement can be used in isolation to make an identification (Figures 4.1486-4.1490).

Anas platyrhynchos (wild and domestic form)/Anas strepera

These species separate out well in bi-plots with only a small amount of overlap in their clusters meaning that an identification can be made using only two measurements in most cases (Figures 4.1491-4.1495). Discriminant function analysis can be used to reliably classify any bone that happens to plot in the overlap areas of the bi-plots discussed above (Figure 4.1496).

Anas querquedula/Anas strepera

Any measurement of the carpometacarpus can be used to differentiate between these species as there is no overlap in the size ranges for each measurement assessed in this thesis (Figures 4.1497-4.1501).

Aythya ferina/Aythya fuligula

These species can be separated with little, or no, overlap in bi-plots meaning an unknown archaeological bone can be identified using just two measurements in most cases (Figures 4.1502-4.1506).

Aythya ferina/Aythya marila

There is a lot of overlap in the clusters of these species in bi-plots and ratio plots as their carpometacarpi are very similar in size and shape. It is only really possible to identify

any unknown bone if it plots in the extremities of the clusters of these species (Figures 4.1507-4.1511). Discriminant function analysis can provide a relatively highly accurate way of classify the carpometacarpi of these species if an unknown plots in the bi-plots discussed above (Figure 4.1512).

*Aythya fuligula/Aythya marila*

There is no overlap in the size ranges of the carpometacarpi of these species for a number of measurements providing a number of options for making and identification using a single measurement (Figures 4.1513-4.1517).

*Melanitta fusca/Melanitta nigra*

The carpometacarpi of *Melanitta fusca* and *Melanitta nigra* separate out in bi-plots with little, or no, overlap in their clusters meaning that it is possible to identify an unknown bone using only two measurements in most cases (Figures 4.1518-4.1522).

*Mergus albellus/Mergus merganser*

The size ranges of these species do not overlap for a number of measurements of the carpometacarpus meaning that there are a number of options for identifying an unknown archaeological bone using a single measurement in isolation (Figures 4.1523-4.1527).

*Mergus albellus/Mergus serrator*

*Mergus albellus* carpometacarpi are much smaller than the carpometacarpi of *Mergus serrator* and so it is possible to differentiate between the two species using a single measurement in most cases (Figures 4.1528-4.1532).

*Mergus merganser/Mergus serrator*

Although there is some overlap in their clusters, the carpometacarpi of these species can be differentiated between using bi-plots meaning that only two measurements are needed in most cases (Figures 4.1533-4.1537).

**Wild compared to domestic (*Anas platyrhynchos*)**

Modern wild and domestic carpometacarpi can be separated with little overlap in bi-plots, and to some extent, ratio plots due to the differences in their size and shape (Figures 4.1538-4.1543). This means that it is often possible to make an identification using only two or three measurements. However, if an unknown bone plots in the overlap area of the scatter plots discussed above it is necessary to use discriminant function analysis to make a classification, which can be achieved with a relatively high degree of accuracy (Figure 4.1544).

## **Femur**

### **Genus**

#### **Anas/Aythya**

As with other bones, the size ranges of *Anas* overlap with the size ranges of the other genera and so it is impossible to use a single measurement in isolation for identification purposes. However, *Anas* and *Aythya* can be separated reliably in bi-plots and ratio plots when the Femurcap measurement is included (Figures 4.1545-4.1548). The Femurpop morphological characteristic can also be used to aid with an identification as around 95% of *Anas* femora were case 2 and around 90% of *Aythya* femora were case 1 (Figure 4.1549).

#### **Anas/Bucephala**

As with *Anas/Aythya* distinctions, *Anas* and *Bucephala* femora can be differentiated between in bi-plots and ratio plots, especially if the Femurcap measurement is included (Figures 4.1550-4.1553). 100% of *Bucephala* femora were case 1 for the Femurpop morphological characteristic meaning any femur with a case 2 could not belong to *Bucephala* (Figure 4.1554).

#### **Anas/Clangula**

The femora of these genera can be separated in bi-plots and ratio plots, albeit with some overlap in some cases (Figures 4.1555-4.1558). Although not 100% reliable, the Femurmtr morphological characteristic can also help with an identification as there is a difference between these genera in most cases (Figure 4.1559).

### *Anas/Melanitta*

There is little overlap in the clusters of these genera in some bi-plots and ratio plots meaning that the femora of the two can be differentiated between without the need for multivariate statistics in most cases (Figures 4.1560-4.1565).

### *Anas/Mergus*

*Anas* and *Mergus* femora can be differentiated between in most cases in bi-plots as the two genera plot on different regression lines (Figures 4.1566-4.1569). Ratio plots may be required to identify any bone that plots in the overlaps between the clusters of the two genera in the bi-plots discussed above (Figures 4.1570-4.1571).

### *Anas/Somateria*

*Anas* femora are generally wider in the shaft in relation to length of the bone compared to *Somateria* femora and so the two genera can be separated in bi-plots with little, or no, overlap (Figures 4.1572-4.1576). The Femurpop morphological characteristic can also be used to differentiate between the two genera as around 95% of *Anas* femora were case 2 and over 90% of *Somateria* femora were case 1 (Figure 4.1577).

### *Anas/Tadorna*

The femora of these genera can be separated in some bi-plots and ratio plots, but there is a degree of overlap and it is necessary to use discriminant function analysis to reliably classify them in most cases (Figures 4.1578-4.1584).

### *Aythya/Bucephala*

*Aythya* and *Bucephala* femora are similar in both size and shape, but can be differentiated between using some bi-plots and ratio plots (Figures 4.1585-4.1589).

### *Aythya/Clangula*

*Clangula* femora are generally smaller than *Aythya* femora and so the two can be distinguished using only two measurements in bi-plots in most cases (Figures 4.1590-4.1594). Although it is unlikely that an unknown bone will always plot in the overlap areas of the bi-plots discussed above, discriminant function analysis does reliably classify these genera (Figure 4.1595).

### *Aythya/Melanitta*

There is a difference in size between the femora of these genera and a difference in shape as evidenced by them plotting on different regression lines in bi-plots and plotting in different areas of the graph in ratio plots (Figures 4.1595-4.1600).

### *Aythya/Mergus*

The femora of these genera can be differentiated between using bi-plots in most cases, with the *Aythya* cluster plotting between the two *Mergus* clusters (Figures 4.1601-4.1605).

### *Aythya/Somateria*

There is no overlap in the size ranges of these genera for a number of measurements of the femur meaning that a single measurement is all that is required in order to make a reliable identification (Figures 4.1606-4.1610).

### *Aythya/Tadorna*

*Aythya* femora are generally smaller than *Tadorna* femora and so the two genera can be differentiated in bi-plots without the need for ratio plots or multivariate statistical analysis (Figures 4.1611-4.1615).

### *Bucephala/Clangula*

*Bucephala* femora tend to be larger than *Clangula* femora and the two genera can be differentiated between in bi-plots and a ratio plot, albeit with some overlap (Figures 4.1616-4.1620). The Femurpop morphological characteristic may also be useful for identification purposes as although just under 60% of *Clangula* femora were case 1, 100% of *Bucephala* were case 1 meaning that any case 2 femur cannot be from *Bucephala* (Figure 4.1621).

### *Bucephala/Melanitta*

The femora of these genera separate out with little overlap in bi-plots and ratio plots meaning that in most cases only two or three measurements are required to make an identification (Figures 4.1622-4.1627).

### *Bucephala/Mergus*

*Bucephala* femora tend to plot in between the *Mergus* clusters in bi-plots with little, or no, overlap and so the two can be differentiated using just two measurements in most cases (Figures 4.1628-4.1632).

### *Bucephala/Somateria*

There is no overlap in the size ranges of the femora of these genera for a number of measurements meaning that an identification can be made reliably using only a single measurement (Figures 4.1633-4.1637).

### *Bucephala/Tadorna*

There is no overlap in the size ranges of the femora for these genera for some measurements and these measurements can be used in isolation to make an identification (Figures 4.1638-4.1640). The measurements that there is an overlap for can be also used in bi-plots to separate these genera (Figures 4.1641-4.1642). The Femurpop morphological characteristic is also useful for identification here as 100% of *Bucephala* femora were case 1 and around 90% of *Tadorna* were case 2 (Figure 4.1643).

### *Clangula/Melanitta*

These genera do not overlap in their size ranges for the measurements of the femur meaning that any measurement can be used in isolation to make an identification (Figures 4.1644-4.1649).

### *Clangula/Mergus*

*Clangula* femora only overlap in size with the smallest *Mergus* femora, but do plot on different regression lines for the bi-plots of some measurements meaning that an identification can be made if these measurements can be taken (Figures 4.1650-4.1654). There is some separation in their clusters in ratio plots, but discriminant function analysis is needed to classify any unknown bone that plots in the overlap areas of the scatter plots discussed above (Figure 4.1655).

### *Clangula/Somateria*

*Clangula* femora are much smaller than *Somateria* femora and so any measurement of the femur can be used in isolation to make an identification (Figures 4.1656-4.1660).

### *Clangula/Tadorna*

There is no overlap in the size ranges of the femora of these genera and so any measurement can be used to make a reliable identification without the need for scatter plots or multivariate statistics (Figures 4.1661-4.1665).

### *Melanitta/Mergus*

*Mergus* femora tend to be wider in the shaft and at the articular ends relative to the length of the bone compared to *Melanitta* meaning that the two genera can be differentiated between using bi-plots and ratio plots with the need for multivariate statistics in most cases (Figures 4.1666-4.1670).

### *Melanitta/Somateria*

There is some overlap in the size ranges of the femora of these genera for some measurements, but they can be readily differentiated between in bi-plots (Figures 4.1671-4.1675).

### *Melanitta/Tadorna*

Bi-plots plots can be used to distinguish between the femora of these genera, albeit with some overlap in some cases (Figures 4.1676-4.1680).

### *Mergus/Somateria*

There is no overlap in the size ranges of the femora of these genera for two measurements meaning that a single measurement is all that is needed to make an identification in some cases (Figures 4.1681-4.1682). Bi-plots can be used for the measurements that there is an overlap in the size ranges (Figures 4.1683-4.1685).

### *Mergus/Tadorna*

These genera overlap in terms of overall size for most measurements of the femur, but can be separated out in bi-plots and ratio plots with little, or no, overlap (Figures 4.1686-4.1691).

### *Somateria/Tadorna*

The femora of these genera are similar in size, but can be separated in bi-plots with no overlap (Figures 4.1692-4.1695). The Femurpop morphological characteristic is also useful for identifications as around 90% of *Somateria* femora were case 1 and just under 90% of *Tadorna* femora were case 2 (Figure 4.1696).

## **Species**

### *Anas acuta/Anas clypeata*

There is no overlap in the size ranges of the femora of these species meaning that they can be distinguished using a single measurement in isolation (Figures 4.1697-4.1701).

### *Anas acuta/Anas crecca*

*Anas acuta* femora are much larger than *Anas crecca* femora and so the two species can be differentiated using a single measurement in all cases (Figures 4.1702-4.1707).

*Anas acuta/Anas penelope*

*Anas acuta* femora are generally larger than *Anas penelope* femora and so the two can be separated out in bi-plots, albeit with some overlap (Figures 4.1708-4.1712). Discriminant function analysis is needed to reliably classify any bone that plots in the overlap area of the bi-plots discussed above (Figure 4.1713).

*Anas acuta/Anas platyrhynchos* (wild and domestic form)

There is a small amount of overlap in the clusters of these species in bi-plots, but in most cases the two can be distinguished using only two measurements (Figures 4.1714-4.1718).

*Anas acuta/Anas querquedula*

There is no overlap in size ranges of the femora of these species and so any measurement can be used in isolation to make an identification (Figures 4.1719-4.1723).

*Anas acuta/Anas strepera*

Although there is some separation in the clusters of these genera in bi-plots, it is often necessary to use discriminant function analysis to classify the femora of the two due to the similarity in their size and shape (Figures 4.1724-4.1726).

*Anas clypeata/Anas crecca*

There are some measurements of the femur that these genera do not overlap in their size ranges and so these measurements can be used in isolation to make an identification if they can be taken (Figures 4.1727-4.1731).

*Anas clypeata/Anas penelope*

The femora of these genera can be separated in bi-plots with little, or no, overlap in their clusters meaning that in many cases only two measurements are required to make an identification (Figures 4.1732-4.1736).

*Anas clypeata/Anas platyrhynchos* (wild and domestic form)

There are many measurements of the femur for which these species do not overlap in their size ranges and so the two species can be distinguished reliably using a single measurement in isolation (Figures 4.1737-4.1741).

*Anas clypeata/Anas querquedula*

There are some measurements for which there is no overlap in the size ranges of the femur for these species, but there is a significant amount of overlap for other measurements meaning that they have to be plotted in bi-plots before they can be used to separate the femora of these species (Figures 4.1742-4.1747).

*Anas clypeata/Anas strepera*

*Anas clypeata* femora tend to be smaller than *Anas strepera* femora and so the two can be separated in bi-plots, with only a minimal amount of overlap in most cases (Figures 4.1748-4.1752).

*Anas crecca/Anas penelope*

*Anas crecca* femora are much smaller than *Anas penelope* femora and so the two species can be differentiated using a single measurement (Figures 4.1753-4.1757).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

A single measurement is all that is needed to distinguish between these two species as there is not overlap in their size ranges (Figures 4.1758-4.1762).

*Anas crecca/Anas querquedula*

The femora of these species are very similar in both size and shape and it is only possible to identify an unknown bone if it plots in the extremities of the clusters in bi-plots (Figures 4.1763-4.1767). Discriminant function analysis is not reliable on this occasion as a significant result could not be obtained, possibly, due to sample size for *Anas querquedula*.

*Anas crecca/Anas strepera*

There is no overlap in the size ranges of these species for all measurements of the femur meaning that any measurement can be used in isolation to differentiate between the two (Figures 4.1768-4.1772).

*Anas penelope/Anas platyrhynchos* (wild and domestic form)

There are some measurements of the femur for which there is no overlap in the size ranges of these two species and so an identification can be made on an unknown bone if one of these measurements can be taken (Figures 4.1773-4.1774). The other measurements can be used in bi-plots to separate the femora of the two species reliably (Figures 4.1775-4.1777).

*Anas penelope/Anas querquedula*

Any measurement of the femur can be used in isolation to distinguish between these species as there is no overlap in their size ranges (Figures 4.1778-4.1782).

*Anas penelope*/*Anas strepera*

*Anas penelope* and *Anas strepera* femora are very similar in both size and shape and cannot be reliably separated in bi-plots and ratio plots. Discriminant function analysis may be useful for distinguishing between the femora of these species, but a greater sample size may be needed to make the result significant and it would also require an unknown bone to be sufficiently complete to allow enough measurements to be taken (Figure 4.1783).

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

The femora of these species are very different in size and any measurement can be used in isolation to differentiate between the two species (Figures 4.1784-4.1788).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

There are some measurements of the femur for which these species do not overlap in their size ranges and so these measurements can be used in isolation to separate the two species (Figures 4.1789-4.1791). The other measurements can be used bi-plots to reliably distinguish between the two (Figures 4.1792-4.1793).

*Anas querquedula*/*Anas strepera*

There is no overlap in the size ranges of these species for all measurements of the femur and so the two species can be distinguished readily using any measurement in isolation (Figures 4.1794-4.1798).

*Aythya ferina*/*Aythya fuligula*

*Aythya ferina* and *Aythya fuligula* femora can be separated in bi-plots, albeit with some overlap in their clusters (Figures 4.1799-4.1803). Discriminant function analysis can be

used to identify an unknown bone that plots in the overlap area of the bi-plots discussed above (Figure 4.1804).

*Aythya ferina/Aythya marila*

There are some bi-plots that the femora of these species can be separated in, although with some overlap in the clusters (Figures 4.1805-4.1809). Discriminant function analysis can be used to make a classification in the event of an unknown bone plotting in the overlap areas of the bi-plots discussed above (Figure 4.1810).

*Aythya fuligula/Aythya marila*

There is no overlap in the size ranges of these species for some measurements of the femur and so the two can be differentiated between using a single measurement in most cases (Figures 4.1811-4.1815).

*Melanitta fusca/Melanitta nigra*

The femora of these species overlap considerably in terms of overall size, but differ in their shape as *Melanitta nigra* has a broader proximal articulation relative to the length of the bone and so the two species can be differentiated between in ratio plots (Figures 4.1816-4.1817). Discriminant function analysis can also be used to aid with classifying an unknown bone, provided that enough measurements can be taken on the bone (Figure 4.1818).

*Mergus albellus/Mergus merganser*

A single measurement is all that is needed to reliably differentiate between the femora of these species as *Mergus albellus* are much smaller than *Mergus merganser* (Figures 4.1819-4.1823)

*Mergus albellus/Mergus serrator*

*Mergus serrator* femora are much larger than *Mergus albellus* femora and all of the measurements of the femur can be used in isolation to differentiate between the two species (Figures 4.1824-4.1828).

*Mergus merganser/Mergus serrator*

There is some overlap between these species in terms of overall size, but the two species can be differentiated in bi-plots (Figures 4.1829-4.1833).

**Wild compared to domestic (*Anas platyrhynchos*)**

Modern wild and modern domestic *Anas platyrhynchos* femora can be distinguished in bi-plots in most cases as there is little or no overlap in their clusters (Figures 4.1834-4.1837). The two are also separated in ratio plots as modern domestic femora are broader in the articular ends relative to the length of the bone (Figures 4.1838-4.1839). It is unlikely that an unknown bone cannot be identified using bi-plots and ratio plots, but if this is the case then discriminant function analysis can be used to reliably differentiate between the two (Figure 4.1840).

## **Tibiotarsus**

### **Genus**

#### **Anas/Aythya**

The tibiotarsi of these genera can be separated in bi-plots and ratio plots with little or no overlap (Figures 4.1841-4.1845).

#### **Anas/Bucephala**

Although the size ranges of *Bucephala* tibiotarsi are completely encompassed by the size ranges of *Anas* tibiotarsi, the two genera can be differentiated in by plots and ratio plots with little or no overlap (Figures 4.1846-4.1852).

#### **Anas/Clangula**

The tibiotarsi of these genera can be separated in bi-plots and ratio plots with little, or no overlap, in their clusters (Figures 4.1852-4.1856). The Tbtmcn2 morphological characteristic can also be useful for making an identification as just under 90% of *Anas* tibiotarsi were case 1 and just over 90% of *Clangula* tibiotarsi were case 2 (Figure 4.1857). The Tbtmcn2 characteristic should not be used in isolation but can be used to support an identification made using the scatter plots and discriminant function analysis discussed above.

#### **Anas/Melanitta**

There is no overlap in the clusters of these genera in bi-plots of the measurements of the articular ends of the tibiotarsus meaning that the two can be separated using only two measurements in most cases (Figures 4.1858-4.1862).

### Anas/Mergus

The tibiotarsi of these genera can be distinguished using bi-plots to some degree, but are more readily separated in ratio plots due to the differences in their shape (Figures 4.1863-4.1868). Discriminant function analysis reliably classifies unknown bones, provided that enough measurements can be taken (Figure 4.1869).

### Anas/Somateria

*Somateria* tibiotarsi could only be confused with the very largest *Anas* tibiotarsi in terms of size, but the two genera separate out well in bi-plots and ratio plots due to the differences in their shape (Figures 4.1870-4.1874). The morphological characteristic Tbtmcn2 can also be useful for identification purposes as 100% of *Somateria* tibiotarsi were case 2 and just under 90% of *Anas* tibiotarsi were case 1 meaning that the two genera can be distinguished with a relatively high degree of accuracy if this characteristic is present (Figure 4.1875).

### Anas/Tadorna

*Anas/Tadorna* distinctions are very similar to *Anas/Somateria* distinctions using the measurements in bi-plots and ratio plots, but there is more overlap between their clusters (Figures 4.1876-4.1880).

### Aythya/Bucephala

The tibiotarsi of these genera are very similar in terms of their overall size but can be separated in bi-plots and ratio plots, albeit with some overlap in their clusters in some cases (Figures 4.1881-4.1885).

### *Aythya/Clangula*

There is a lot of overlap between the clusters of these genera in bi-plots and ratio plots and so it is only really possible to identify an unknown bone using these if it plots in the extremities of the clusters (Figures 4.1886-4.1891). Discriminant function analysis may be the only way to reliably classify the tibiotarsi of these genera, provided that enough measurements can be taken on an unknown bone (Figure 4.1892).

### *Aythya/Melanitta*

The tibiotarsi of these genera can be distinguished in most cases using bi-plots and ratio plots, albeit with some overlap in their clusters (Figures 4.1893-4.1898).

### *Aythya/Mergus*

*Aythya* tibiotarsi plot in between the *Mergus* clusters in bi-plots with little, or no, overlap and so they can be distinguished using only two measurements in most cases (Figures 4.1899-4.1903). It is necessary to use discriminant function analysis for any bone that cannot be identified using the scatter plots (Figure 4.1904).

### *Aythya/Somateria*

There is no overlap in the size ranges of the measurements of the tibiotarsus for these genera meaning that the two can be distinguished using any measurement in isolation (Figures 4.1905-4.1909).

### *Aythya/Tadorna*

Some measurements can be used in isolation to differentiate between the tibiotarsi of these genera with no overlap in their ranges (Figures 4.1910-4.1914).

### *Bucephala/Clangula*

There is some separation between the tibiotarsi of these genera in bi-plots, but there is complete separation in some ratio plots meaning that the two can be reliably distinguished if these measurements can be taken (Figures 4.1915-4.1919). The Tbtmcn2 morphological characteristic can be useful for distinguishing between the tibiotarsi of these genera if it is present as 100% of the assessed *Bucephala* tibiotarsi were case 1 and around 90% of the *Clangula* tibiotarsi were case 2 (Figure 4.1920).

### *Bucephala/Melanitta*

There are some measurements of the tibiotarsus for which there is no overlap in the size ranges of *Bucephala* and *Melanitta* and so these measurements can be used in isolation to distinguish them if they can be taken (Figures 4.1921-4.1923). Bi-plots can be used to reliably separate these genera using the measurements that there is an overlap in their size ranges of (Figures 4.1924-4.1925). The Tbtmcn2 morphological characteristic can also be used to make an identification, although not 100% reliable, as 100% of *Bucephala* tibiotarsi were case 1 and just over 80% of *Melanitta* tibiotarsi were case 2 (Figure 4.1926).

### *Bucephala/Mergus*

*Bucephala* tibiotarsi generally plot in the space between the *Mergus* clusters in bi-plots with little, or no, overlap meaning that the two genera can be distinguished using only two measurements in most cases (Figures 4.1927-4.1929). Ratio plots can also be used to differentiate between the genera (Figures 4.1930-4.1931).

### *Bucephala/Somateria*

There is no overlap in the size ranges of the measurements of the tibiotarsus for these genera and so the two can be differentiated using any measurement in isolation (Figures 4.1932-4.1936). Although the tibiotarsi of these genera can be distinguished readily using a single measurement, the Tbtmcn2 morphological characteristic can be reliably used to make an identification as 100% of *Bucephala* tibiotarsi were case 1 and 100% of the *Somateria* tibiotarsi were case 2 (Figure 4.1937).

### *Bucephala/Tadorna*

There are a number of measurements of the tibiotarsus for which there is no overlap in the size ranges of these genera and so they can be distinguished using a single measurement in most cases (Figures 4.1938-4.1942).

### *Clangula/Melanitta*

*Clangula* tibiotarsi are much smaller than *Melanitta* tibiotarsi and so the two can be separated reliably using a single measurement in all cases (Figures 4.1943-4.1947).

### *Clangula/Mergus*

*Clangula* clusters between the *Mergus* clusters in bi-plots (Figures 4.1948-4.1952). The Tbtmcn2 morphological characteristic can also aid with identification as just over 90% of *Clangula* tibiotarsi were case 2 and around 80% of *Mergus* tibiotarsi were case 1 (Figure 4.1953).

### Clangula/Somateria

*Somateria* tibiotarsi are much larger than *Clangula* tibiotarsi and so the two can be reliably separated using any of the measurements in isolation (Figures 4.1954-4.1958). Although *Clangula* and *Somateria* tibiotarsi can be differentiated between easily using a single measurement, it may be useful to know that the Tbtmcn1 morphological characteristic can be used, although it is not 100% reliable. Figure 4.1959 shows that around 95% of *Somateria* tibiotarsi were case 1 and just under 80% of *Clangula* tibiotarsi were case 2.

### Clangula/Tadorna

In most cases a single measurement is all that is needed to differentiate the tibiotarsi of these genera as there are several measurements for which there is no overlap in their size ranges (Figures 4.1960-4.1964). The Tbtmcn2 morphological characteristic can also be useful for differentiating between the tibiotarsi of these genera as 100% of *Tadorna* tibiotarsi were case 1 and around 90% of *Clangula* tibiotarsi were case 2 (Figure 4.1965).

### Melanitta/Mergus

The tibiotarsi of these two genera can be differentiated between in bi-plots and ratio plots using some measurements of the proximal end of the bone, albeit with some overlap (Figures 4.1966-4.1970).

### Melanitta/Somateria

There is no overlap in the size ranges of these genera for the Tbtbpcn measurement meaning that the two can be distinguished using this measurement in isolation if it can be taken (Figure 4.1971). Bi-plots can be used to identify an unknown bone in most other cases (Figures 4.1972-4.1975).

### Melanitta/Tadorna

The tibiotarsi of these two genera can be differentiated between in bi-plots (Figures 4.1976-4.1980). 100% of *Tadorna* tibiotarsi were case 1 for the Tbtmcn2 morphological characteristic and around 80% of *Melanitta* tibiotarsi were case 2 meaning at that this is a useful morphological characteristic to use for identification purposes if it is present on an unknown bone (Figure 4.1981).

### Mergus/Somateria

Due to differences in their shapes, the tibiotarsi of these genera can be reliably separated in bi-plots and ratio plots with no overlap (Figures 4.1982-4.1986). The Tbtmcn2 morphological characteristic can be useful for supporting an identification made using the scatter plots discussed above as 100% of *Somateria* tibiotarsi were case 2 and around 80% of *Mergus* tibiotarsi were case 1 (Figure 4.1987).

### Mergus/Tadorna

*Mergus* and *Tadorna* tibiotarsi can be reliably differentiated between using bi-plots and ratio plots (Figures 4.1988-4.1993).

### Somateria/Tadorna

There are some bi-plots that can be used to reliably differentiate between the tibiotarsi of these genera (Figures 4.1994-4.1998). Tbtmcn2 is the only morphological characteristic that can reliably differentiate between the tibiotarsi of these genera, but if it is present is very reliable as in this study 100% of *Somateria* tibiotarsi were case 2 and 100% of *Tadorna* tibiotarsi were case 1 (Figure 4.1999).

## **Species**

### *Anas acuta/Anas clypeata*

There are some measurements of the tibiotarsus for which there is no overlap in the size ranges of these species meaning that they can be reliably distinguished using a single measurement if they can be taken (Figures 4.2000-4.2004).

### *Anas acuta/Anas crecca*

All measurements of the tibiotarsus can be used in isolation to differentiate between these two species therefore only a single measurement is needed to make an accurate identification (Figures 4.2005-4.2009).

### *Anas acuta/Anas penelope*

Figures 4.2010-4.2014 show that there is some separation between the two species in bi-plots, albeit with a certain amount of overlap in their clusters. Discriminant function analysis may be the only option for classifying the tibiotarsi of these species, provided that enough measurements can be taken on a bone (Figure 4.2015).

### *Anas acuta/Anas platyrhynchos* (wild and domestic form)

There is some separation between the two species in bi-plots, and an unknown bone can be identified if it does not plot in the overlap areas of the clusters of these species (Figures 4.2016-4.2020). The last stage of the identification process is to use discriminant function analysis to classify an unknown archaeological bone, which is reliable provided that enough measurements can be taken on the bone (Figure 4.2021).

*Anas acuta/Anas querquedula*

There is no overlap in the size ranges of the measurements of the tibiotarsus for these species and so any measurement can be used in isolation to make a distinction between the two (Figures 4.2022-4.2025).

*Anas acuta/Anas strepera*

The tibiotarsi of these species are very similar in both size and shape meaning that they are difficult to tell apart. The two do separate to some degree in bi-plots (Figures 4.2026-4.2030), but this is only useful if an unknown bone plots at the extremities of the clusters. Discriminant function analysis may be useful for classifying the tibiotarsi of these species, but a significant result was not obtained in this study. This may be due to sample size, or just because the tibiotarsi of these species are so similar in both size and shape.

*Anas clypeata/Anas crecca*

The tibiotarsi of these species can be separated using a single measurement in most cases as there is no overlap in their size ranges for many measurements (Figures 4.2031-4.2035).

*Anas clypeata/Anas penelope*

*Anas clypeata* tibiotarsi are generally smaller than *Anas penelope* tibiotarsi, and the two species can be separated in bi-plots, albeit with some overlap in their clusters for some cases (Figures 4.2036-4.2040).

*Anas clypeata/Anas platyrhynchos* (wild and domestic form)

With the exception of the measurements of the distal end of the bone, there is no overlap in the size measurements of the tibiotarsus for these species meaning that a single measurement is all that is needed to distinguish between the two in most cases (Figures 4.2041-4.2044). A bi-plot of the Tbtbd and Tbtdd measurements shows that the two species can be separated even if only these two measurements can be taken (Figure 4.2045).

*Anas clypeata/Anas querquedula*

There are a number of measurements of the tibiotarsus for which there is no overlap in the size ranges of these two species meaning that a single measurement is all that is needed to differentiate between them if the measurement can be taken on an unknown archaeological bone (Figures 4.2046-4.2049).

*Anas clypeata/Anas strepera*

The tibiotarsi of these species can generally be separated in bi-plots, but it is necessary to use discriminant function analysis for any bone that plots in the overlap area of bi-plot clusters (Figures 4.2050-4.2054).

*Anas crecca/Anas penelope*

Any of the measurements of the tibiotarsus can be used to differentiate between these species as there is no overlap in their size ranges for all measurements (Figures 4.2055-4.2059).

*Anas crecca*/*Anas platyrhynchos* (wild and domestic form)

*Anas crecca* tibiotarsi are much smaller than *Anas platyrhynchos* tibiotarsi and so the two species can be distinguished using any of the measurements of the tibiotarsus assessed in this thesis (Figures 4.2060-4.2064).

*Anas crecca*/*Anas querquedula*

The tibiotarsi of these species are very similar in both size and shape and so there is only a few bi-plots that show any separation of the two (Figures 4.2065-4.2069). Unfortunately no significant result could be obtained using discriminant function analysis in this study, therefore an unknown bone can only be identified if it plots outside of the overlap areas of the bi-plots discussed above.

*Anas crecca*/*Anas strepera*

There is no overlap in the size ranges of the measurements of the tibiotarsus for these species and so any measurement can be used to make a distinction between the two (Figures 4.2070-4.2074).

*Anas penelope*/*Anas platyrhynchos* (wild and domestic form)

Although there is some overlap between the tibiotarsi of these species in terms of overall size, the two can be separated in bi-plots with little, or no, overlap in their clusters (Figures 4.2075-4.2079).

*Anas penelope/Anas querquedula*

*Anas penelope* tibiotarsi are much larger than *Anas querquedula* and so the two species can be distinguished using any of the single measurements of the tibiotarsus in isolation (Figures 4.2080-4.2084).

*Anas penelope/Anas strepera*

There is some separation between the tibiotarsi of these species in bi-plots, but in some cases it is necessary to the identification to the last stage and classify the bone using discriminant function analysis (Figures 4.2085-4.2088).

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

There is a substantial difference in the size of the tibiotarsi of these species and so they can be differentiated between using a single measurement in all cases (Figures 4.2089-4.2093).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

These two species separate out in bi-plots with little, or no, overlap in their clusters (Figures 4.2094-4.2098).

*Anas querquedula/Anas strepera*

There is no overlap in the size ranges of the tibiotarsi of these two species and so a single measurement is all that is needed to differentiate the two of them (Figures 4.2099-4.2103).

*Aythya ferina/Aythya fuligula*

*Aythya ferina* and *Aythya fuligula* tibiotarsi can be reliably separated in bi-plots meaning that just two measurements are needed to make an identification (Figures 4.2104-4.2108).

*Aythya ferina/Aythya marila*

The tibiotarsi of these species are very similar in both size and shape and so it is difficult to identify an unknown bone using bi-plots unless it plots in the extremities of the clusters in some bi-plots (Figures 2.109-4.2110). Discriminant function analysis can be used to classify an unknown bone with a relatively high degree of accuracy, but it does require many measurements to be taken on a bone for it to work (Figure 4.2111).

*Aythya fuligula/Aythya marila*

There is no overlap in the clusters of these species in bi-plots of the measurements of the tibiotarsus and so the two can be readily differentiated between using only two measurements (Figures 4.2112-4.2116).

*Melanitta fusca/Melanitta nigra*

The tibiotarsi of these two species can be separated in bi-plots with little, or no, overlap in their clusters meaning that in most cases the two can be distinguished using only two measurements (Figures 4.2117-4.2121).

*Mergus albellus/Mergus merganser*

There is no overlap in the size ranges of the tibiotarsus for these species meaning that any measurement can be used in isolation to differentiate between the two (Figures 4.2122-4.2126).

*Mergus albellus/Mergus serrator*

*Mergus albellus* tibiotarsi are much smaller than *Mergus serrator* tibiotarsi and so the two can be reliably distinguished using any of the measurements assessed in this thesis (Figures 4.2127-4.2131).

*Mergus merganser/Mergus serrator*

There is some overlap between these species in terms of overall size for the tibiotarsus, but the two separate out well in bi-plots with little, or no, overlap in their clusters (Figures 4.2132-4.2136).

**Wild compared to domestic (*Anas platyrhynchos*)**

There is little, or no, overlap in the clusters of modern wild and modern domestic *Anas platyrhynchos* tibiotarsi in bi-plots meaning that in most cases the two can be distinguished using only two measurements (Figures 4.2137-4.2140). Not only are modern wild and domestic *Anas platyrhynchos* tibiotarsi different in their sizes, but also shapes as evidenced by the separation of their clusters in ratio plots (Figures 4.2141-4.2142). Discriminant function analysis is not always necessary for identifying an unknown bone, but can be used to reliably classify a bone if needed (Figure 4.2143)

## **Tarsometatarsus**

### **Genus**

#### **Anas/Aythya**

The tarsometatarsi of these genera can be separated in bi-plots and ratio plots due to differences in their shapes (Figures 4.2144-4.2149). *Aythya* tarsometatarsi tend to be wider in the shaft relative to the length of the bone.

#### **Anas/Bucephala**

*Anas/Bucephala* tarsometatarsi distinctions are very similar to *Anas/Aythya* tarsometatarsi distinctions in that the two can be distinguished in bi-plots and ratio plots with little, or no, overlap in their clusters (Figures 4.2150-4.2154).

#### **Anas/Clangula**

Although the size ranges of the *Clangula* tarsometatarsi are completely within the size ranges of *Anas* tarsometatarsi, the two can be differentiated between in bi-plots and ratio plots with little, or no, overlap in their clusters (Figures 4.2155-4.2159). In the event of an unknown bone plotting in the overlap areas of the scatter plots discussed above, it is necessary to use discriminant function analysis to classify the bone (Figure 4.2160).

#### **Anas/Melanitta**

The tarsometatarsi of these genera can be distinguished in some bi-plots and ratio plots (Figures 4.2161-4.2165). The Tmtmhyp1 morphological characteristic may also be useful adding confidence in an identification as around 97% of *Anas* tarsometatarsi were case 1 and just over 80% of *Melanitta* tarsometatarsi were case 2 (Figure 4.2166).

### Anas/Mergus

*Anas* and *Mergus* tarsometatarsi overlap considerably in terms of overall size, but can be separated in ratio plots due to the differences in their shape, albeit with some overlap in their clusters (Figures 4.2167-4.2168). Discriminant function analysis can be used to classify any unknown bone that plots in the overlap areas of the ratio plots discussed above, provided that enough measurements can be taken on the bone (Figure 4.2169).

### Anas/Somateria

The tarsometatarsi of these genera can be separated in bi-plots and ratio plots with little, or no, overlap in their clusters (Figures 4.2170-4.2175).

### Anas/Tadorna

*Tadorna* tarsometatarsi overlap in size with the larger *Anas* tarsometatarsi but the two can be differentiated between in bi-plots, albeit with some overlap in their clusters (Figures 4.2176-4.2177). Discriminant function analysis can also be used to reliably classify the tarsometatarsi of these genera (Figures 4.2178).

### Aythya/Bucephala

The tarsometatarsi of these genera are very similar in both size and shape meaning that it is difficult to separate them in bi-plots and ratio plots. Discriminant function analysis can only be used as an indicator rather than a reliable method of identification as the modern *Aythya* and *Bucephala* were only correctly classified in 78.2% of cases (Figure 4.2179).

### *Aythya/Clangula*

*Aythya* and *Clangula* tarsometatarsi can be differentiated between in bi-plots and ratio plots with little, or no, overlap in their clusters (Figures 4.2180-4.2184).

### *Aythya/Melanitta*

There is little, or no, overlap in the clusters of the tarsometatarsi of these genera meaning that in many cases all that is needed to distinguish them is two measurements (Figures 4.2185-4.2189).

### *Aythya/Mergus*

There are a number bi-plots and ratio plots that show the tarsometatarsi of these genera can be separated with little, or no, overlap in their clusters (Figures 4.2190-4.2195).

### *Aythya/Somateria*

There are some measurements of the tarsometatarsus for which there is no overlap in the size ranges of these two genera meaning at that the two can be readily distinguished if these measurements can be taken (Figures 4.2196-4.2200).

### *Aythya/Tadorna*

A single measurement is all that is needed to differentiate between the tarsometatarsi of these genera as there is no overlap in their size ranges for the measurements of the tarsometatarsus (Figures 4.2201-4.2205).

### *Bucephala/Clangula*

*Bucephala* tarsometatarsi are generally larger than *Clangula* tarsometatarsi and so the two genera can be separated in bi-plots and ratio plots with little, or no, overlap (Figures 4.2206-4.2211).

### *Bucephala/Melanitta*

Although there is some overlap between the tarsometatarsi of these genera in terms of their overall size, the two can be reliably separated in bi-plots with no overlap in their clusters (Figures 4.2212-4.2217).

### *Bucephala/Mergus*

*Bucephala* tarsometatarsi plot between the two *Mergus* clusters in bi-plots and so the two genera can be differentiated between using only two measurements in most cases (Figures 4.2218-4.2223).

### *Bucephala/Somateria*

There is no overlap in the size ranges of the tarsometatarsus for these genera and so any measurement can be used in isolation to distinguish between their genera (Figures 4.2224-4.2228).

### *Bucephala/Tadorna*

*Bucephala* tarsometatarsi are much smaller than *Tadorna* tarsometatarsi and so the two can be separated using any of the measurements of the tarsometatarsus assessed in this thesis without the need for scatter plots or discriminant function analysis (Figures 4.2229-4.2233).

### *Clangula/Melanitta*

A single measurement is all that is needed to reliably differentiate between the tarsometatarsi of these genera as there is no overlap in their size ranges (Figures 4.2234-4.2235).

### *Clangula/Mergus*

Bi-plots can be used to reliably differentiate between the two genera as *Clangula* tarsometatarsi plot between the two *Mergus* clusters with little, or no, overlap (Figures 4.2239-4.2243).

### *Clangula/Somateria*

*Clangula* tarsometatarsi are much smaller than *Somateria* tarsometatarsi and so the two genera can be easily distinguished using any of the measurements assessed in this thesis in isolation (Figures 4.2244-4.2248).

### *Clangula/Tadorna*

A single measurement is all that is needed to separate the tarsometatarsi of these genera as there is no overlap in their size ranges (Figures 4.2249-4.2253).

### *Melanitta/Mergus*

There is a substantial amount of overlap in the size ranges of the tarsometatarsi of these genera, but the two can be separated to some degree in bi-plots and ratio plots as *Melanitta* is generally broader in the articular ends relative to the length of the bone (Figures 4.2254-4.2258). Discriminant function analysis can be used to reliably classify an unknown

bone if it happens to plot in the overlap areas of the scatter plots discussed above, provided that enough measurements can be taken on the unknown bone (Figure 4.2259).

#### *Melanitta/Somateria*

There is some overlap in the size ranges of the tarsometatarsus for these genera and so it is necessary to use bi-plots and ratio plots to determine the correct classification for an unknown bone (Figures 4.2260-4.2264). The Tmthyp1 morphological characteristic can add confidence in any identification if it is present in an unknown bone as around 95% of *Somateria tarsometatarsi* were case 1 and just over 80% of *Melanitta tarsometatarsi* were case 2 (Figure 4.2265)

#### *Melanitta/Tadorna*

The tarsometatarsi of these genera can be separated in bi-plots with little or no overlap in their clusters (Figures 4.2266-4.2270). The Tmtmhyp1 morphological characteristic is useful for identification purposes as just over 95% of *Tadorna tarsometatarsi* were case 1 and just over 80% of *Melanitta tarsometatarsi* were case 2 (Figure 4.2271). Although not 100% accurate, and should not be relied upon in isolation, this morphological criterion can be useful for adding credence to an identification.

#### *Mergus/Somateria*

Although there is an overlap between the tarsometatarsi of these genera in terms of overall size, they two can be separated in bi-plots with little, or no, overlap in their clusters (Figures 4.2272-4.2276).

### Mergus/Tadorna

Bi-plots show that the tarsometatarsi of these genera can be separated using only two measurements in most cases (Figures 4.2277-4.2281).

### Somateria/Tadorna

The tarsometatarsi of these genera are very similar to each other in terms of overall size, but the two can be separated in bi-plots and ratio plots due to the differences in their shape (Figures 4.2282-4.2286). *Tadorna* tarsometatarsi tend to be broader in their articular ends relative to the length of the bone.

## **Species**

### Anas acuta/Anas clypeata

There are some measurements of the tarsometatarsus for which there is no overlap in the size ranges of these two species, meaning that in some cases the two can be distinguished using a single measurement in isolation (Figures 4.2287-4.2291).

### Anas acuta/Anas crecca

*Anas acuta* and *Anas crecca* tarsometatarsi do not overlap in their size ranges so the two species can be reliably distinguished using any of the measurements of the tarsometatarsus in isolation (Figures 4.2292-4.2296).

### Anas acuta/Anas penelope

*Anas acuta* tarsometatarsi are generally larger than *Anas penelope* tarsometatarsi and so the two species can generally be separated in bi-plots, albeit with some overlap (Figures 4.2297-4.2301).

*Anas acuta/Anas platyrhynchos* (wild and domestic form)

Bi-plots show that there is a considerable amount of overlap in the clusters of these species for the measurements of the tarsometatarsus, but if an unknown bone plots outside of the *Anas acuta* cluster and in the larger *Anas platyrhynchos* cluster, then the unknown bone is very unlikely to belong to *Anas acuta* (Figures 4.2302-4.2306). Discriminant function analysis may be a useful tool for classifying the tarsometatarsi of these species, but no significant result was obtained in this study, possibly related to the sample size of *Anas acuta*.

*Anas acuta/Anas querquedula*

There is no overlap in the size ranges of the tarsometatarsi measurements for these species and so the two can be reliably differentiated between using any of the measurements assessed in this thesis in isolation (Figures 4.2307-4.2311).

*Anas acuta/Anas strepera*

*Anas acuta* tarsometatarsi are generally larger than *Anas strepera* tarsometatarsi and there is some separation between the two species in bi-plots, albeit with some overlap in their clusters (Figures 4.2312-4.2316). Discriminant function analysis may be useful for classifying the tarsometatarsi of these species, but in this case no significant result was obtained, possibly due to sample size. Increasing the sample size in future may be beneficial as every bone was correctly classified in this case, even if the result is considered non-significant.

*Anas clypeata/Anas crecca*

There is no overlap in the size ranges of these species for the measurements of the tarsometatarsus assessed in this thesis meaning the two can be reliably distinguished using any measurement in isolation (Figures 4.2317-4.2321).

*Anas clypeata/Anas penelope*

The tarsometatarsi of these species are very similar in size and shape and so cannot easily be differentiated in scatter plots. Figures 4.2322-4.2326 show that an unknown bone can only be identified in bi-plots if it plots in the extremities of the clusters and therefore it is necessary to use discriminant function analysis to classify an unknown bone that plots in the bi-plot overlap areas (Figure 4.2327).

*Anas clypeata/Anas platyrhynchos* (wild and domestic form)

There are some measurements of the tarsometatarsus for which there is no overlap in the size ranges of these species and so the two can be distinguished using any of these single measurements (Figure 4.2328-4.2332).

*Anas clypeata/Anas querquedula*

There is no overlap in the size ranges of these species for the measurements of the tarsometatarsus and so the two species can be distinguished using any of the measurements assessed in this thesis (Figures 4.2333-4.2337).

*Anas clypeata/Anas strepera*

The tarsometatarsi of these species can be separated in bi-plots, albeit with some overlap in their clusters (Figures 4.2338-4.2342). Unfortunately no significant result was

obtained using discriminant function analysis in this thesis, but it may be a very useful tool for classifying the tarsometatarsi of these species in the future if the sample size was increased.

*Anas crecca/Anas penelope*

There is no overlap in the size ranges of these species for the measurements of the tarsometatarsus and so any measurement can be used in isolation to distinguish them (Figures 4.2343-4.2347).

*Anas crecca/Anas platyrhynchos* (wild and domestic form)

*Anas crecca* tarsometatarsi are much smaller than *Anas platyrhynchos* tarsometatarsi and so a single measurement is all that is needed to tell the two apart (Figures 4.2348-4.2352).

*Anas crecca/Anas querquedula*

The tarsometatarsi of these species are very similar in both size and shape meaning it is difficult to differentiate between the two of them. An unknown bone can be identified if it plots at the extremities of the clusters in some bi-plots (Figures 4.2353-4.2357), but it is not possible to identify it if it plots in the overlap area. Discriminant function analysis did not work as a classification tool in this instance, possibly due to sample size.

*Anas crecca/Anas strepera*

A single measurement is all that is needed to distinguish between the tarsometatarsi of these species as their size ranges do not overlap (Figures 4.2358-4.2362).

*Anas penelope*/*Anas platyrhynchos* (wild and domestic form)

There is little, or no, overlap in the clusters of these species in bi-plots meaning that their tarsometatarsi can be distinguished using only two measurements in most cases (Figures 4.2363-4.2367).

*Anas penelope*/*Anas querquedula*

The tarsometatarsi of these species can be distinguished using any of the measurements assessed in this thesis in isolation as there is no overlap in their size ranges (Figures 4.2368-4.2372).

*Anas penelope*/*Anas strepera*

*Anas penelope* and *Anas strepera* tarsometatarsi are very similar to each other in terms of size and shape and so an unknown bone can only be identified if it plots in the extremities of the clusters in bi-plots (Figures 4.2373-4.2374). Ratio plots and discriminant function analysis do not reliably distinguish between the two species.

*Anas platyrhynchos* (wild and domestic form)/*Anas querquedula*

There is no overlap in the size ranges of these two species for the measurements of the tarsometatarsus and so the two can be easily distinguished using any of the measurements assessed in this thesis (Figures 4.2375-4.2378).

*Anas platyrhynchos* (wild and domestic form)/*Anas strepera*

There is little, or no overlap, between the clusters of these species in bi-plots of the measurements of the tarsometatarsus meaning that the two can be distinguished using only two measurements in most cases (Figures 4.2379-4.2383).

*Anas querquedula/Anas strepera*

Any measurement of the tarsometatarsus assessed in this thesis can be used to differentiate between these species as there is no overlap in their size ranges (Figures 4.2384-4.2388).

*Aythya ferina/Aythya fuligula*

*Aythya ferina* and *Aythya fuligula* tarsometatarsi can be separated in bi-plots with little or no overlap in their clusters meaning that an identification can be made using only two measurements in most cases (Figures 4.2389-4.2393).

*Aythya ferina/Aythya marila*

There is almost a complete overlap in the clusters of these species in bi-plots and ratio plots of the measurements of the tarsometatarsus meaning that they cannot be reliably distinguished using scatter plots. Discriminant function analysis is the only way determining whether an archaeological bone belongs to one of these two species (Figures 4.2394).

*Aythya fuligula/Aythya marila*

There is a considerable amount of overlap in the size ranges of these species for some measurements of the tarsometatarsus and so they can only be separated in some bi-plots, and with some overlap in their clusters (Figures). It may be necessary to use discriminant function analysis to classify any bone that plots in the overlap areas of the bi-plots, but it is not as reliable as for making other species classifications (Figure 4.2395-4.2399).

Melanitta fusca/Melanitta nigra

In most cases these species can be distinguished using just two measurements in bi-plots as there is little, or no, overlap in their clusters (Figures 4.2400-4.2404). Discriminant function analysis can be used to reliably classify an unknown bone if happens to plot in the overlap areas of the bi-plots discussed above, provided that enough measurements can be taken on the bone (Figure 4.2405).

Mergus albellus/Mergus merganser

There is no overlap in the size ranges of these species for all measurements of the tarsometatarsus and so these species can be distinguished using any measurement in isolation (Figures 4.2406-4.2410).

Mergus albellus/Mergus serrator

A single measurement is all that is needed to distinguish the tarsometatarsi of these species as there is no overlap in their size ranges (Figures 4.2411-4.2415).

Mergus merganser/Mergus serrator

Although there is some overlap between the tarsometatarsi of these species in terms of overall size, the two can be separated with little overlap in bi-plots meaning an unknown bone can be identified using only two measurements in most cases (Figures 4.2416-4.2420).

**Wild compared to domestic (*Anas platyrhynchos*)**

There is very little overlap in the size ranges of modern domestic and modern wild *Anas platyrhynchos* tarsometatarsi and so the two can be reliably distinguished in bi-plots in most cases (Figures 4.2421-4.2425). Ratio plots do not really sufficiently separate modern

from wild tarsometatarsi, but discriminant function analysis is very reliable, provided that enough measurements can be taken on the bone (Figure 4.2426). None of the morphological characteristics assessed in this thesis showed any reliable differences between the modern wild and domestic *Anas platyrhynchos* tarsometatarsi, indeed there was very little difference in their shape according to the ratio plots and morphological characteristic analysis. Size seems to be the determining factor in differentiating between the tarsometatarsi of the wild and domestic forms.

### **Summary**

*Anas* overlap in size with every other genera and so it is necessary to use bi-plots, ratio plots, and discriminant function analysis to determine whether a bone was from a member of the *Anas* genus or not. The other genera can largely be separated by size, and in many cases a single measurement, or a bi-plot, is all that is needed to make a reliable identification. In some cases it is necessary to use ratio plots and discriminant function analysis for genera that are similar sizes (*e.g. Mergus* and *Melanitta*). There are some differences in morphology that can reliably differentiate between genera (*e.g.* the distal end of the femur in for *Anas* and *Aythya* distinctions), but in most cases it will be necessary to take, and analyse, linear measurements to make an identification.

Species identifications within each genus can usually be achieved using single measurements or bi-plots as the variation in size is usually sufficient to separate them. On occasion, there are some species that are similar in size for some bones (*e.g. Anas acuta* and *Anas penelope* femora), and so it is necessary to use discriminant function analysis to classify the bone. Species within each genus are usually too similar in shape for any morphological characteristic to be useful for identification purposes.

Modern wild and domestic ducks (*Anas platyrhynchos*) can be distinguished by size in bi-plots in most cases with little overlap in their clusters. Some bones show a variation in shape as well, such as for the humerus where wild and domestic ducks plot in different areas of ratio plots. Discriminant function analysis can be used for most bones to classify an unknown archaeological bone as belonging to a wild or domestic individual if the bone plots in the overlap area of previously mentioned bi-plots and ratio plots. If it is the case that domestic ducks were morphologically different to wild ducks in the past as well as the present, then it is possible to reliably identify an archaeological bone using the criteria outlined above.

## **Chapter 5~** **Goose genus and species distinctions**

The structure of this chapter is the same as the previous two in terms of the order in which the bones are discussed in and the order of the classification levels. The figures discussed in the paragraphs below are in appendix 5.

### **Coracoid**

#### **Genus**

##### **Anser/Branta**

In most cases the coracoids of these genera can be separated in bi-plots with little overlap in their clusters (Figures 5.1-5.4). Although these genera can usually be separated using only two measurements, it will be necessary to use discriminant function analysis to differentiate between the larger *Branta* and the smaller *Anser* (Figure 5.5).

#### **Species**

##### **Anser albifrons/Anser anser (wild and domestic form)**

The coracoids of these species can be differentiated reliably in bi-plots as there is no overlap in their clusters (Figures 5.6-5.8). Ratio plots are not useful in this case due to the similarity in their shapes and discriminant function analysis is not necessary if the measurements for the bi-plots can be taken.

##### **Anser albifrons/Anser brachyrhynchus**

The coracoids of these two species are very similar in both size and shape and so it is difficult to differentiate between them. *Anser albifrons* coracoids tend to be smaller than *Anser brachyrhynchus* coracoids and so an identification can be made if a bone plots at the

extremities of the clusters in some bi-plots (Figures 5.9-5.10). Ratio plots are not an effective tool for distinguishing between these species and discriminant function analysis did not produce a significant result, possibly due to sample size or a genuine lack of variability in the morphology of these species.

#### *Anser albifrons*/*Anser fabalis*

*Anser albifrons* coracoids are generally smaller than *Anser fabalis* coracoids and the two species can be separated in bi-plots with little overlap in their clusters (Figures 5.11-5.13). An unknown bone can be identified as long as it does not plot in the overlap area of the bi-plots discussed above. There was too much overlap in the clusters in ratio plots for that to be a useful identification tool, and discriminant function analysis did not produce a significant result on this occasion.

#### *Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

The coracoids of these species can be separated in bi-plots, albeit with some overlap, meaning an unknown archaeological bone can only be identified if it plots outside the overlap areas (Figures 5.14-5.16). Discriminant function analysis can be used to classify an unknown bone if it plots in the overlap areas of the bi-plots discussed above (Figure 5.17). Although this is not 100% reliable, it is much more reliable a method than making an identification by eye.

#### *Anser anser* (wild and domestic form)/*Anser fabalis*

Bi-plots can be used to separate the coracoids of these species in many cases provided that an unknown bone does not plot in the overlap areas of the clusters (Figures 5.18-5.20). Unknown archaeological bones that plot in the overlap areas of the bi-plots discussed above

can be classified using discriminant function analysis, provided that enough measurements can be taken on the bone (Figure 5.21).

*Anser brachyrhynchus/Anser fabalis*

The coracoids of these two species are very similar in both size and shape and an unknown bone can only be identified if plots at the extremities of the clusters in bi-plots (Figures 5.22-5.24). Ratio plots do not show any distinction between these species and discriminant function analysis did not produce a significant result in this case.

*Branta bernicla/Branta leucopsis*

There is no overlap in the size ranges of these species for the Corlm measurement meaning that a reliable identification can be made using this single measurement if it can be taken (Figure 5.25). For the other measurements of the coracoid there is little, or no, overlap in the clusters of these species in bi-plots meaning the two can be readily distinguished using only two measurements (Figures 5.26-5.28). There is no need for ratio plots or discriminant function analysis to be used in this case.

**Wild compared to domestic (*Anser anser*)**

Modern wild and domestic *Anser anser* coracoids overlap in terms of overall size, but can be separated in bi-plots, particularly for the measurements of the distal end of the coracoid (Figures 5.29-5.30). A ratio plot can also be used as an indicator of whether a bone belongs to a wild individual or a domestic individual, albeit with some overlap in their clusters (Figure 5.31). The result of the discriminant function analysis shows that although it is not 100% reliable, it correctly classifies *Anser anser* coracoids as wild or domestic in 91.7% of cases (Figure 5.32).

## **Scapula**

### **Genus**

#### **Anser/Branta**

There are only two measurements of the scapula assessed in this thesis and so there is a limited amount of options for making a distinction between these genera. However, there is little overlap in the clusters of these genera in a bi-plot and a ratio plot meaning that they can be distinguished using the two measurements in most cases (Figures 5.33-5.34). Discriminant function analysis cannot be used to identify any unknown bone that plots in the overlap areas of the scatter plots discussed above as only two measurements of the scapula were taken.

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

*Anser albifrons* scapulae are generally smaller than *Anser anser* and the two species separate out well in a bi-plot and a ratio plot (Figures 5.35-5.36).

#### **Anser albifrons/Anser brachyrhynchus**

The scapulae of these species separate out in a bi-plot and a ratio plot, albeit with some overlap in their clusters (Figures 5.37-5.38). An unknown bone can be identified provided that it does not plot in the overlap areas of the scatter plots discussed above.

#### **Anser albifrons/Anser fabalis**

A bi-plot and a ratio plot show that the scapulae of these two species can be separated with little overlap, meaning that an unknown bone can be identified in most cases provided that the two measurements can be taken (Figures 5.39-5.40).

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

*Anser anser* scapulae are generally larger than *Anser brachyrhynchus* scapulae and so the two species can be separated in a bi-plot and ratio plots, albeit with some overlap in their clusters (Figures 5.41-5.42). An unknown archaeological bone can be identified provided that it does not plot in the overlap area.

*Anser anser* (wild and domestic form)/*Anser fabalis*

The scapulae of these species overlap in size considerably and the range of *Anser fabalis* falls almost completely within the lower end of the *Anser anser*. *Anser fabalis* can be ruled out for the identification if an unknown bone plots outside of its clusters in a bi-plot and a ratio plot, but inside the *Anser anser* clusters (Figures 5.43-5.44).

*Anser brachyrhynchus*/*Anser fabalis*

The scapulae of these species are very similar in both size and shape meaning that it is difficult to distinguish between the two. Only two measurements of the scapula were assessed in this thesis meaning that it is not possible to assess them using discriminant function analysis. It may be possible to rule out a species if an unknown bone plots in the extremities of the clusters in a bi-plot and a ratio plot, and not in the overlap area, as *Anser fabalis* scapulae tend to be a little larger (Figures 5.45-5.46).

*Branta bernicla*/*Branta leucopsis*

There is no overlap in the size ranges of these species for the Scapgl measurement and so the two can be reliably separated if this measurement can be taken on an unknown bone (Figure 5.47). There is some overlap in their ranges for the Scapdic measurement but this only impacts on the identification of the largest *Branta bernicla* and the smallest *Branta*

*leucopsis* meaning that in most cases this measurement can also be used in isolation to make an identification (Figure 5.48).

#### **Wild compared to domestic (*Anser anser*)**

Modern wild and domestic *Anser anser* scapulae can be separated in a bi-plot and a ratio plot, albeit with overlap in their clusters (Figures 5.49-5.50). There are no significant differences in the morphological characteristics of the scapula between the modern wild and domestic *Anser anser*.

## **Humerus**

### **Genus**

#### **Anser/Branta**

There are several measurements of the humerus for which there is very little overlap in the size ranges of these genera meaning that they separate out well in bi-plots (Figures 5.51-5.55). This means that these genera can be distinguished using just two measurements in most cases.

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

The humeri of these species can be separated in bi-plots with little overlap in their clusters (Figures 5.56-5.60). Ratio plots do not separate the two species but discriminant function analysis can be used to classify any unknown bone with a relatively high degree of accuracy, provided that enough measurements can be taken on the bone (Figure 5.61). This suggests that there is little difference in shape between these two species and that size is the key difference.

#### **Anser albifrons/Anser brachyrhynchus**

The humeri of these species are very similar in terms of overall size, but can be separated in some bi-plots, albeit with some overlap in their clusters (Figures 5.62-5.63). Discriminant function analysis may be a useful tool for classifying the humeri of these two species, but no significant result was obtained on this occasion, possibly due to sample size.

*Anser albifrons*/*Anser fabalis*

*Anser albifrons* humeri are generally smaller than *Anser fabalis* humeri and so the two species can be separated in bi-plots with little, or no, overlap in their clusters (Figures 5.65-5.69). A ratio plot shows that not only are the humeri of these two species different sizes, but also different shapes and can generally be distinguished using four measurements in a single plot (Figures 5.70).

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

There is some overlap between the clusters of these species in bi-plots, but an unknown bone can be identified provided that it does not plot in the overlap areas (Figures 5.71-5.74). There is some separation of these species in a ratio plot, but if an unknown bone plots in the overlap areas then discriminant function analysis is needed to classify it (Figures 5.75-5.76).

*Anser anser* (wild and domestic form)/*Anser fabalis*

The size ranges of *Anser fabalis* fall completely within that of *Anser anser*, albeit at their lower ends, *Anser anser* meaning that bi-plots can be used to rule out *Anser fabalis* provided that an unknown bone does not plot in the overlap area (Figures 5.77-5.80). A ratio plot shows differences between these species as the two plot in different areas (Figure 5.81). Discriminant function analysis can be used to classify these two species, but only if enough measurements can be taken on a bone (Figure 5.82).

*Anser brachyrhynchus*/*Anser fabalis*

There is some separation between these species in bi-plots with *Anser fabalis* humeri generally being the larger of the two (Figures 5.83-5.87). Discriminant function analysis

reliably classifies the humeri of these species meaning that a researcher can be confident in an identification, provided that enough measurements can be taken for the analysis (Figure 5.88).

#### *Branta bernicla/Branta leucopsis*

There are a number of measurements of the humerus for which there is no overlap in the size ranges of these species meaning that there are several options for making an identification using only a single measurement (Figures 5.89-5.93).

#### **Wild compared to domestic (*Anser anser*)**

Bi-plots show that even though there is an overlap in their clusters, modern wild and domestic *Anser anser* humeri can be separated relatively well and an unknown bone can be identified provided that it does not plot in the overlap areas (Figures 5.94-5.98). Ratio plots show that there is little difference between the two in terms of overall shape, but discriminant function analysis can classify an *Anser anser* humerus as wild or domestic with a relatively high degree of reliability (Figure 5.99). None of the morphological characteristics of the humerus assessed in this thesis showed significant differences between modern wild and domestic *Anser anser*.

## **Ulna**

### **Genus**

#### **Anser/Branta**

A number of bi-plots show that the ulnae of these genera can be differentiated using only two measurements in most cases (Figures 5.100-5.104).

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

*Anser albifrons* ulnae are generally much smaller than *Anser anser* ulnae and so the two species can be differentiated in most cases using bi-plots (Figures 5.105-5.109).

#### **Anser albifrons/Anser brachyrhynchus**

The ulnae of these two species separate out in bi-plots and ratio plots, albeit with some overlap in their clusters (Figures 5.110-5.114). An unknown bone can be identified as long as it does not plot in the overlap areas of the scatter plots discussed above. Discriminant function analysis can be used to classify the humeri of these species, but only correctly classifies a bone in 80.6% of cases (Figure 5.115).

#### **Anser albifrons/Anser fabalis**

There is little or no overlap in the clusters of these two species in bi-plots of the measurements of the ulna meaning that only two measurements are needed to make an identification in most cases (Figures 5.116-5.120). Ratio plots do not separate the two species and there was no significant result for the discriminant function analysis, possibly due to the small sample size.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

The ulnae of these species can be separated in bi-plots with little or no overlap meaning that the two can be distinguished using only two measurements in most cases (Figures 5.121-5.125). Discriminant function analysis may be a useful tool for classifying the ulnae of these species, but a significant result was not obtained on this occasion, possibly due to the small sample size.

*Anser anser* (wild and domestic form)/*Anser fabalis*

The size ranges of *Anser fabalis* ulnae fall within the ranges of *Anser anser* ulnae and so it is only possible to rule out *Anser fabalis* in bi-plots if an unknown bone plots outside of that cluster (Figures 5.126-5.130). Discriminant function analysis can be used to classify an unknown bone if plots in the overlap areas of the scatter plots discussed above but is only accurate in around 80% of cases (Figure 5.131).

*Anser brachyrhynchus*/*Anser fabalis*

Bi-plots and some ratio plots show that the ulnae of these species can be distinguished based on their size and shape with *Anser fabalis* tending to be the larger of the two (Figures 5.132-5.136). Discriminant function analysis can classify an unknown bone with a relatively high degree of accuracy if it plots in the overlap areas of the scatter plots discussed above (Figure 5.137).

*Branta bernicla*/*Branta leucopsis*

In most cases a single measurement is all that is needed to differentiate between the ulnae of these species, as there are number of measurements for which there is no overlap in their size ranges (Figures 5.138-5.142).

### **Wild compared to domestic (*Anser anser*)**

The ulnae of modern wild and domestic *Anser anser* can be separated in bi-plots with little overlap in their clusters (Figures 5.143-5.145). This means that in most cases that two can be distinguished using only two measurements. Ratio plots show that not only can modern wild and domestic *Anser anser* ulnae be separated by size, but also their shape with the domestic *Anser anser* generally being wider at the articular ends relative to the length of the bone (Figures 5.146-5.147). Discriminant function analysis can correctly classify modern *Anser anser* ulnae as wild or domestic 84.2% of the time meaning that it is a relatively reliable method of identification (Figure 5.148).

## **Radius**

### **Genus**

#### **Anser/Branta**

*Anser* and *Branta* radii can be separated in bi-plots, albeit with some overlap in their clusters (Figures 5.149-5.150). Discriminant function analysis cannot be used to identify any unknown archaeological bone that plots in the overlap areas of the bi-plots as only three measurements of the radius were assessed in this thesis.

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

Bi-plots show that there is little, or no, overlap in the clusters of these two species for the measurements of the radius (Figures 5.151-5.152). Ratio plots do not really show a great deal of separation of these two species and it is not possible to conduct a discriminant function analysis using the three measurements of the radius assessed in this thesis.

#### **Anser albifrons/Anser brachyrhynchus**

Bi-plots show that these two species overlap in size considerably and therefore bi-plots can only be used to identify a bone if it does not plot in the overlap areas of the clusters (Figures 5.153-5.154).

#### **Anser albifrons/Anser fabalis**

Two bi-plots can be used to reliably distinguish between the radii of these species (Figures 5.155-5.156). Ratio plots do not separate *Anser albifrons* and *Anser fabalis* radii, presumably because they are too similar in their overall shapes.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

*Anser anser* and *Anser brachyrhynchus* radii are best distinguished using bi-plots as there is little overlap in their clusters (Figures 5.157-5.158).

*Anser anser* (wild and domestic form)/*Anser fabalis*

The *Anser fabalis* radii plot at the lower end of the range of the *Anser anser* radii, but *Anser fabalis* can be ruled out of the identification if an unknown bone plots outside of the *Anser fabalis* clusters (Figures 5.159-5.160). Ratio plots show that *Anser fabalis* radii tend to plot between the wild and domestic *Anser anser* clusters and so confidence in an identification can be increased when all three measurements of the radius are used in one plot (Figures 5.161-5.162).

*Anser brachyrhynchus*/Anser fabalis

Bi-plots show that the radii of these species can be separated with only a small amount of overlap in their clusters using just two measurements (Figures 5.163-5.164). Ratio plots do not separate these species.

*Branta bernicla*/Branta leucopsis

There is no overlap in the size ranges of these species for the Radgl measurement and so a reliable identification can be made if this measurement can be taken on an unknown archaeological bone (Figure 5.165). The other two measurements can be used in a bi-plot to separate these species with no overlap in their clusters (Figure 5.166).

### **Wild compared to domestic (*Anser anser*)**

Two bi-plots demonstrate that modern wild and domestic *Anser anser* radii can be separated using just two measurements in most cases (Figures 5.167-5.168). Ratio plots show that not only are modern wild and domestic *Anser anser* different in terms of their size, but also their shape with domestic *Anser anser* being broader in their distal articular end relative to the length of the bone and breadth of the shaft (Figures 5.169-5.170).

## **Carpometacarpus**

### **Genus**

#### **Anser/Branta**

The carpometacarpi of these genera can be separated in bi-plots with little overlap meaning that they can be differentiated using only two measurements in most cases (Figures 5.171-5.175).

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

The carpometacarpi of these species can be distinguished in bi-plots with little, or no, overlap in their clusters meaning that an identification can be made using only two measurements in most cases (Figures 5.176-5.180).

#### **Anser albifrons/Anser brachyrhynchus**

The carpometacarpi of these species are very similar in both size and shape meaning that there is not much separation between them in scatter plots. Two bi-plots show some separation and it is only possible to identify an archaeological bone if it plots at the extremity of a cluster (Figures 5.181-5.182). Discriminant function analysis is not useful for classification purposes in this case as no significant result was obtained.

#### **Anser albifrons/Anser fabalis**

*Anser fabalis* carpometacarpi tend to be larger than *Anser albifrons* carpometacarpi and so the two can be separated in bi-plots with little overlap, particularly for plots involving the Cmcddid measurement (Figures 5.183-5.186). Ratio plots do not show much separation of

the two species and discriminant function analysis did not produce a significant result on this occasion, perhaps due to the small sample size.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

Bi-plots can be used to separate the carpometacarpi of these species with little overlap meaning that an unknown bone can be identified using only two measurements in most cases (Figures 5.187-5.191).

*Anser anser* (wild and domestic form)/*Anser fabalis*

The carpometacarpi of these species can be distinguished in bi-plots, albeit with some overlap in their clusters (Figures 5.192-5.196). An unknown archaeological bone can be identified provided it does not plot in the overlap areas of the bi-plots discussed above. Ratio plots cannot be used to reliably differentiate between these species and discriminant function analysis was not useful for classification purposes on this occasion as no significant result was obtained.

*Anser brachyrhynchus*/*Anser fabalis*

Some bi-plots show that there is a difference between the carpometacarpi of these species and it is possible to identify an unknown archaeological bone if it does not plot in the overlap area of the clusters (Figures 5.197-5.200). Ratio plots do not distinguish between these species and discriminant function analysis is not useful here as no significant result was obtained.

*Branta bernicla/Branta leucopsis*

A number of measurements of the carpometacarpus can be used in isolation to differentiate between these species as there is no overlap in their size ranges (Figures 5.201-5.204).

**Wild compared to domestic (*Anser anser*)**

The carpometacarpi of modern wild and domestic *Anser anser* can be distinguished in bi-plots with the domestic form generally being larger, although there is some overlap in their clusters (Figures 5.205-5.206). Ratio plots can also be useful for identifying an unknown archaeological bone as the domestic carpometacarpi tend to be broader in their articular ends relative to the length of the bone, particularly for the distal end (Figures 5.207-5.208).

Discriminant function analysis can be used to classify any bone that plots in the overlap areas of the scatter plots discussed above and correctly classified the modern reference bones in 85.2% of cases (Figure 5.209).

## **Femur**

### **Genus**

#### **Anser/Branta**

*Anser* and *Branta* femora can be readily distinguished in bi-plots with little overlap in their clusters (Figures 5.210-5.214).

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

The femora of *Anser albifrons* are generally much smaller than the femora of *Anser anser* and so the two species can be differentiated in bi-plots with little, or no, overlap in their clusters (Figures 5.215-5.219).

#### **Anser albifrons/Anser brachyrhynchus**

There is some separation of the femora of these species in bi-plots with *Anser albifrons* being the smaller of the two species (Figures 5.220-5.224). An unknown bone can be identified if it does not plot in the overlap areas of the bi-plots mentioned above, but ratio plots and discriminant function analysis cannot be used to reliably classify a bone on this occasion as no significant result was obtained.

#### **Anser albifrons/Anser fabalis**

Bi-plots can be used to distinguish between the femora of these species with little, or no, overlap in their clusters (Figures 5.225-5.229). However, ratio plots cannot be used to separate the two species, and discriminant function analysis did not produce a significant result.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

Only two measurements are needed to differentiate between these species in most bi-plots, albeit with some overlap in their clusters (Figures 5.230-5.234). An unknown bone that plots in the overlap areas of the scatter plots can only be classified using discriminant function analysis (Figure 5.235).

*Anser anser* (wild and domestic form)/*Anser fabalis*

There is a significant amount of overlap in the clusters of these species in bi-plots, but it is still possible to rule out *Anser fabalis* for the identification of an unknown bone if it plots outside that cluster in bi-plots (Figures 5.236-5.240). On this occasion ratio plots were not useful for identification purposes, but discriminant function analysis can be used to classify an unknown bone, provided that enough measurements can be taken (Figure 5.241).

*Anser brachyrhynchus*/*Anser fabalis*

Bi-plots show that there is little overlap in the clusters of these two species and so their femora can be differentiated using only two measurements in most cases (Figures 5.242-5.244).

*Branta bernicla*/*Branta leucopsis*

*Branta leucopsis* femora are generally larger than *Branta bernicla* and as such there is a number of measurements of the femur for which these two species do not overlap in their size ranges (Figures 5.245-5.248).

### **Wild compared to domestic (*Anser anser*)**

In most cases modern wild and domestic *Anser anser* femora can be differentiated using only two measurements as they separate out relatively well in bi-plots (Figures 5.249-5.251). It has previously been suggested that wild and domestic femora can be distinguished due to differences in their shape, with the domestic goose being broad in the articular ends relative to the length (*e.g.* Serjeantson 2002). The potential shape differences between the femora of the two forms described by other authors is demonstrated in figures 5.252-5.253, albeit with some overlap in their clusters. It may be the case that an unknown bone plots in the overlap areas of the scatter plots discussed above and so discriminant function analysis is needed to classify it. Discriminant function analysis correctly classified the modern reference wild and domestic *Anser anser* femora in 87.5% of cases, which, although not completely reliable, it is more reliable than making an identification by eye alone (Figure 5.254).

## **Tibiotarsus**

### **Genus**

#### **Anser/Branta**

There is some overlap between the larger *Branta* and smaller *Anser* tibiotarsi in their overall size, but an unknown bone can be identified using bi-plots in most cases (Figures 5.255-5.259).

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

The tibiotarsi of these species can be separated in bi-plots with little, or no, overlap in their clusters meaning that an identification can be made using just two measurements in most cases (Figures 5.260-5.264).

#### **Anser albifrons/Anser brachyrhynchus**

*Anser albifrons* tibiotarsi and *Anser brachyrhynchus* tibiotarsi are very similar in both size and shape meaning they are difficult to differentiate in bi-plots and ratio plots. Some bi-plots show that it is possible to identify an unknown bone that plots in the extremities of the clusters and not in the overlap areas (Figures 5.265-5.268). Ratio plots do not show any reliable separation between the tibiotarsi of these species and discriminant function analysis did not provide a significant result.

#### **Anser albifrons/Anser fabalis**

*Anser albifrons* tibiotarsi tend to be smaller than *Anser fabalis* tibiotarsi and so the two can be separated in bi-plots, albeit with some overlap in their clusters (Figures 5.269-5.272). An unknown archaeological bone can be identified, provided that it does not plot in

the overlap areas of the bi-plots discussed above, but unfortunately ratio plots do not separate the two species, and no significant result was obtained using discriminant function analysis.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

*Anser anser* tibiotarsi are larger than *Anser brachyrhynchus* tibiotarsi and the two species can be separated in bi-plots with little, or no, overlap in their clusters (Figures 5.273-5.276). An identification can be made in most cases using just two measurements, but an unknown bone that plots in the overlap areas of the bi-plots can only be classified using discriminant function analysis as ratio plots do not separate these species (Figure 5.277).

*Anser anser* (wild and domestic form)/*Anser fabalis*

Bi-plots show that the tibiotarsi of these species can be separated using just two measurements in most cases (Figures 5.278-5.281). An unknown archaeological bone can be identified provided it does not plot in the overlap areas of the bi-plots above. Discriminant function analysis did not produce a significant result on this occasion and so cannot be used to classify an unknown bone.

*Anser brachyrhynchus*/Anser fabalis

An unknown archaeological bone can be identified if it plots in the extremities of the clusters in bi-plots, but it is not possible to make an identification if it plots in the overlap areas (Figures 5.282-5.285). Unfortunately, no significant result was obtained for discriminant function analysis, therefore it cannot be used to classify an unknown bone. This may be due to the small sample size.

*Branta bernicla/Branta leucopsis*

As is the case for most other elements, there is no overlap in the size ranges of these species for a number of measurements meaning that in most cases a single measurement is all that is needed to differentiate between the tibiotarsi of these species (Figures 5.286-5.289).

**Wild compared to domestic (*Anser anser*)**

The tibiotarsi of modern wild and domestic *Anser anser* can be distinguished in bi-plots with little, or no, overlap in their clusters (Figures 5.290-5.292). This means that an identification can be made using only two measurements in most cases. Modern wild and domestic tibiotarsi also differ in their shape. Ratio plots show that the two separate out into different clusters as the domestic *Anser anser* tibiotarsi are broader in the shaft and articular ends relative to the length of the bone (Figures 5.293-5.294). Figure 5.295 shows that discriminant function analysis can be used to classify a tibiotarsus as wild or domestic, but it was necessary to include ratio values as well as measurement values to obtain a significant result.

## **Tarsometatarsus**

### **Genus**

#### **Anser/Branta**

In most cases the tarsometatarsi of these genera can be distinguished using just two measurements in bi-plots as there is little overlap in their clusters (Figures 5.296-5.299). In some cases their differences in shape can be identified and so they can also be separated in ratio plots (Figures 5.300-5.301).

### **Species**

#### **Anser albifrons/Anser anser (wild and domestic form)**

*Anser albifrons* tarsometatarsi and *Anser anser* tarsometatarsi can be separated in bi-plots with only a minimal amount of overlap in their clusters meaning that an identification can be made using only two measurements in most cases (Figures 5.302-5.306).

#### **Anser albifrons/Anser brachyrhynchus**

The tarsometatarsi of these species are very similar in both size and shape meaning that they cannot be distinguished in most scatter plots. Only two bi-plots show any degree of separation and, even then, a species can only be ruled out of if the bone plots in the extremities of one of the clusters (Figures 5.307-5.308). No significant result was obtained for the discriminant function analysis meaning this cannot be used to reliably classify the tarsometatarsi of these species.

#### **Anser albifrons/Anser fabalis**

Bi-plots show that in some cases the tarsometatarsi of these species plot in different areas of the graph, albeit with some overlap in their clusters (Figures 5.309-5.311). An

unknown bone can be identified using just two measurements, as long as it does not plot in the overlap areas. Discriminant function analysis did not produce a significant result for classifying the tarsometatarsi of these two species, possibly due to the small sample size.

*Anser anser* (wild and domestic form)/*Anser brachyrhynchus*

Bi-plots show that there is little, or no, overlap in the clusters of these species meaning that in most cases an identification can be made using just two measurements (Figures 5.312-5.316).

*Anser anser* (wild and domestic form)/*Anser fabalis*

*Anser anser* and *Anser fabalis* tarsometatarsi overlap in terms of size but can generally be separated in bi-plots (Figures 5.317-5.320a). No significant result was obtained for the discriminant function analysis, possibly due to the small sample size.

*Anser brachyrhynchus*/*Anser fabalis*

The tarsometatarsi of these species can be differentiated in some bi-plots as there is little overlap in their clusters, particularly if the measurements of the distal end of the bone are included (Figures 5.320b-5.323). Discriminant function analysis did not produce a significant result and so cannot be used to make a classification.

*Branta bernicla*/*Branta leucopsis*

Most measurements of the tarsometatarsus can be used in isolation to distinguish between these species as there is no overlap in their size ranges (Figures 5.324-5.327). There is no need to use scatter plots or discriminant function analysis to classify these species.

### **Wild compared to domestic (*Anser anser*)**

The tarsometatarsi of modern wild and domestic *Anser anser* can be separated in bi-plots with only a small amount of overlap in their clusters (Figures 5.328-5.332). It may be the case that an unknown archaeological bone plots in the overlap areas of the scatter plots discussed above and it is necessary to take the identification process to the last stage.

Discriminant function analysis can be used to classify an unknown bone as being from a wild or domestic *Anser anser* with a relatively high degree of accuracy, provided that enough measurements can be taken (Figure 5.331).

### **Summary**

*Anser* and *Branta* bones can be differentiated by size alone in most cases, for most bones. This means that for the majority of archaeological bones a single measurement is all that is needed to make a positive, and reliable, identification to at least the genus level.

Within the genus *Anser*, there is a considerable overlap in terms of size for all of the species discussed here. In some cases, and for some bones, species can be distinguished based upon size but often it is necessary to use discriminant function analysis to make a reliable identification (where possible). *Anser* species are far more similar to each other in terms of size and shape than for any other genus discussed in this thesis.

Of the two *Branta* species discussed, there is no need to use scatter plots or discriminant function analysis to make an identification in most cases as there is no overlap in their size ranges for a number of measurements. The two *Branta* species discussed here are often reliably differentiated using a single measurement.

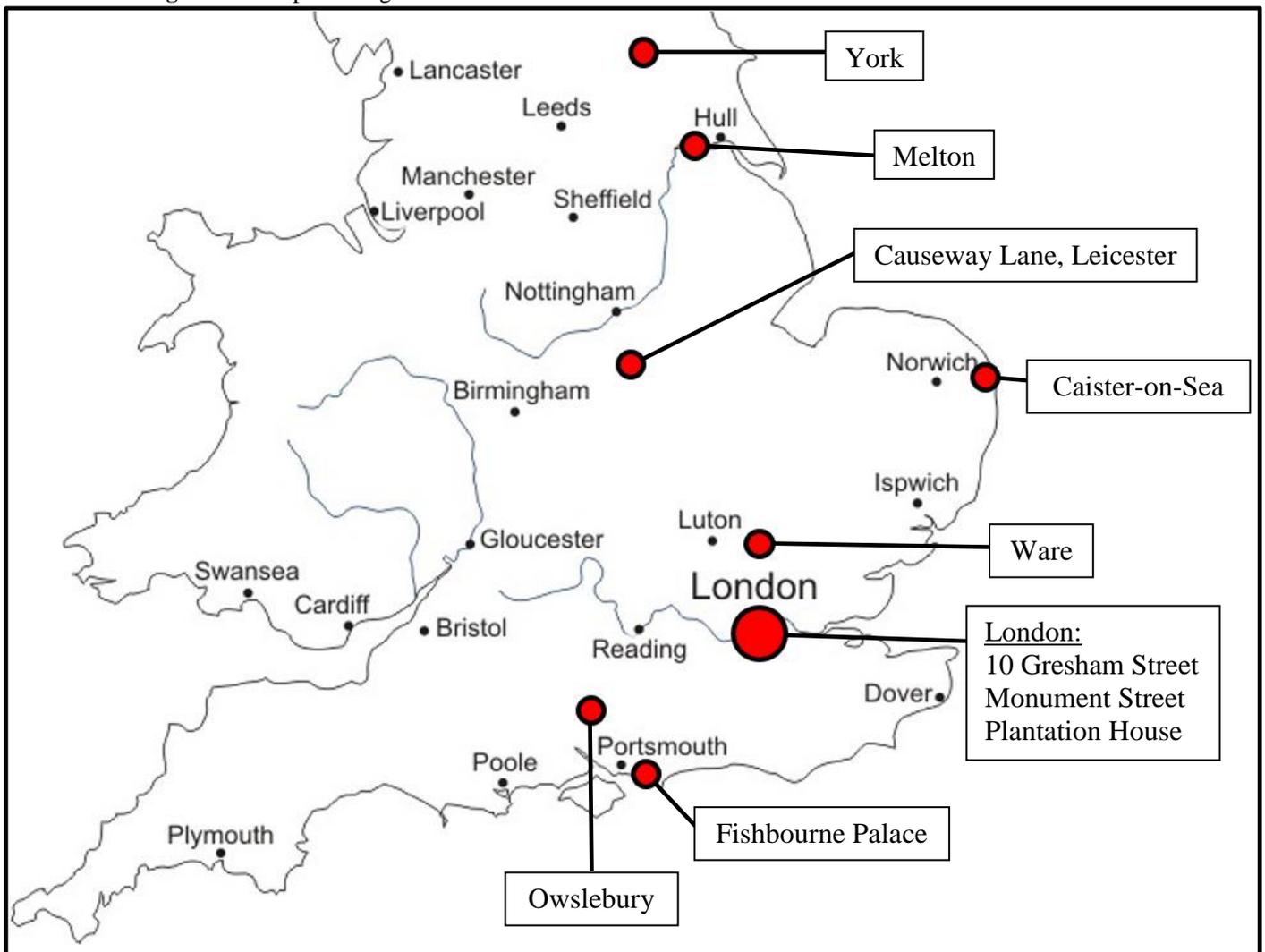
Modern domestic and wild *Anser anser* can usually be differentiated between using size due to the domestic form being much larger than the wild variety in most cases. This does not necessarily mean that the larger archaeological specimens were domesticated (due to

the impossibility of knowing morphological variation in the past), but at the very least shows that there was a variation in the morphology of geese in Britain through time from the Roman period until now. Geese are more difficult to differentiate between than ducks at the species level (particularly *Anser* compared to *Anas*), but that does not mean that geese cannot be differentiated using traditional morphometry. At the very worst, this chapter aids any future researcher with establishing which goose identifications cannot be achieved using traditional morphometrics and which measurements can be relied upon.

## **Chapter 6~** **Sites and assemblages: Background information**

This chapter provides the background information for the assemblages discussed in chapters 7 and 8. The key information is the site location and geographical context, the period of occupation of the sites, previous work on the archaeological material from the sites, and the pertinent research questions to discuss using the zooarchaeological material. Figure 6.1 shows the location of each site within Britain and Table 6.1 lists the sites discussed, their dates of occupation, and site type. The information discussed in this chapter is presented by site alphabetically below.

**Figure 6.1.** Map showing the location of the sites included in this thesis.



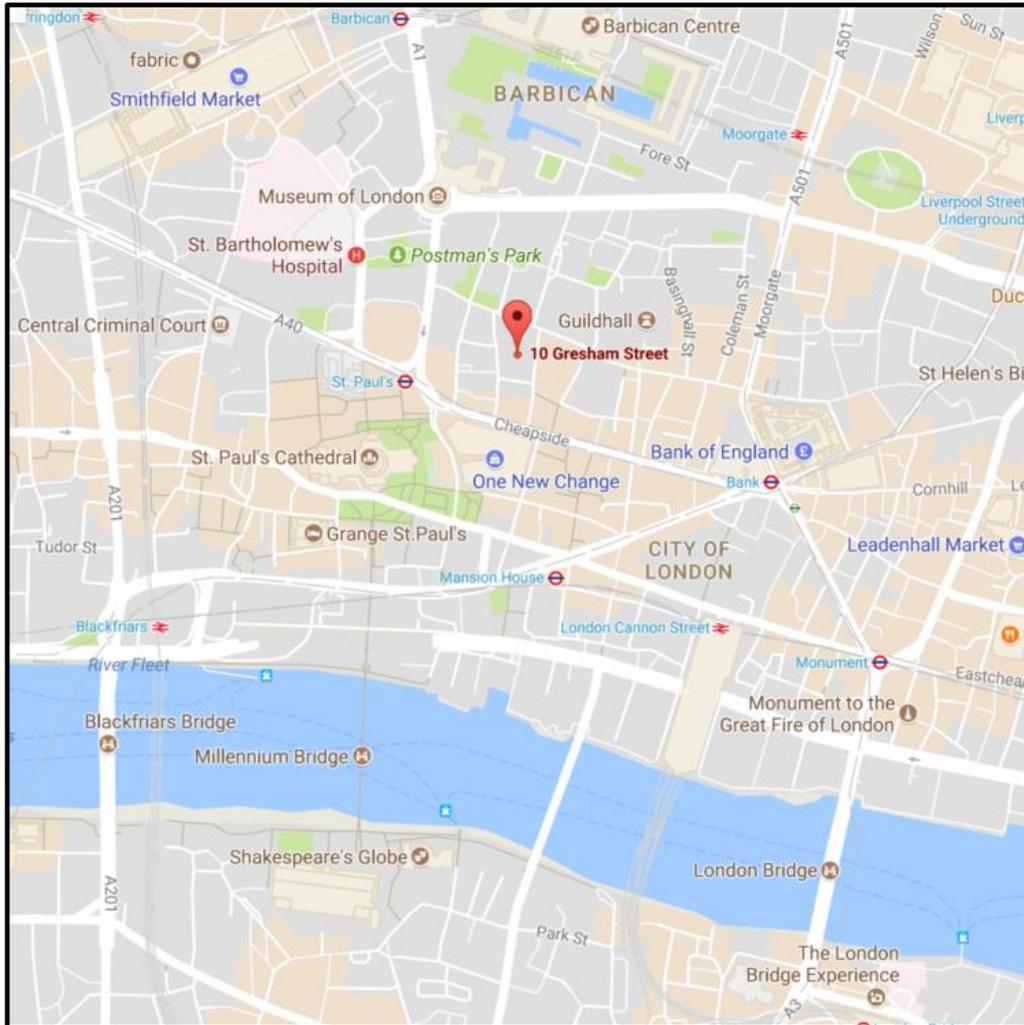
**Table 6.1.** Table detailing site name, dates of occupation, and site type.

Site	Dates of Roman period occupation	Site type 1	Site type 2
10 Gresham Street, London	Late 1st - early 2nd Century AD	Urban domestic	Inland
Caister-on-Sea, Norfolk	3rd and 4th century AD	Fort	Coastal
Causeway Lane, Leicester	1st - 4th century AD	Urban domestic	Inland
Docklands Light Railway (Monument Street), London	1st century AD onwards	Urban domestic	Inland
Fishbourne Palace, Sussex	1st to 4th century AD	High status	Coastal
Melton, Yorkshire	Roman - undetermined	Rural domestic	Inland
Owslebury, Hampshire	43AD - 4th century AD	Rural domestic	Inland
Plantation House, Chesterfield House (Plantation Place), London	1st - 2nd century AD	Urban domestic	Inland
Tanner Row, York	2nd century AD onwards	Fort	Inland
Ware, Hertfordshire	1st century AD onwards	Roadside settlement	Inland

### **10 Gresham Street, London**

This site is located in London near to the modern day Museum of London and St. Paul's Cathedral (Figure 6.2). Excavated in July 1997 by Museum of London Archaeology (MOLA), the site yielded evidence of a Roman gravel road with associated clay and timber buildings (Casson *et al.* 2014). The nature of the excavation was an evaluation of the site and the main method of recovery was through boreholes. The animal bone is in a relatively good state of preservation, presumably because the Roman phase was later sealed by gravel from a later widening of the road, before medieval buildings and pits were built (Casson *et al.* 2014). To date, there is no published analysis of the archaeological material from the site, including any assessment of the zooarchaeological material. However, it is an interesting site to include in this thesis because it lies on the road linking the fort at Cripplegate (Salway 1993) and the *via decumana*, the main street of Roman London (Rowsome 2000). An analysis of the duck and goose remains held at the London Archaeological Archive and Research Centre (LAARC) is useful, particularly in comparison with other contemporary sites in the area (see Plantation House and Monument Street below).

**Figure 6.2.** Map showing the location of 10 Gresham Street in London (© 2017 Google).

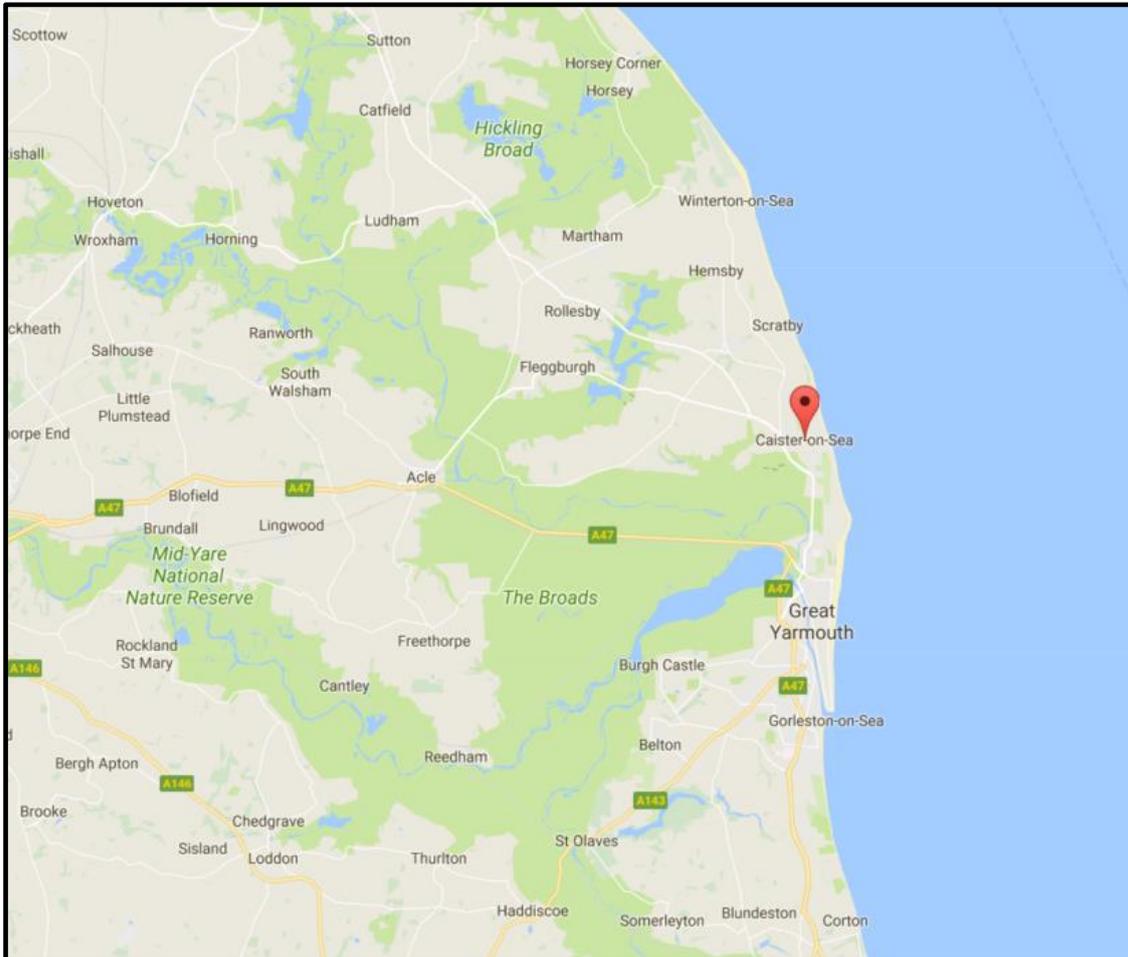


### **Caister-on-Sea, Norfolk**

Excavations at Caister-on-Sea revealed a Roman fort dating from the early 3<sup>rd</sup> century, which is thought to have been constructed to help protect shipping coming into the area (Darling and Gurney 1993). The site is situated just north of Great Yarmouth on the Norfolk coast and is next to the Norfolk Broads, an area famed for its avifauna today (Figure 6.3). The main excavations were conducted between 1951 and 1955, directed by Charles Green, and produced a large animal bone assemblage including 211 duck and goose bones from Roman contexts (Harman 1993). The fort seems to have been built on land with no previous occupation, covered an area of 8.75 acres, and was designed with a defensive wall

backed by an earthen rampart with no bastions, but possibly had internal towers (Darling and Gurney 1993).

**Figure 6.3.** Map showing the location of Caister-on-Sea, Norfolk (© 2017 Google).



Historical and artefactual evidence shows that the fort had very strong ties with mainland Europe and there has been some suggestion that the animals kept by the inhabitants of the fort may have had more in relation to animals bred on the continent than with local breeds from Britain (Harman 1993). The study of the ducks and geese from Caister-on-Sea will be particularly illuminating as whatever the results of the analysis are, there will be information about the attitudes of the fort's inhabitants to the area around them. If there is a great variety in wild species present, then this may suggest that the utilisation of local

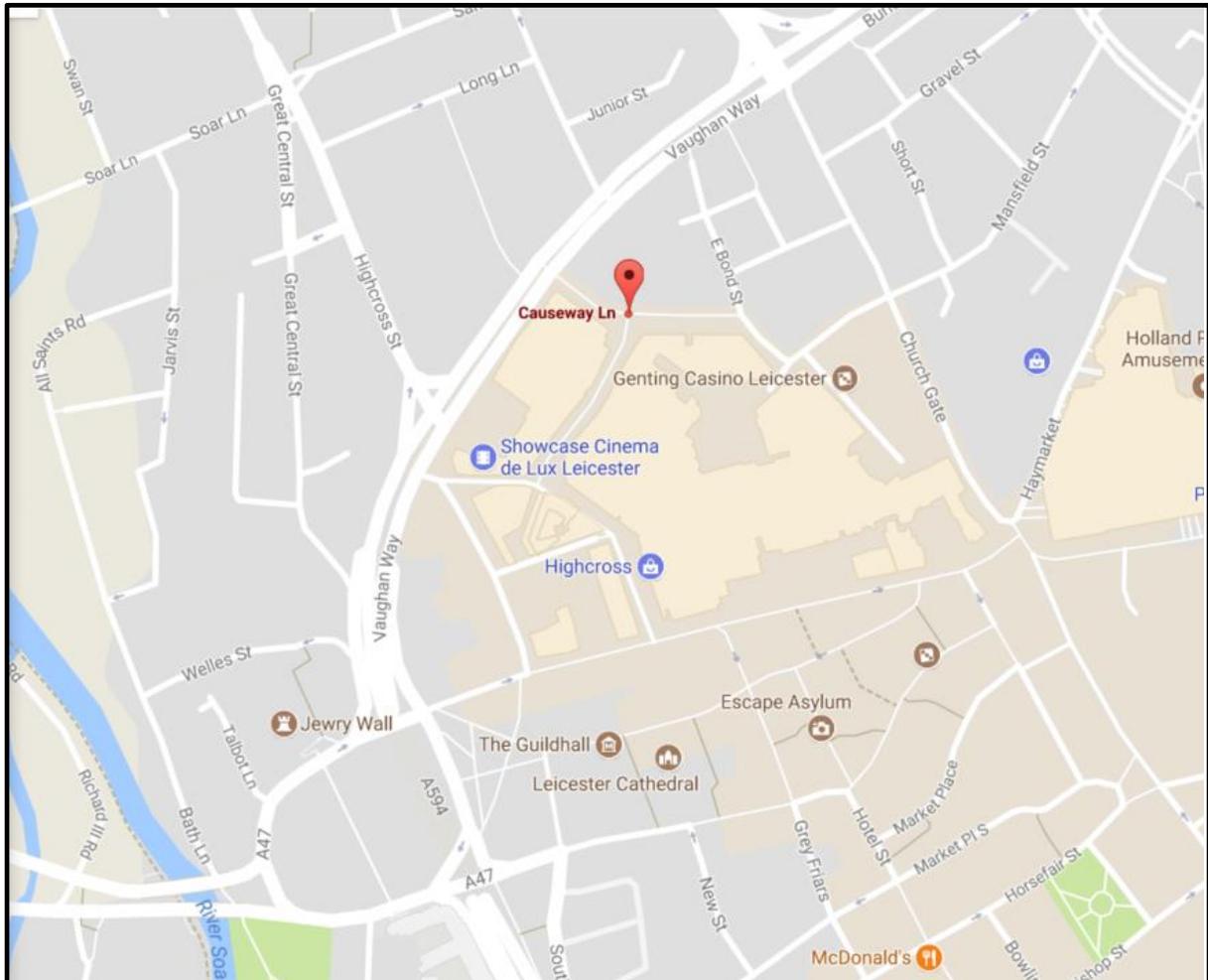
resources was important, with no real focus on a particular species. If there was a focus on one particular species then this may indicate that Roman attitudes to ducks and geese were more selective than suggested by the historical evidence discussed in chapter 1. Lastly, if the consumption of ducks and geese at Caister-on-Sea is more similar to mainland Europe than the rest of Britain then this will reinforce the notion that the inhabitants of this fort were culturally more aligned with Europe than the local population from Britain. In any case, the study of the duck and goose assemblage from Caister-on-Sea promises interesting and useful results.

### **Causeway Lane, Leicester**

Located in central Leicester, near to the Jewry Wall Museum (Figure 6.4), the site at Causeway Lane produced a vast amount of material following excavations in 1980 and 1991 and the material is stored at the Leicester City Council Museums and Galleries stores. Assemblages from two phases were available to study; one dating from the 1<sup>st</sup> until the 2<sup>nd</sup> century AD and the other from the 3<sup>rd</sup> to the 4<sup>th</sup> century AD. The animal bone assemblage was originally analysed by Louisa Gidney and the results were published in 1999 (Gidney 1999). Domestic fowl overwhelmingly formed the majority of the bird assemblage, and their use as food is also attested by chicken eggshells found at the site (Boyer 1999). There were, however, some ducks and geese identified, albeit not to the species level in most cases (Gidney 1999). The potential amount of ducks and geese available for analysis (65 NISP), and the location within central Britain, made this an ideal assemblage to include in this thesis. However, the actual amount of material available for analysis was reduced as many bones were fragmented or they belonged to anatomical elements not selected for this research. The main questions concerning this site will be whether there was an exploitation of wild resources and, if so, whether they were local or brought in from further afield (*e.g.* were

coastal species brought to the site?). Of course I will also investigate the potential keeping of domestic ducks and geese at the site.

**Figure 6.4.** Map showing the location of Causeway Lane, Leicester (© 2017 Google).

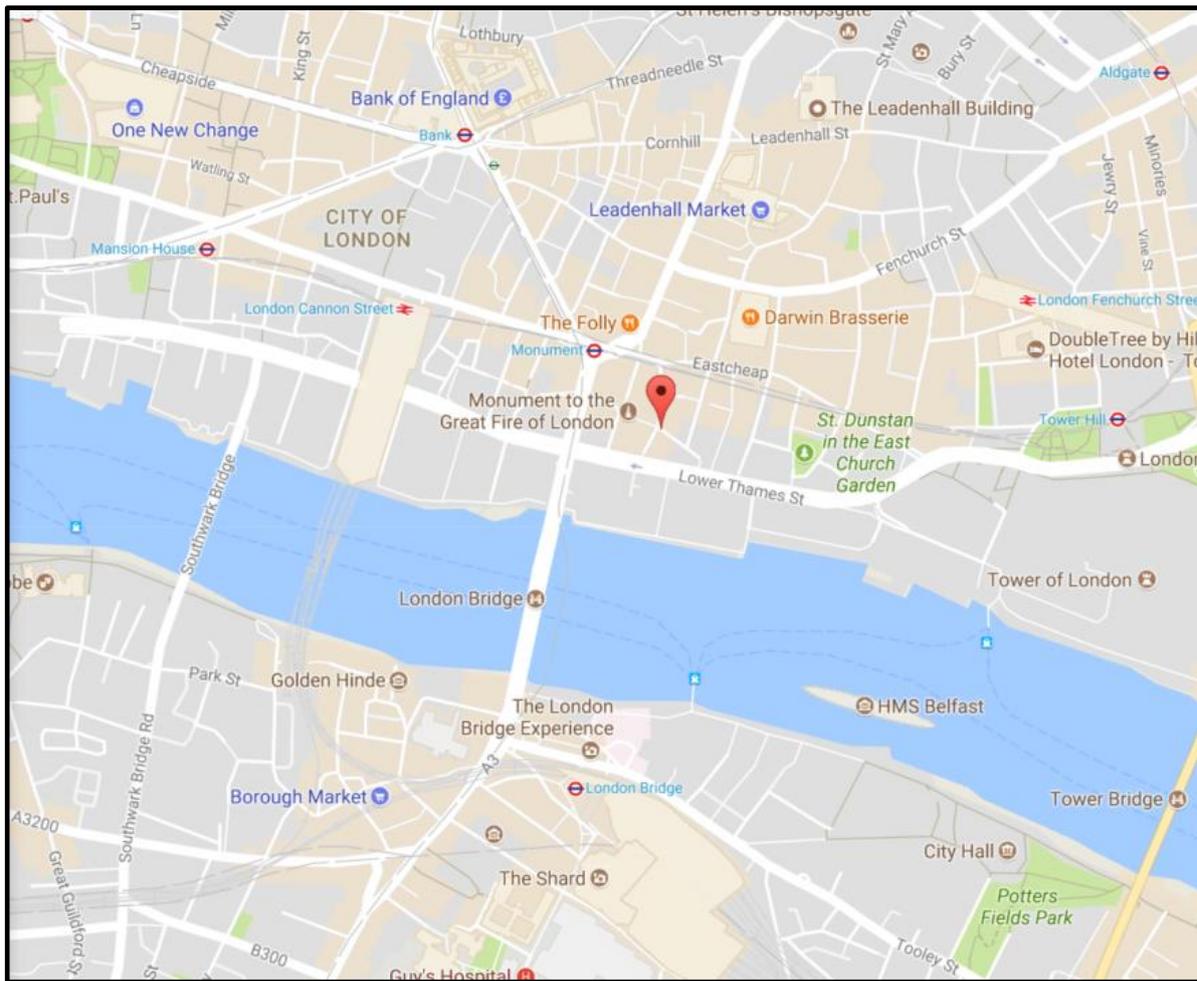


### **Docklands Light Railway (Monument Street), London**

The site at Monument Street was excavated by MOLA in 1987 and revealed the presence of a well, dated to the Flavian dynasty, which had been back filled with waste from a nearby inn or restaurant (Schofield and Maloney 1998). Today the site is located to the north of London Bridge, but was relatively close to the forum during the Roman period (Figure 6.5). Although not the only feature of the site, the well provided the majority of the finds including a vast amount of animal bone. There was a wide range of objects discarded in

the well along with the animal bone including samian ware ceramics, glass, and iron utensils (Wallace 2014). Given the high quality nature of the objects discarded in the well, it is thought that the inn, or restaurant, must have catered for high status customers visiting London during the Roman period and so perhaps the evidence from the animal bone assemblage reflects this customer base (Schofield and Maloney 1998). The animal bone collection has never been fully analysed but an assessment was carried out by Alan Pipe and the preliminary identifications are recorded in the LAARC database. The preliminary results show that there was a wide range of animals consumed and perhaps there was a preference for exotic food at the site. The initial identifications of the anatids lists a number of duck and goose taxa, interestingly including domestic geese (Pipe, pers. comm.). However, the identifications were only preliminary and may not be accurate as they were achieved quickly, by eye, using a limited reference collection (Pipe, pers. comm.). Indeed, these identifications should not be viewed as final identifications as the anatids were placed in size categories - *i.e.* teal sized duck, mallard sized duck, greylag sized goose, domestic sized goose - rather than proper taxonomic identifications (Pipe, pers. comm.). Therefore at the very least the ducks and geese need to be properly analysed and identified in order to contextualise them with the rest of the animal bone assemblage and the high quality artefacts. The main question here is to see if the ducks and geese follow the rest of the animal bone assemblage, namely whether there is great diversity and so reflecting the taste for variety in the food served. Another aim for the analysis of this assemblage is to assess how similar, or dissimilar, the use of ducks and geese was in an urban environment compared to the fort at Caister-on-Sea and the high status site of Fishbourne Palace. All three assemblages are of a similar size and, therefore, largely comparable.

**Figure 6.5.** Map showing the location of the Docklands Light Railway (Monument Street) site. (© 2017 Google).

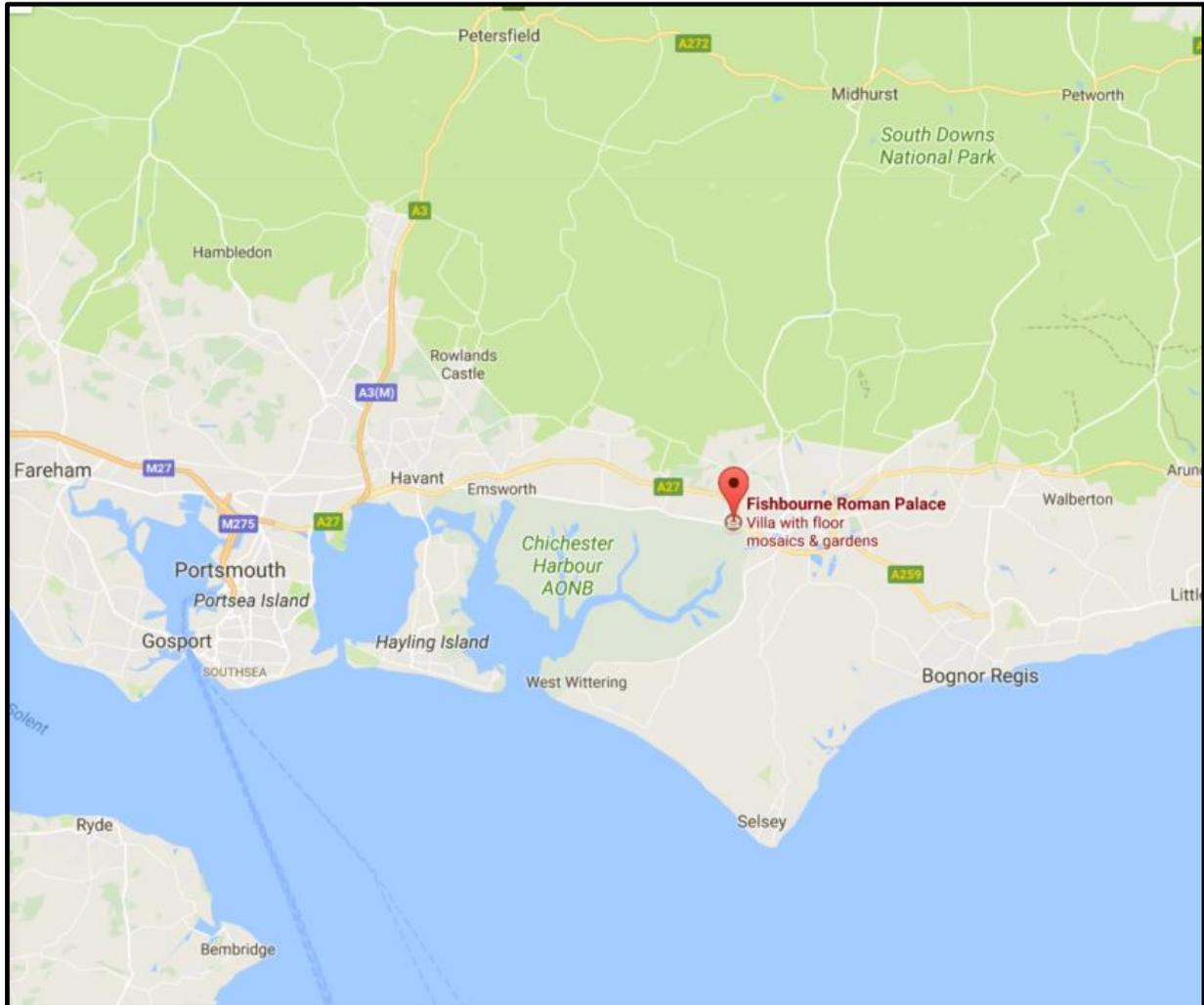


### **Fishbourne Palace, Sussex**

Located on the Sussex south coast, Fishbourne Palace was a palace in the true sense of the word and was the focal point for activity in the region (de la Bédoyère 2013) (Figure 6.6). Famed for its mosaics and garden, the wealth of the occupants of the site was reflected in their material culture and the food they ate. A wide range of animals was consumed, including species seen nowhere else in contemporary Britain (Allen 2011). Excavations by Barry Cunliffe in 1960 demonstrated the existence of several construction phases before the eventual decline of the site, with the most affluent period occurring between the 2<sup>nd</sup> and 3<sup>rd</sup> centuries AD. The site report details the excellent preservation of much of the site and the

recovery methods employed during the excavation. Recovery seems to have been particularly good and much of the site now can be enjoyed by the public at the excellent Fishbourne Palace Museum. The museum stores all the artefacts recovered from the site, including the animal bones, and has an excellent catalogue making it easy to access individual bones. The animal bone collection, including ducks and geese, were analysed as part of a PhD thesis by Martin Allen and the results and discussion was extensive and thorough (Allen, 2011). Allen identified many species that were consumed at the site, including fallow deer (*Dama dama*), which was thought to be absent from Britain before Norman times (Sykes *et al.* 2011). One suggestion for the presence of the fallow deer at the site is that there was a custom of displaying wealth and status through the animals kept at the site, the idea being that the more exotic the animal the better (Sykes 2014). One must be wealthy to acquire and then maintain exotic animals for no obvious economic reason and so displaying or consuming these animals represents a display of wealth (Sykes 2012). One of the research aims of this project, concerning the Fishbourne Palace assemblage, is to ascertain how the ducks and geese were used at the site, particularly if there is any evidence for them being domestic. If domestic ducks and/or geese were present during the Roman period at Fishbourne, and nowhere else in Britain, then this may suggest that the occupiers of the site acquired their domestic birds from a foreign source. This may mean that these birds were viewed as exotic and therefore added to the display of wealth at the site. There are other examples of the “exotic domestic” as discussed by Sykes (Sykes 2014).

**Figure 6.6.** Map showing the location of Fishbourne Palace, Sussex (© 2017 Google).



Aside from assisting with our understanding of the use animals at the site, the study of ducks and geese from Fishbourne will also be useful for understanding Roman attitudes to these birds in Britain in a more general sense. It will be particularly interesting to compare the data from Fishbourne and Caister-on-Sea, two coastal sites that were likely to have had access to broadly similar coastal avifauna. Investigating the similarities and differences in the use of certain species, particularly the wild species, may be useful for inferring Roman attitudes to wild resources and local food sources.

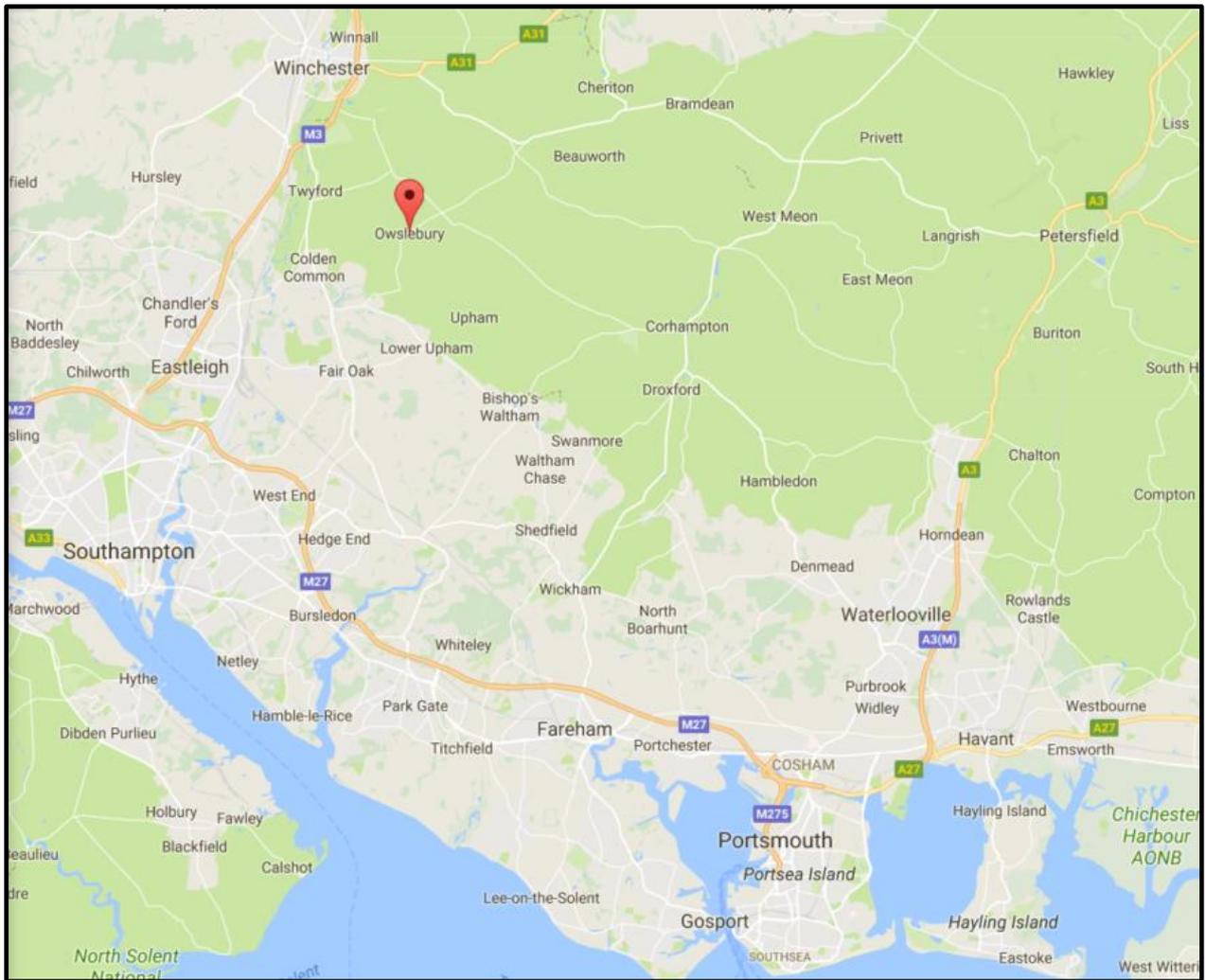
### **Melton, Yorkshire**

At the time of writing, the excavations at Melton had not been fully completed and only a sample of the animal bone assemblage had been analysed. As such the excavation and animal bone evaluation reports were not available to the author. The site is just west of Hull and so is the most northerly site discussed in this thesis. Artefactual evidence and the site plan were not available to the author but, from discussions with the animal bone analyst, it seems that the bones analysed in this thesis come from the base of a disused well, dating to the Roman period (Sewpaul, pers. comm.). The main reasons to include the analysis of the bones from this site at this stage was because of its northern location and its proximity to York (for comparison of assemblages). Although there are obvious limitations in analysing only two sites from the north of England, it will be interesting to see if Melton and York have more in common with each other than the other sites from the south. In other words, it will be interesting to find out whether geography, in a cultural and/or environmental sense, played a role in determining the exploitation pattern of the anatids

### **Owslebury, Hampshire**

The site of Owslebury is about five miles about away from Winchester (Figure 6.7) and the occupation period was from the 4<sup>th</sup> century BC to the 4<sup>th</sup> century AD (Collis 1994). Excavations directed by John Collis in the sixties and seventies showed that the initial phase of Roman occupation (43AD onwards) did not alter the structure of the site significantly, but the material culture changed with the appearance of samian pottery artefacts (Collis 1990). A full analysis of the animal bones recovered from the site has never been published, but the analysis was carried out by Mark Maltby and is available as grey literature (Maltby 1987).

**Figure 6.7.** Map showing the location of Owslebury, Hampshire (© 2017 Google).



The animal bone assemblage has been subject to various studies including a recent study on the source of the cattle at the site using isotopic analysis (Minniti *et al.* 2014). For this study the assemblage was temporarily housed at the Department of Archaeology at the University of Sheffield and so presented an excellent opportunity to include a study of the ducks and geese for this thesis. It would have been a great opportunity to look at how the use of ducks and geese at this site changed from the Iron Age to the Roman period, in comparison with the main mammal species, and how their use compared to sites in the south of England.

However, on assessment of the bird remains it became evident that only one bone could be

identified using the criteria established in this thesis. This was for a range of reasons including the presence of very few ducks and geese in the assemblage, the fragmentation of the remains, and the occurrence of anatomical elements not relevant to this research. Even though only one bone was identifiable using the new criteria, it was included in this thesis to add to the general overview of the use of ducks and geese in Britain during the Roman period, but there will be no comparison between this site and the other sites included in this thesis.

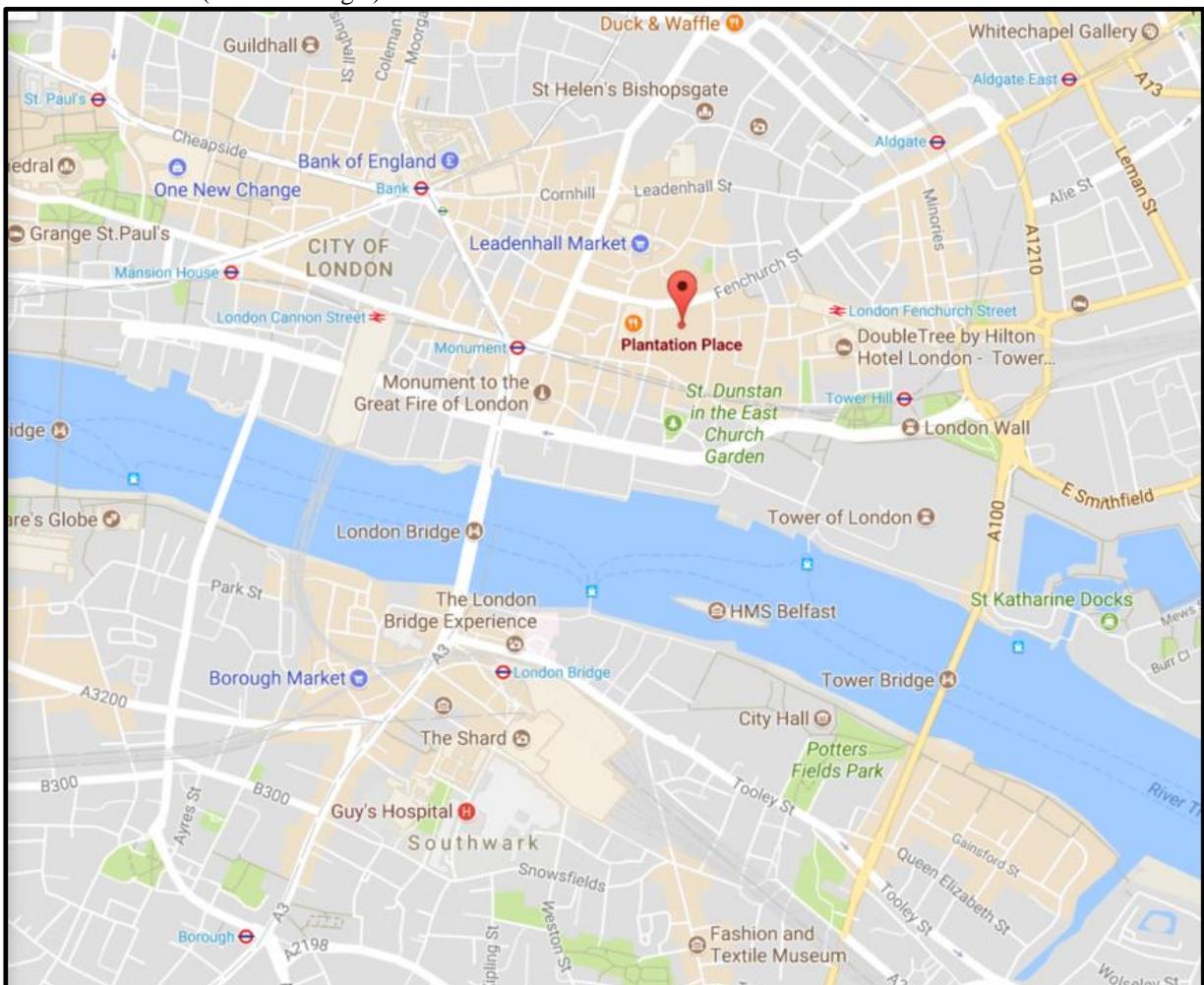
### **Plantation House, Chesterfield House (Plantation Place), London**

The site at what is now Plantation Place is located in central London, just off Fenchurch Street, and is near to the Monument Street site discussed above and the site of the Roman forum (Figure 6.8). The excavation was carried out in 1997 by MOLA and revealed 1<sup>st</sup> century mudbrick and timber buildings that appear to have been destroyed in the Boudican revolt, then a series of clay and timber buildings along the *via decumana* dating to the 2<sup>nd</sup> century AD, a number of wells and cess pits, and a building with a masonry foundation that is presumed to have been of higher status than the other contemporary buildings (Dunwoodie *et al.* 2016).

The archaeological material from the site is stored at the LAARC and the animal bone assemblage was originally assessed by Alan Pipe (Unpublished). Several duck and goose bones were identified and similar to the other two London sites the identifications were taken to size type rather than species. The potential of this assemblage is that a range of different duck and goose sizes were identified, including domestic goose, meaning it is likely that a range of wild and possibly domestic resources were used at the site. The results of the analysis of this assemblage will be compared to the other two sites in London analysed in this thesis and will be amalgamated with the other sites in Britain to evaluate if there is a general

trend in the use of these animals during the Roman period. Even though only three London sites have been analysed in this thesis, comparing the sites will at least start to allow for an understanding of whether there is a general similarity in the use of ducks or geese in the area or if there is variation within the urban centre. If there is a general similarity in the use of ducks and geese in London, then it will be interesting to see if this is consistent in the rest of Britain or if London is different.

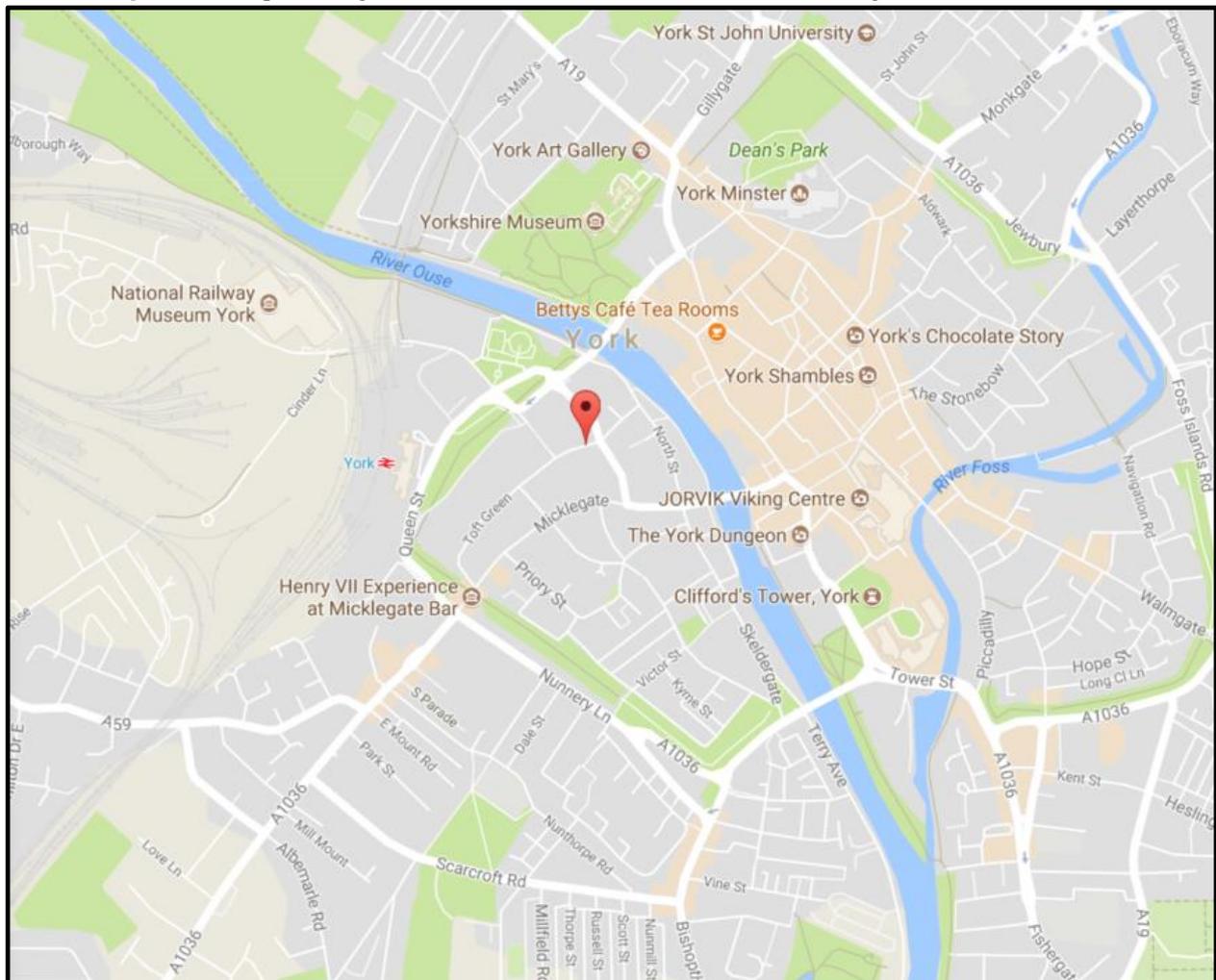
**Figure 6.8.** Map showing the location of Plantation House, Chesterfield House (Plantation Place) (© 2017 Google).



## Tanner Row, York

Excavations at the General Accident site on Tanner Row in the centre of York (Figure 6.9) revealed several building phases, from the initial use of the site in the middle of the 2<sup>nd</sup> century AD until the early 13<sup>th</sup> century (McComish 2015). There was a sizeable fort in Roman York (Eboracum) that housed a garrison of the Ninth Legion and the fort was surrounded by a vicus. Excavations directed by N.F. Pearson in 1983 and 1984 produced a wealth of material which was in various states of preservation due to the differences in soil conditions in the various strata (McComish 2015).

**Figure 6.9.** Map showing the location of Tanner Row, York (© 2017 Google).



The animal bone is stored at the York Archaeological Trust's (YAT) Resource Centre and the initial inspection of the Roman material by the author suggested that preservation was generally quite good. The original analysis of the zooarchaeological material was conducted by Terry O'Connor and several interesting results were discussed in the subsequent publication (O'Connor 1988). Mature cattle was the main source of meat in York during the Roman period and this seems to have been generally consistent with other contemporary fort sites (Alcock 2010). During the time of occupation the site appears to have been infested with black rats (*Rattus rattus*), which is was thought to be consistent with a highly populated fort and an increasingly urban environment surrounding it (O'Connor 2012). As the amount of people in a relatively small space increased, so did the amount of waste and food for vermin.

Key zooarchaeological objectives that came out of the analysis were to compare the use of animals within the fort and the surrounding town, and to compare the fort at York and other forts in Britain. O'Connor identified several species of bird dating to the Roman period with domestic fowl being overwhelmingly the most frequent (O'Connor 1988). A number of goose species were identified but it was surmised that the majority of the geese were likely to be from domestic birds due to their size (O'Connor 1988). This makes this assemblage an obvious target for the application of the new identification criteria presented in this thesis, to test the presence or absence of domestic birds in York.

Several different duck species were identified, although far fewer in number than the geese. O'Connor chose to place the "cf. Domestic duck" with the wild birds as at the time there was a lack of reliable identification criteria for separating the duck species (O'Connor 1988). What was evident from the initial analysis of the anatids was that there appeared to be many more geese than ducks, which is different from the sites in the south of Britain, but similar to the most local site assessed in this thesis; Melton. Key aspects of this assemblage that will be looked at following the re-identification of the material are how likely it was that

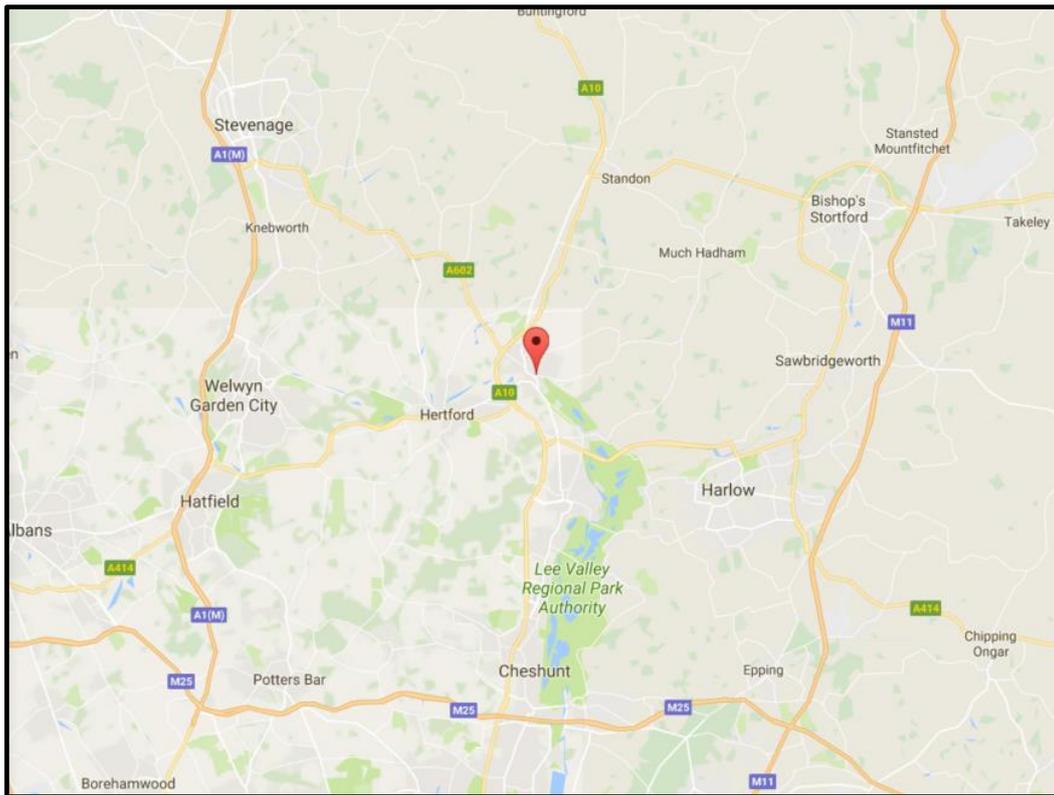
domestic geese were present during the Roman period, how much variation there was in the use of ducks and geese, and how similar/different was the use of these birds at this fort site compared to Caister-on-Sea.

### **Ware, Hertfordshire**

Excavations between 1976 and 1978 revealed the remnants of a Roman roadside settlement at the former Allen and Hanbury pharmaceuticals factory near Ware (Figure 6.10). The animal bone assemblage was recently analysed at the Tony Legge Zooarchaeology Laboratory at the University of Sheffield. The main species that was identified in the assemblage was cattle and it is thought that meat would have been traded up and down the Roman road, meaning that, despite the low social status of the settlement, the people at the site were well provisioned (Wright *et al.* in prep.). There is a growing body of research on roadside settlements in Roman Britain (*e.g.* Wright *et al.* in prep.) but at present there is no clear understanding of how this site, or type of site, functioned exactly in relation to other types of settlements.

Domestic fowl, or possibly domestic fowl, formed the majority of the bird assemblage which appears to be typical for this period (Wright *et al.* in prep.). Some ducks and geese were identified and the ducks in a range of sizes types suggesting that that there was not a focus on one particular species. Although not a large anatid assemblage, it will be interesting to see if the use of these birds is different at this type of site compared to more urban settlements, such as London, or coastal sites such as Caister-on-Sea and Fishbourne Palace. In any case the presence of a range of duck and/or goose species may tell us more of the environment around Ware during the Roman period and how wild resources were used.

**Figure 6.10.** Map showing the location of Ware, Hertfordshire (© 2017 Google).



## **Chapter 7~** **Assemblage analysis results**

Presented in this chapter are the results of the analyses of the archaeological assemblages discussed in chapter 6. The results from each site are first discussed individually and then in an integrated way to give an overview of the zooarchaeological evidence in Britain for the Roman period. The discussion of similarities and differences between the various sites are discussed in the next chapter, along with a general discussion of the results presented below. What is presented here is the results of the taxon identification of the 10 assemblages from Roman archaeological sites discussed in chapter 6 in order to discuss the research questions outlined in chapter 1. What is not presented here is the frequency, and nature, of any incidences of butchery, pathology, age at death, or body part representation, although these are discussed where relevant in the next chapter.

### **Methods**

Some bones from the archaeological material were not recorded as part of this project as the new identification criteria could not be applied to them. The elements that were recorded were the coracoid, the scapula, the humerus, the ulna, the radius, the carpometacarpus, the femur, the tibiotarsus, and the tarsometatarsus as these were the elements that the identification criteria were developed for on the modern material (chapters 3-5). Juvenile anatid bones were not included as the bones are not fully developed, meaning the necessary measurements would not have been comparable. This is unlikely to impact on any interpretations of the results presented below as osteologically immature bones were rare in the assemblages analysed, which tends to be the case in bird bone assemblages in general (Serjeantson 2009, Gal 2013). Fragmented bones that clearly belonged to an anatid, but could not be measured, were not included. If there was evidence of pathology on a bone in an area

where a measurement needed to be taken, then the measurement was not recorded as it would have been altered by the pathology. Other measurements would still have been taken on the bone if they were not directly affected by the condition. It is unlikely that not recording the measurements of pathological parts of bones/whole bones will impact on any interpretation of the results as pathologies on archaeological bird bones are rarely present (Gal 2013), which was also the case for the material analysed in this thesis (appendix 2).

All identifications listed below were made using the criteria outlined in chapters 3-5 and three examples of how these criteria were applied to the archaeological material are presented. One example concerns bone 6004, which was classified as Domestic Goose, another is bone 5679, which was classified as a Mallard, and the last one is bone 5866, which was classified as Tufted Duck.

#### Example application of criterion 1: Bone number 6004 - Domestic Goose

This example demonstrates how an unknown archaeological bone from Caister-on-Sea (bone number 6004) was identified as belonging to a Domestic Goose at each stage of the identification. The first stage was to establish whether the bone belonged to a duck or a goose. Figures 7.1 and 7.2 show that bone number 6004 plots within the goose clusters and well outside of the duck clusters in bivariate scatter plots meaning that it can be confidently identified as belonging to a goose. There was no need for ratio plots or discriminant function analysis at this stage. Size is the best way of distinguishing between *Anser* and *Branta* in the majority of cases and figures 7.3 and 7.4 show that bone 6004 plots within the *Anser* clusters and outside of the *Branta* clusters. Size can also be useful in some cases for distinguishing between the various *Anser* species. We can see that there is some separation of the *Anser* species in bivariate scatter plots (figures 7.5 to 7.7) and that the as yet unidentified archaeological bone plots within the *Anser anser* cluster and away from the other species'

clusters. As the unidentified bone consistently plots only with *Anser anser* there is no need to use ratio plots or discriminant function analysis for this particular bone. This archaeological bone could belong to a wild or domestic *Anser anser* and so it is necessary to take the identification process to the final stage. Figures 7.8 and 7.9 show that bone number 6004 plots exclusively with the modern Domestic Geese and away from the modern Greylag Geese. This could be enough to make a reliable identification in this case, but to add further confidence in the identification a discriminant function analysis was run using the measurements that could be taken on the archaeological bone. Figure 7.10 shows that bone 6004 plots with the Domestic Geese and the results are statistically significant meaning that the bone 6004 very likely came from a Domestic Goose.

Figure 7.1.

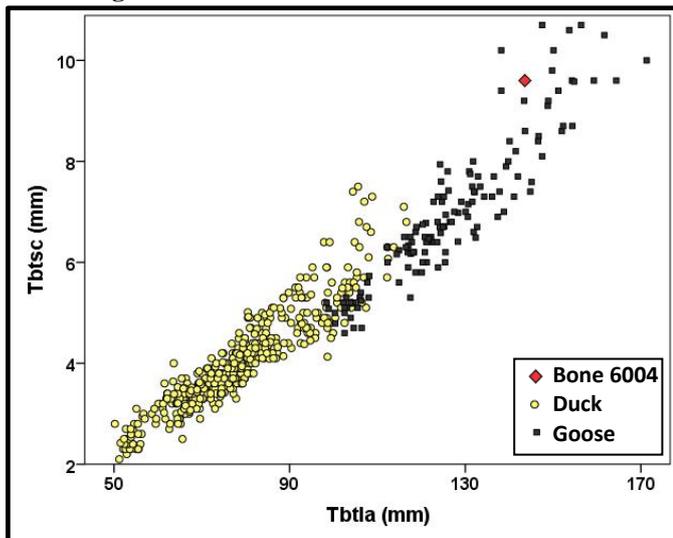


Figure 7.2.

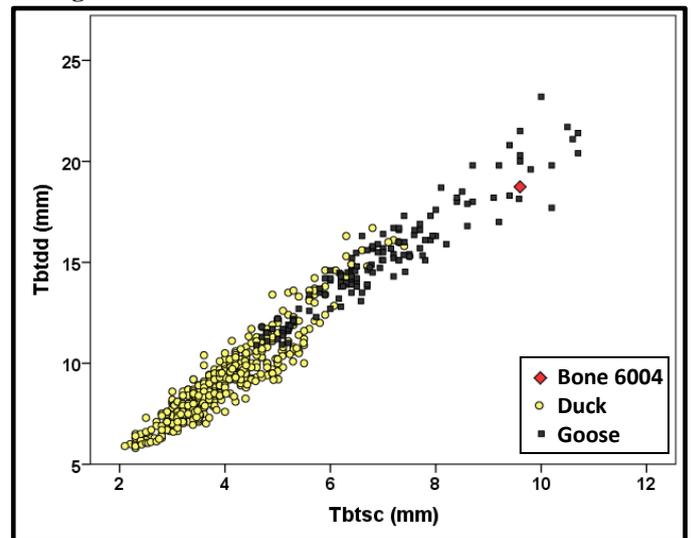


Figure 7.3.

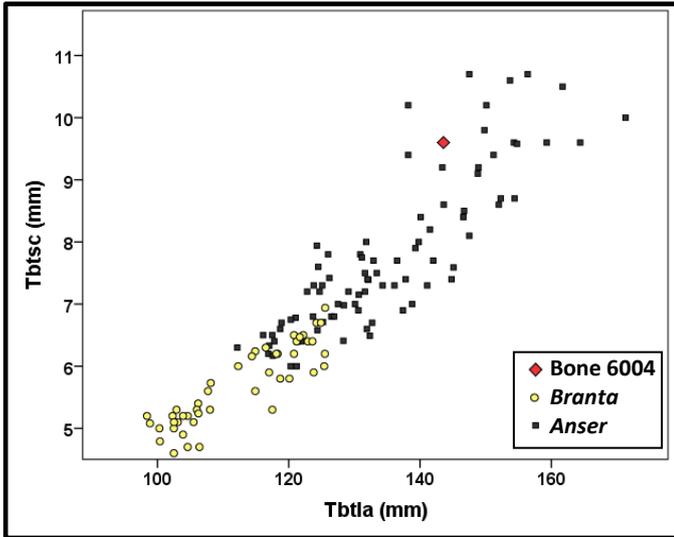


Figure 7.4.

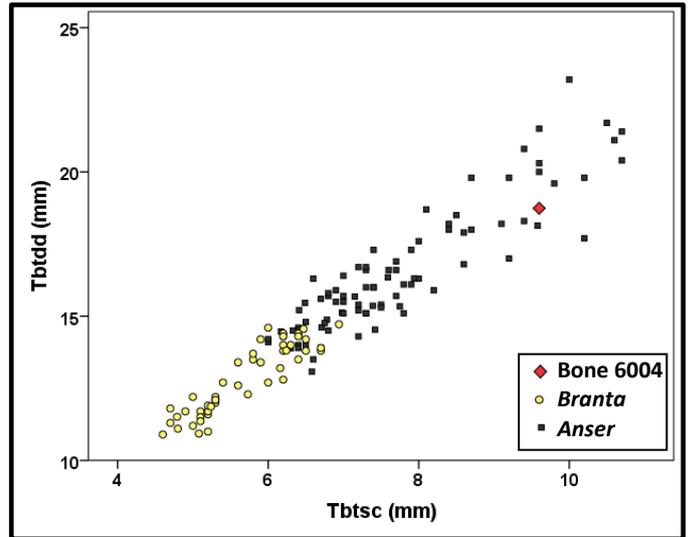


Figure 7.5.

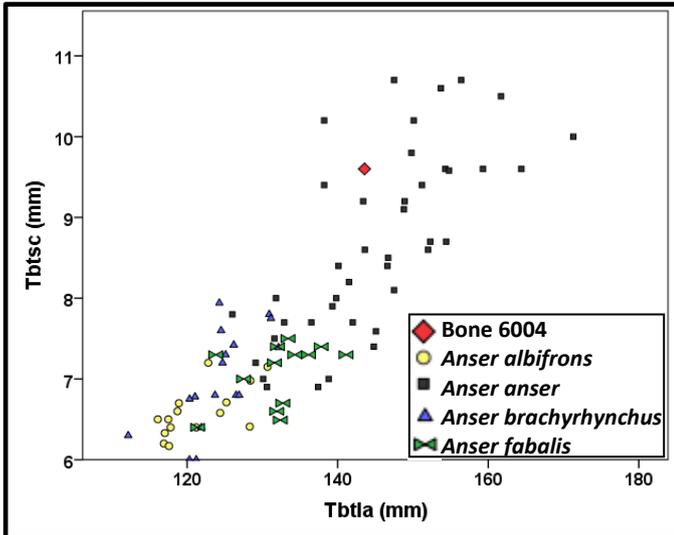


Figure 7.6.

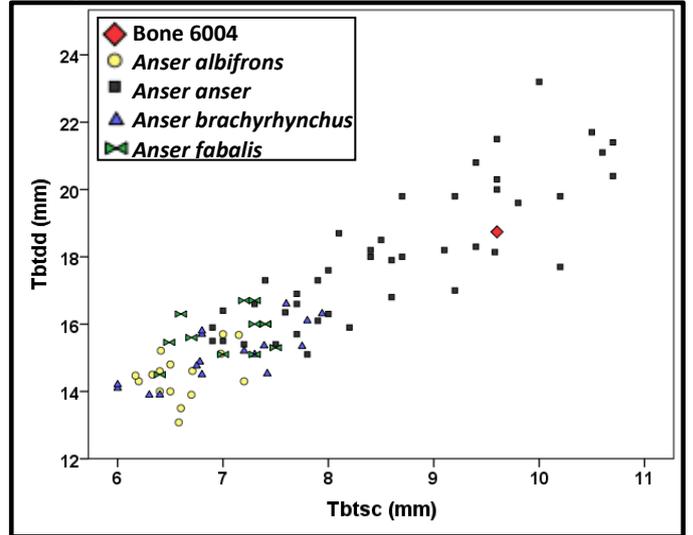


Figure 7.7.

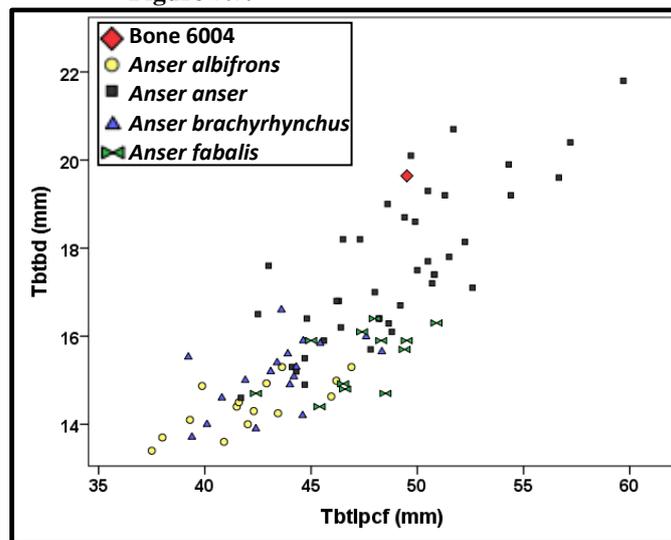


Figure 7.8.

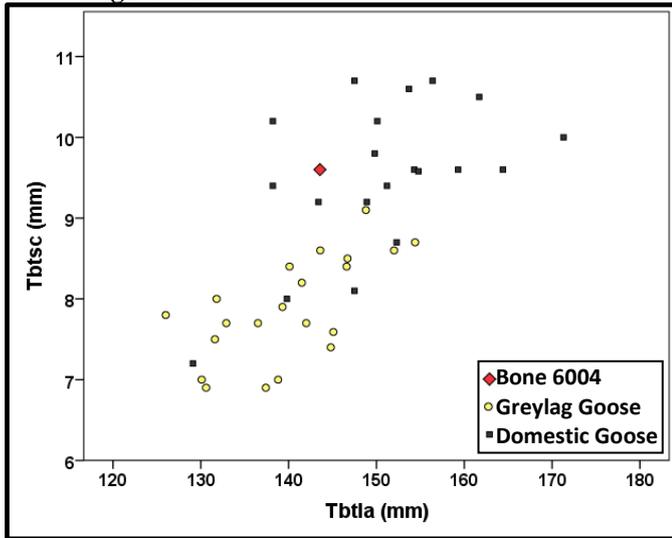


Figure 7.9.

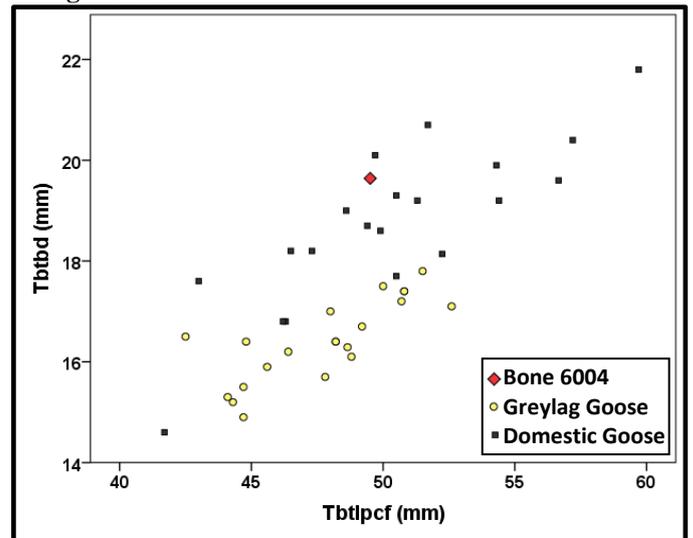
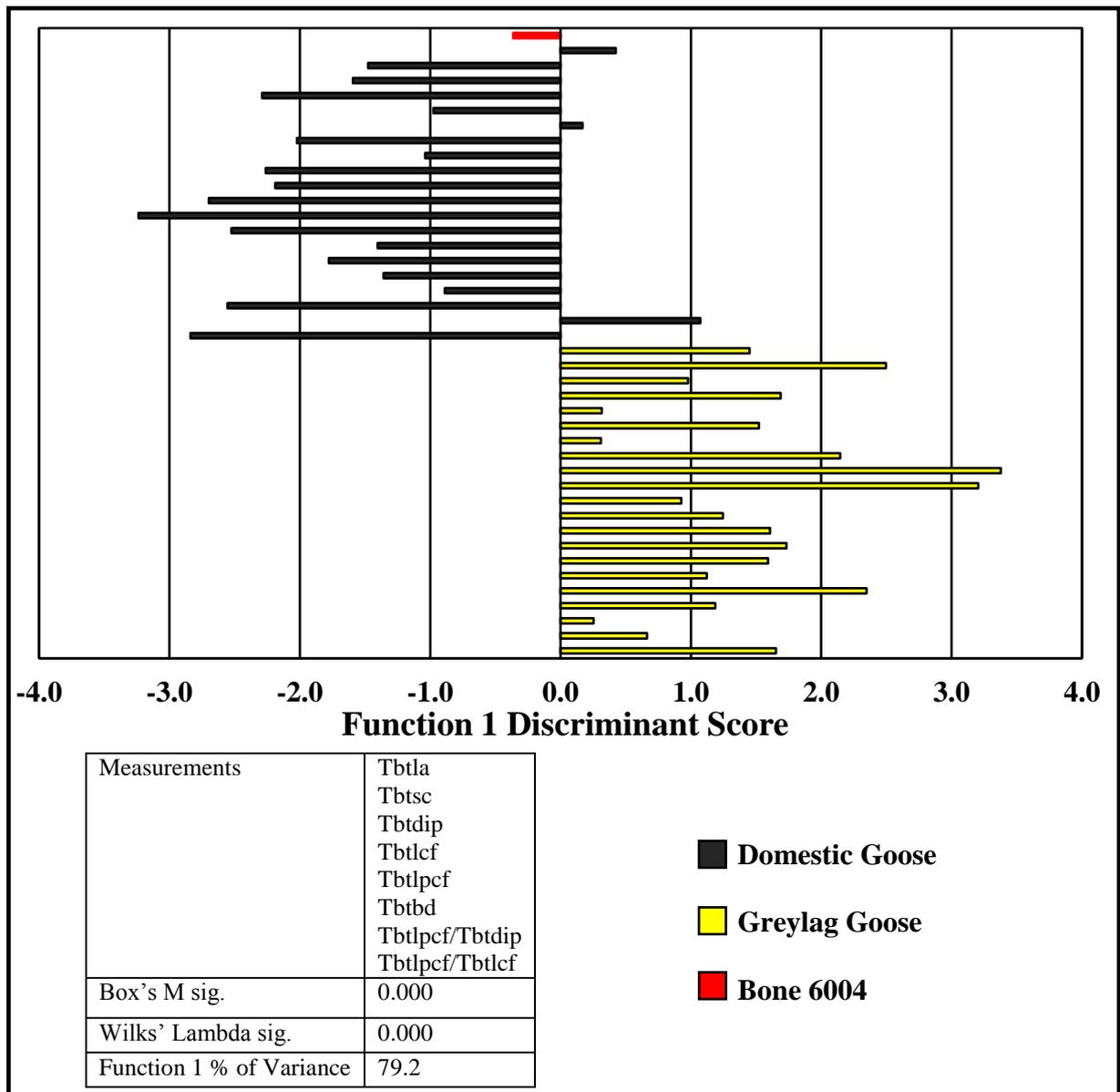


Figure 7.10.



### Example application of criterion 2: Bone 5679 - Mallard

This example shows how an unknown archaeological humerus from the site on Monument Street in London was identified as being a wild *Anas platyrhynchos*, consistent with a modern Mallard. Figures 7.11 and 7.12 show that the archaeological bone can be confidently identified as belonging to a duck using only a single measurement as the archaeological bone plots reliably within the duck range and outside of the goose range. Figures 7.13 and 7.14 show that some genera (*Aythya*, *Bucephala*, *Clangula*, *Melanitta*, and *Somateria* in this case) can be ruled out for the identification based upon size alone. A ratio plot and a discriminant function analysis (figures 7.15 and 7.16) show that bone 5679 was not a *Mergus* but could still be from *Anas*, and *Tadorna* was ruled out using a combination of bi-variate and ratio scatter plots (figures 7.17 and 7.18). Size is often the easiest way of distinguishing between the *Anas* species and figures 7.19 and 7.20 show that all species apart from *Anas platyrhynchos* can be ruled out using bi-variate scatter plots. As this bone is from an *Anas platyrhynchos* it must be decided whether it is from a domestic or wild individual. Modern wild and domestic *Anas platyrhynchos* can be separated well based on size and figures 7.21 and 7.22 show that bone 5679 plots within the wild clusters and outside of the domestic clusters in bi-variate scatter plots. Discriminant function analysis can be used to add confidence to the identification and figure 7.23 shows that bone 5679 has a discriminant score for function 1 that is consistent with modern Mallards. It is of course also possible that this was a domestic duck that had not been subjected to any of the morphometric changes that we see in modern domesticated forms. If this were the case it is, however, likely that such unmodified ducks would interbreed regularly with wild mallards and probably not live under full human control. The most parsimonious explanation remains that this was a wild specimen.

Figure 7.11.

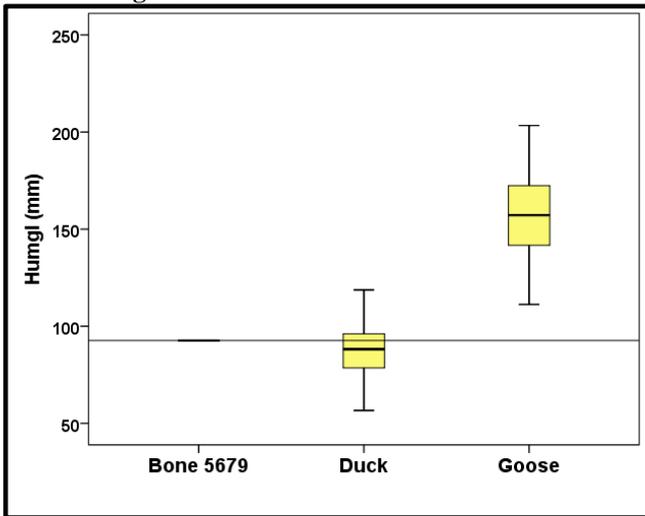


Figure 7.12.

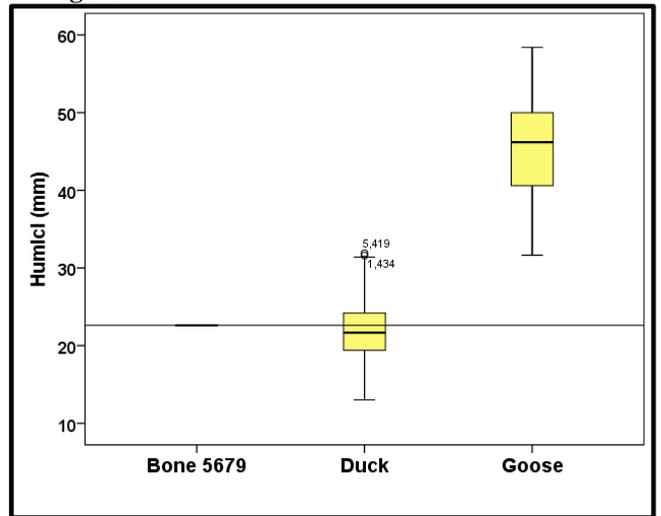


Figure 7.13.

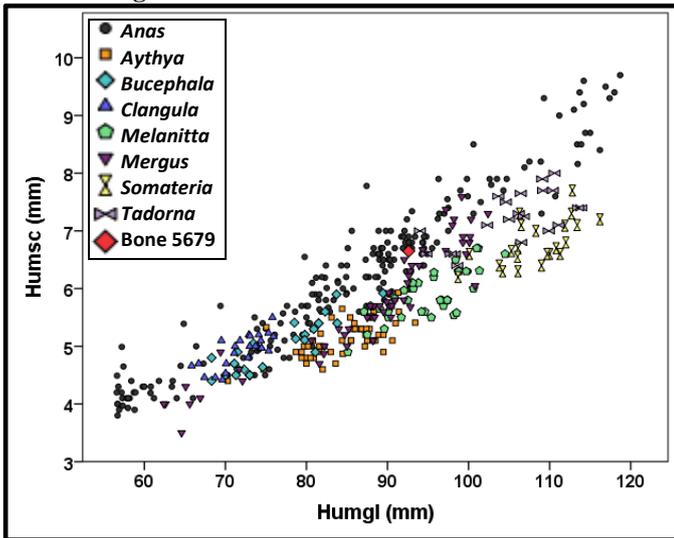


Figure 7.14.

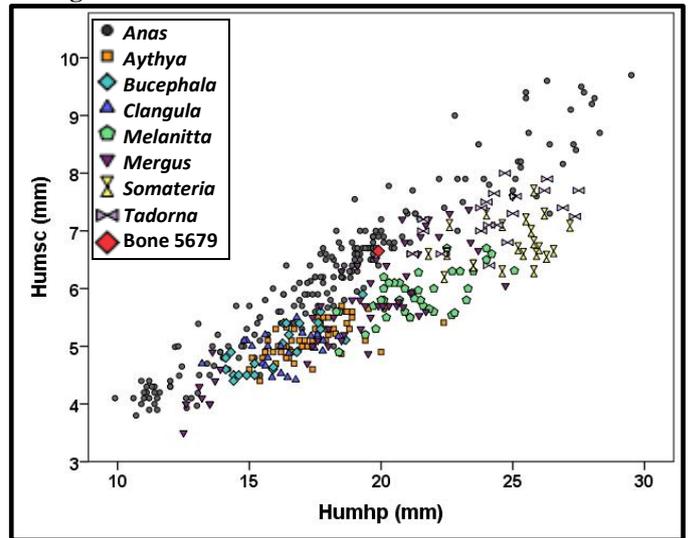


Figure 7.15.

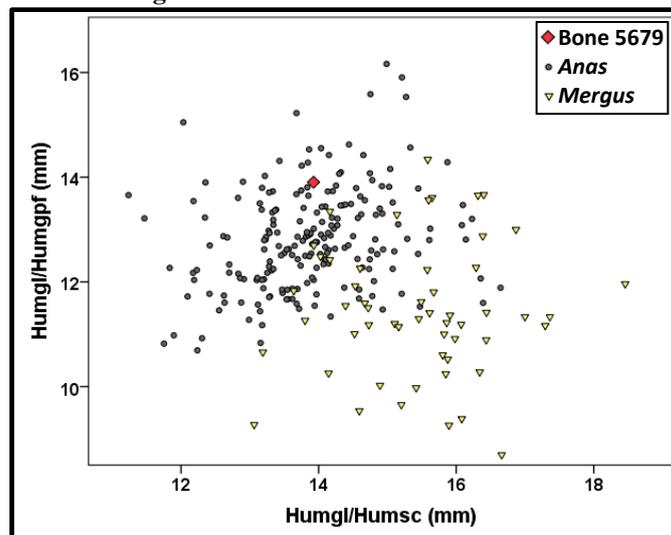


Figure 7.16.

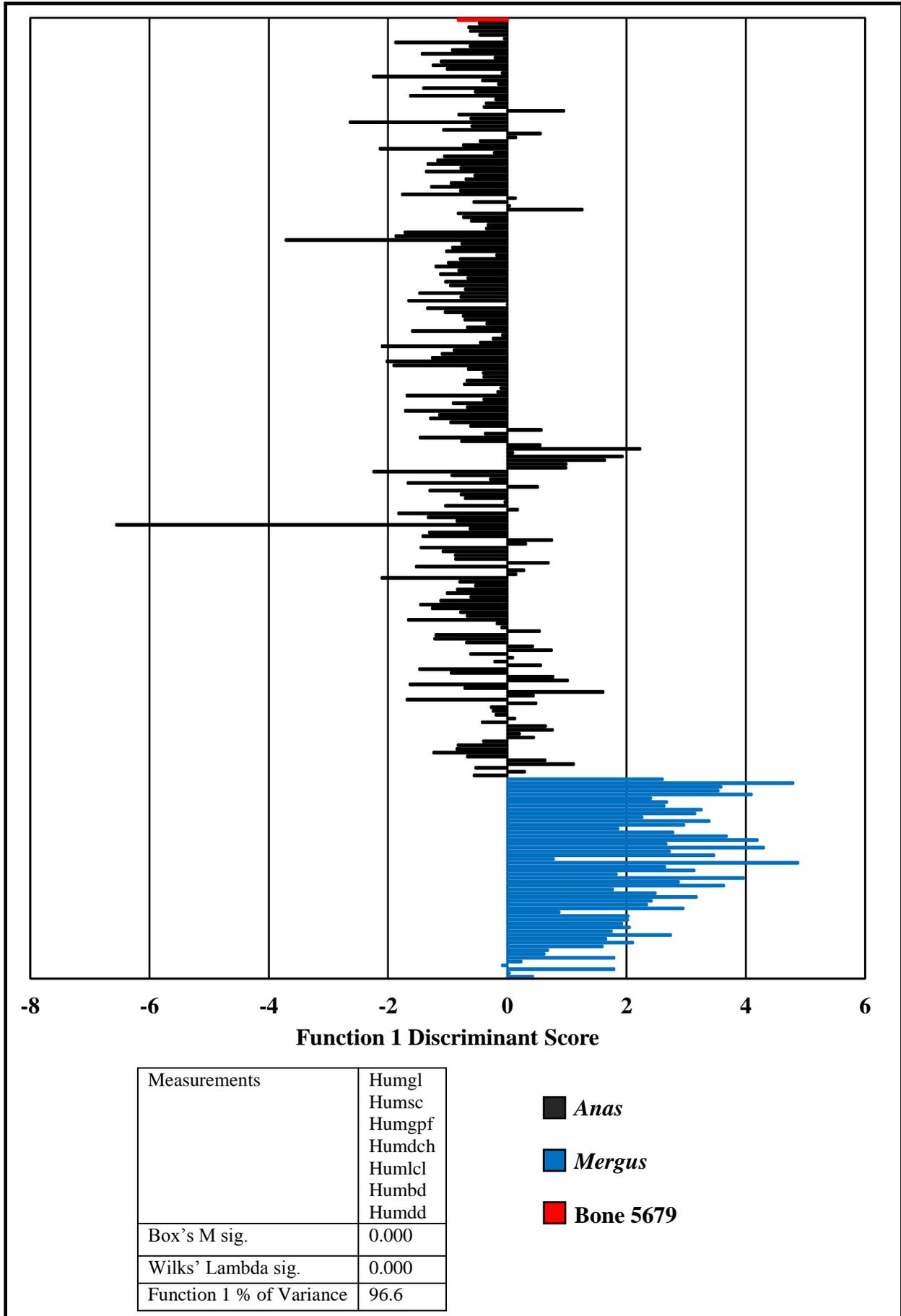


Figure 7.17.

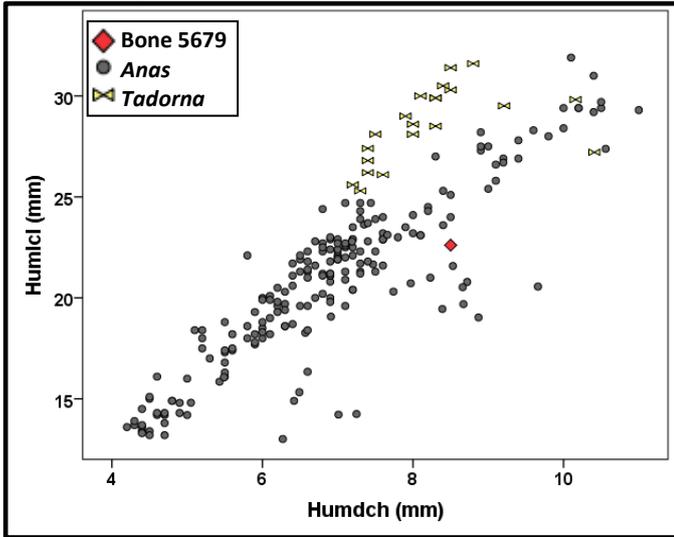


Figure 7.18.

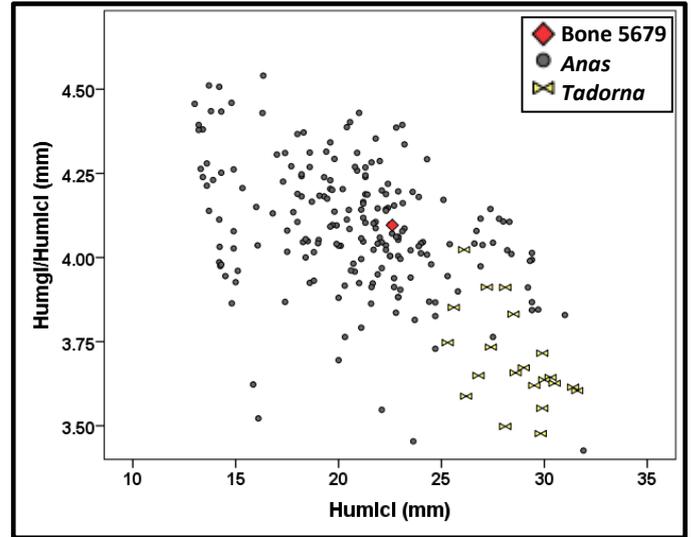


Figure 7.19.

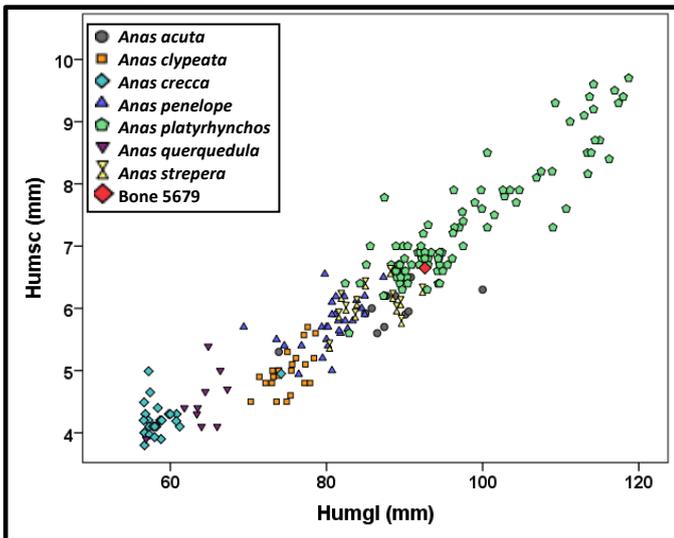


Figure 7.20.

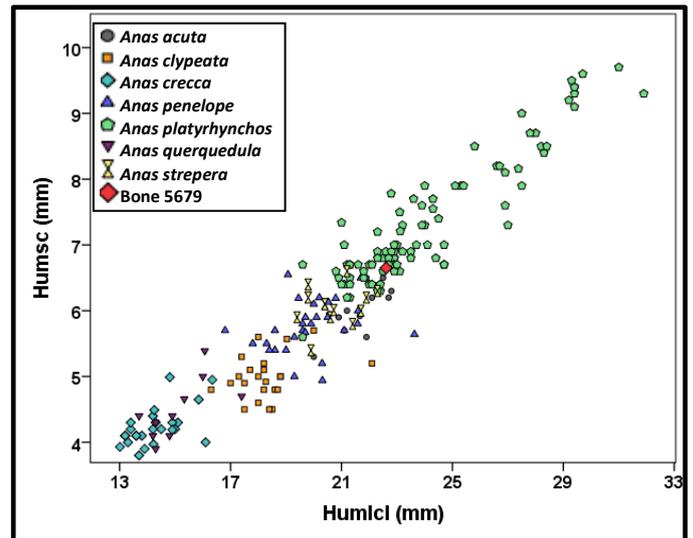


Figure 7.21.

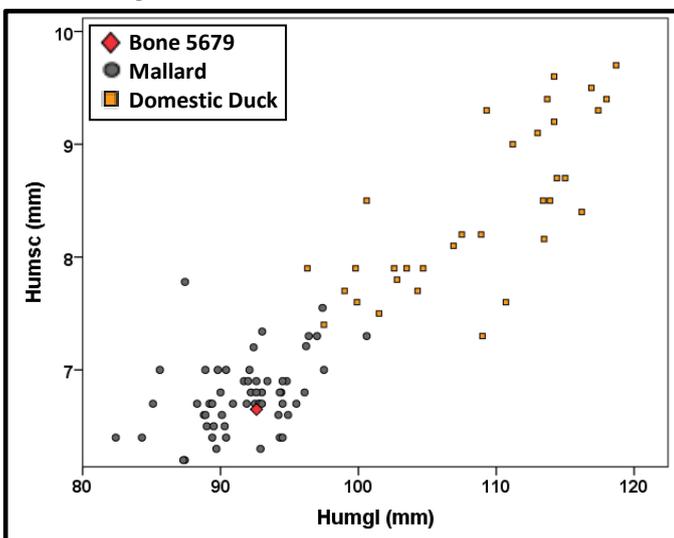


Figure 7.22.

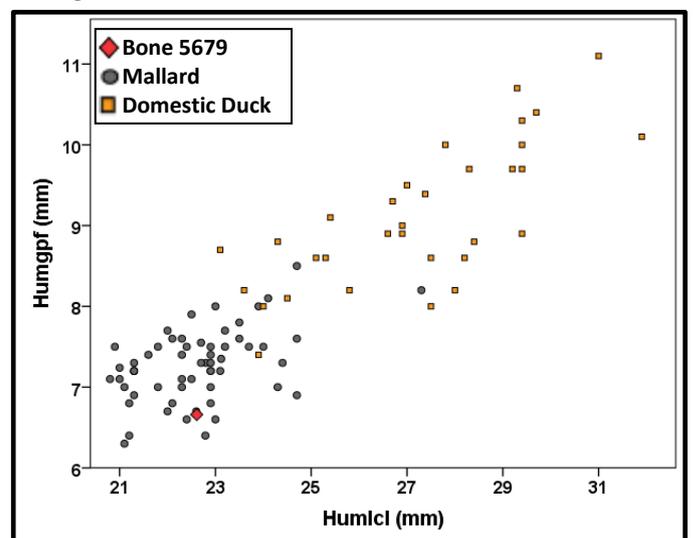
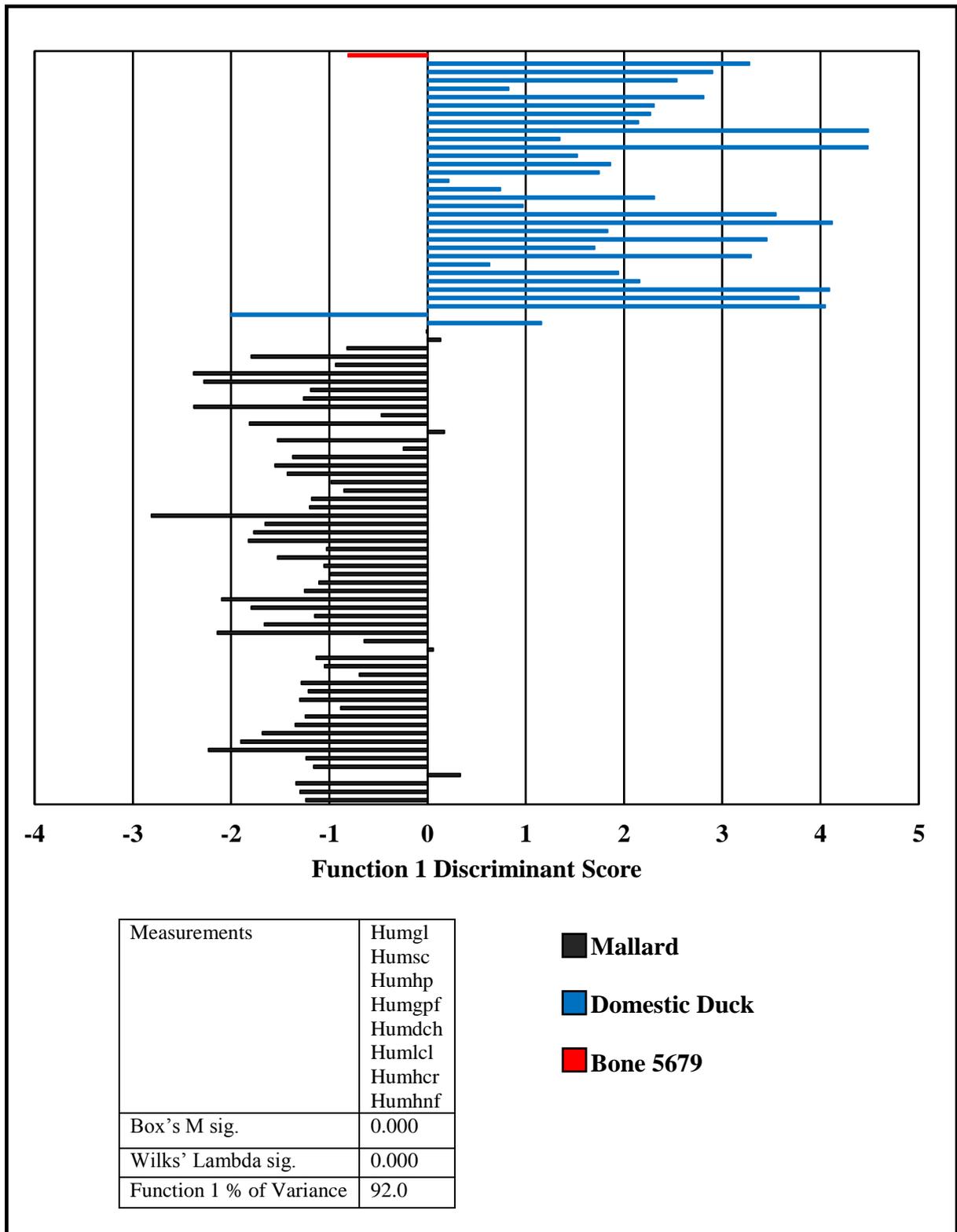


Figure 7.23.



### Example application of criterion 3: Bone 5866 - Tufted Duck

The third example of the application of the identification criteria presented concerns bone number 5866, which was identified as a Tufted Duck. Figures 7.24 and 7.25 show that the archaeological humerus was from a duck and was well outside the size range of geese based on size alone. Bi plots show that some genera, such as *Melanitta*, *Somateria*, and *Tadorna* can be ruled (figures 7.26 and 7.27). Figures 7.28 and 7.29 show that *Anas* can be ruled out using ratio plots and discriminant function analysis. The remaining genera were ruled out using a combination of bi-plots, ratio plots, and discriminant function analysis until only *Aythya* was left as a possible candidate for the genus identification of bone number 5866 (figures 7.30 to 7.34). For the species identification Scaup was ruled out based on size alone (figures 7.35 and 7.36) and Pochard was ruled out using a discriminant function analysis (figure 7.37). Therefore, bone 5866 was identified as belonging to a Tufted Duck (*Aythya fuligula*) with no other possible candidates left for the identification.

Figure 7.24.

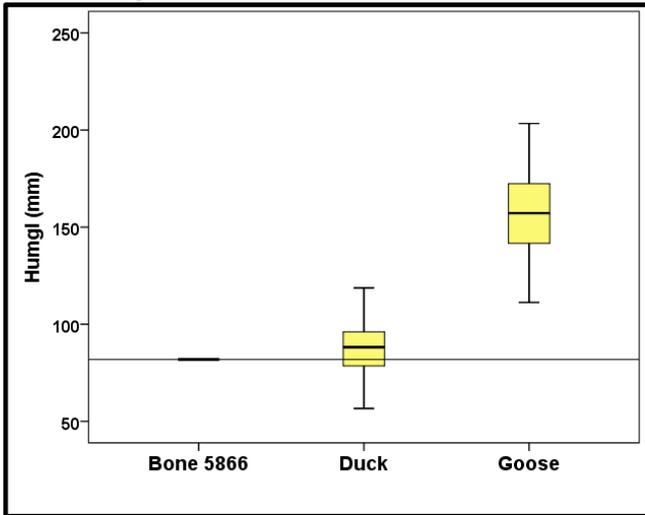


Figure 7.25.

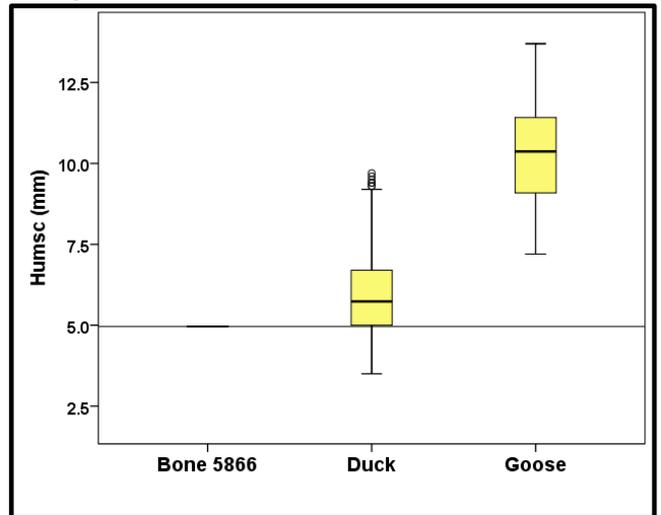


Figure 7.26.

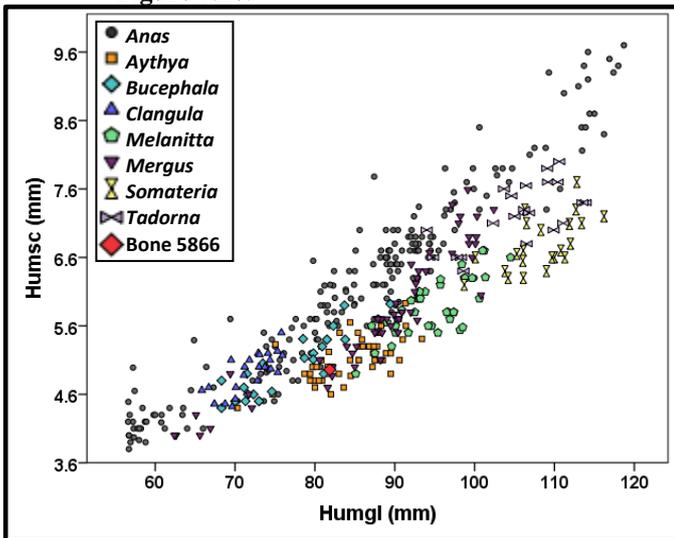


Figure 7.27.

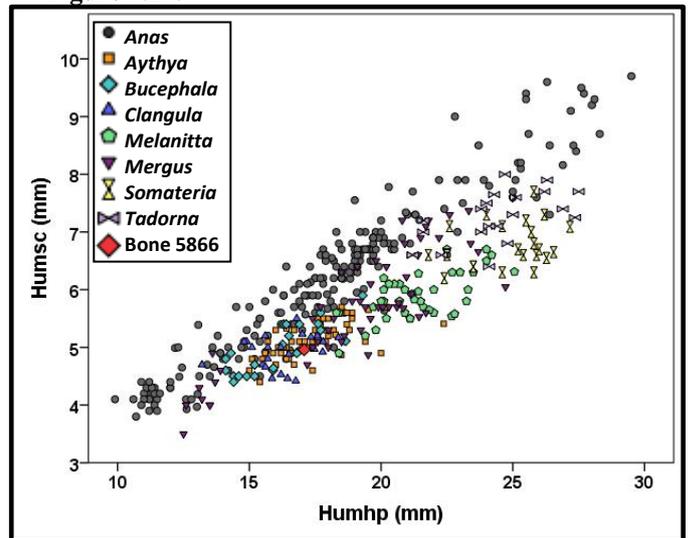


Figure 7.28.

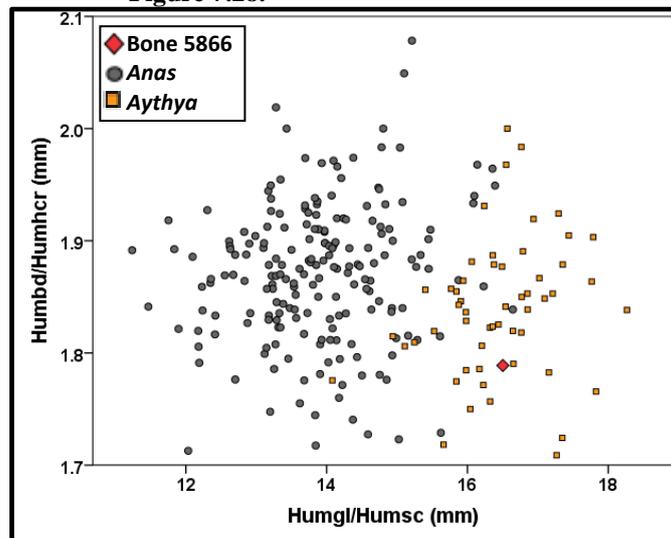


Figure 7.29.

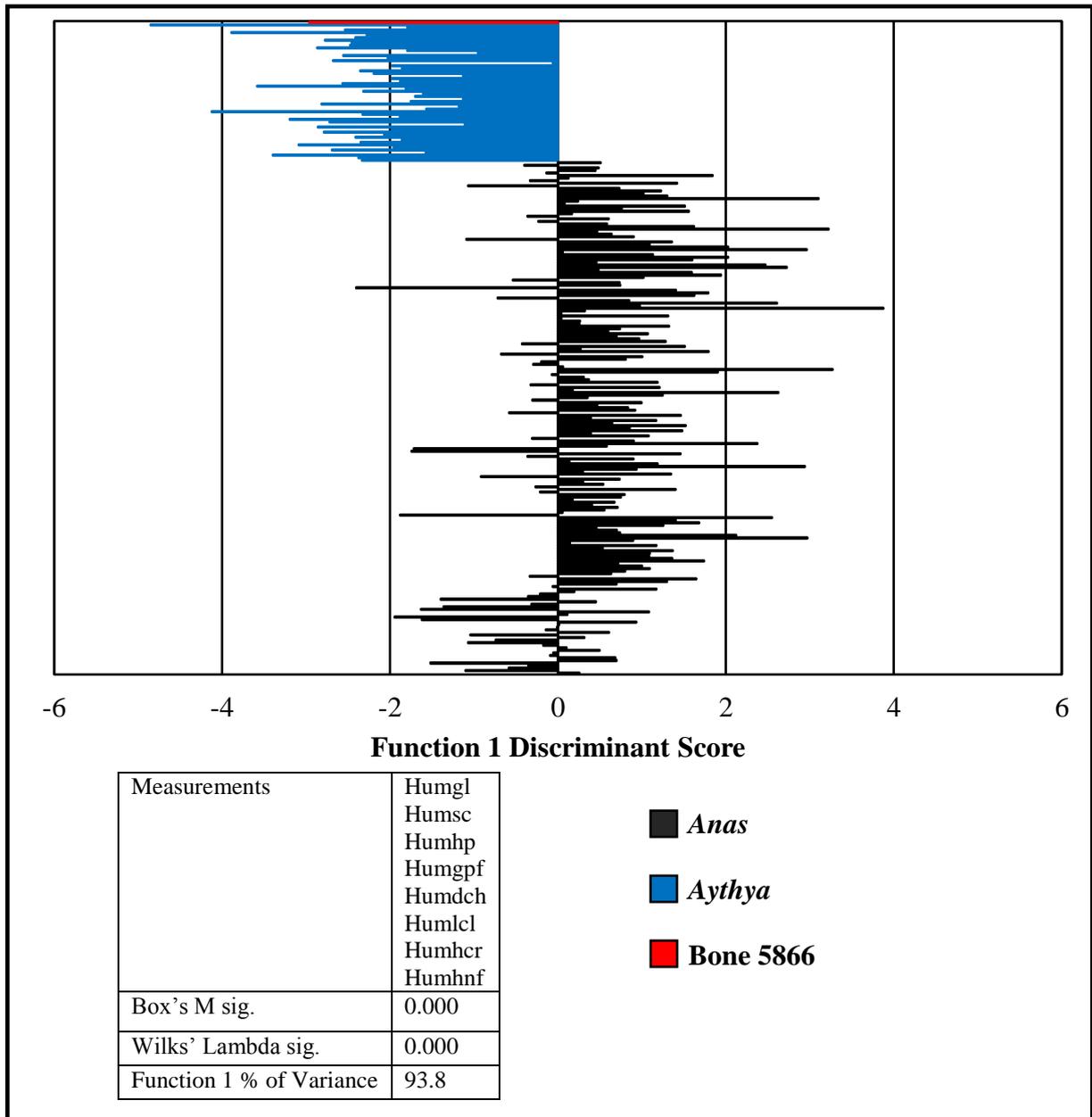


Figure 7.30.

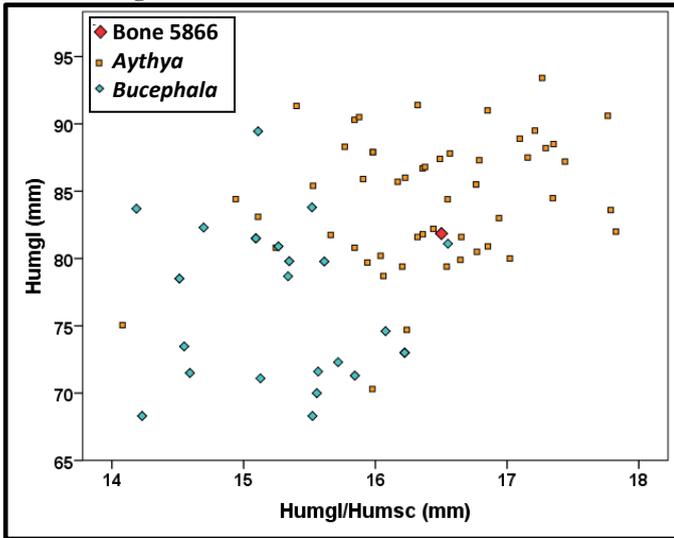


Figure 7.31.

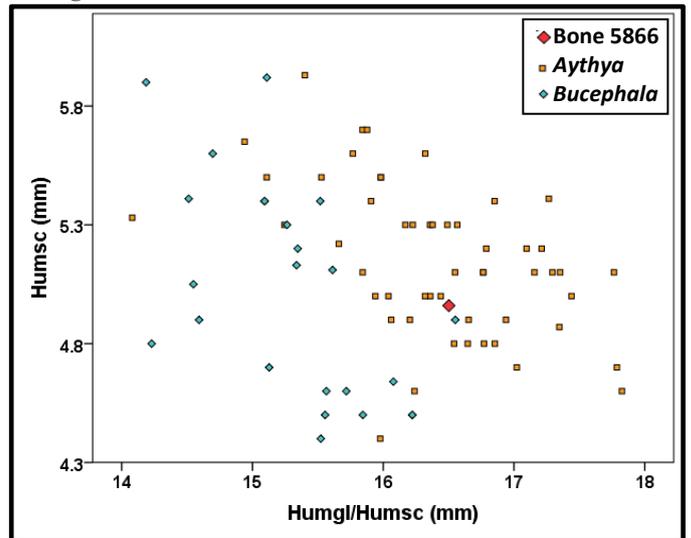


Figure 7.32.

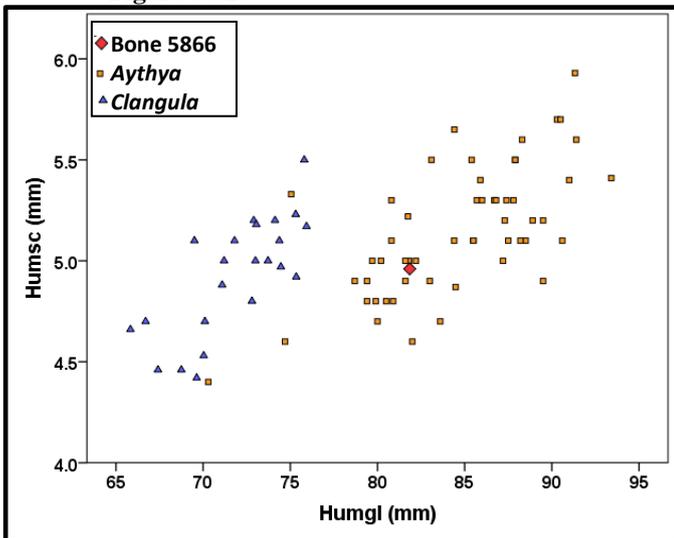


Figure 7.33.

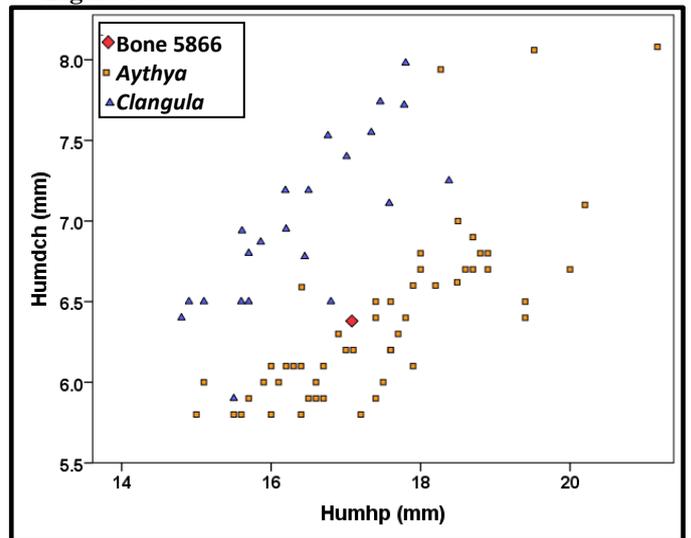


Figure 7.34.

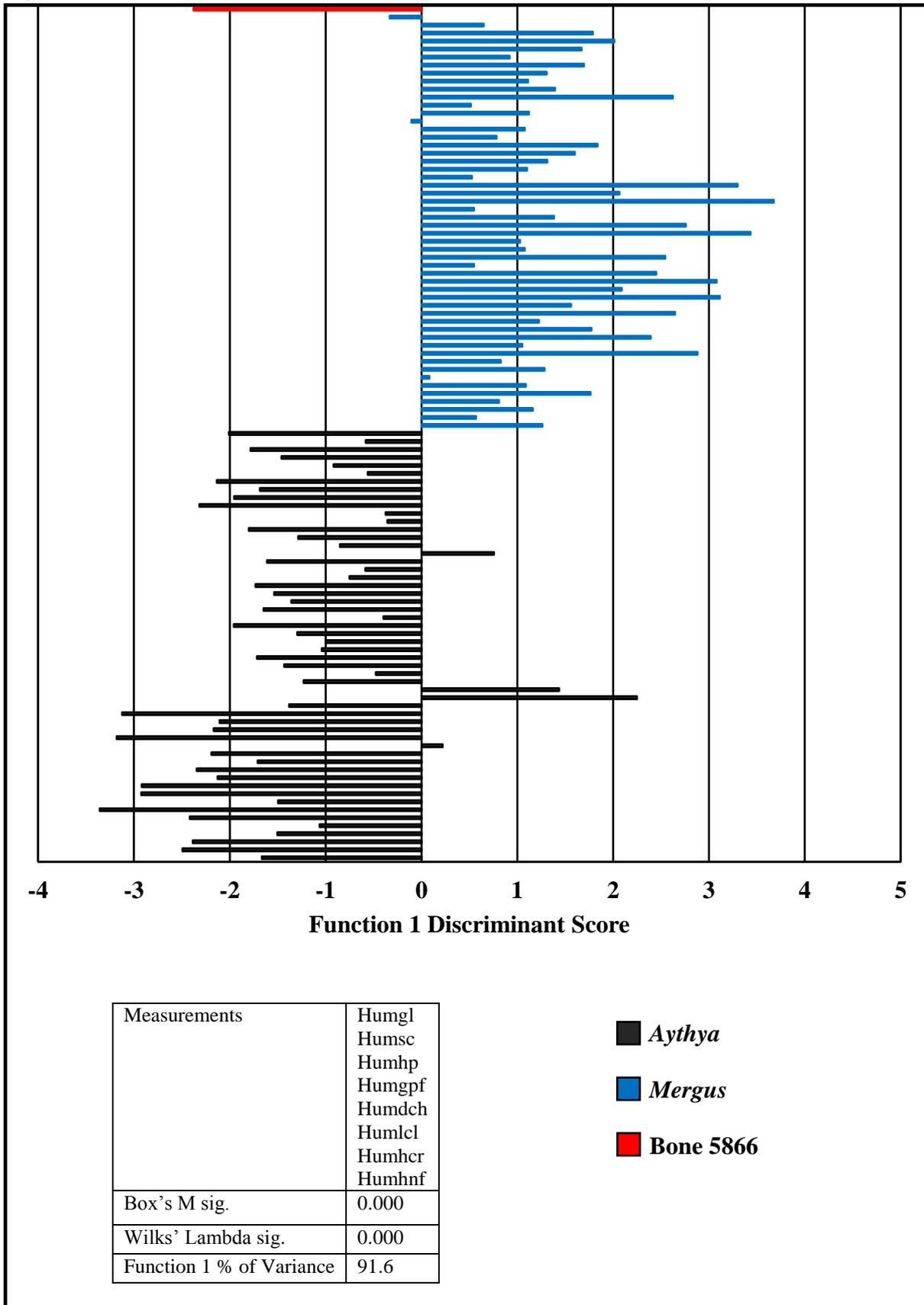


Figure 7.35.

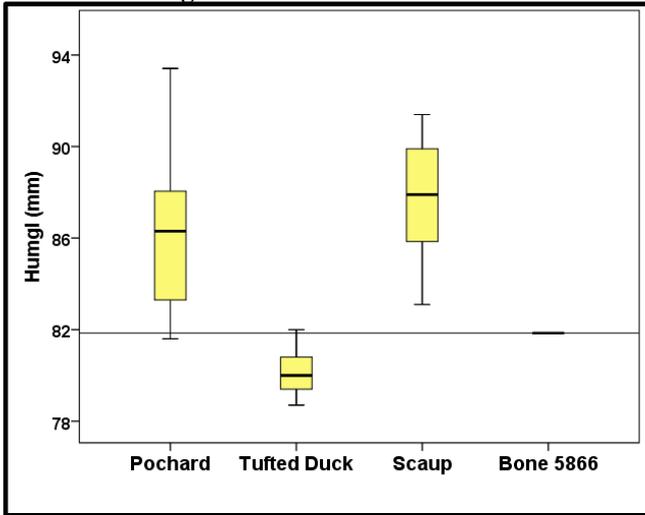


Figure 7.36.

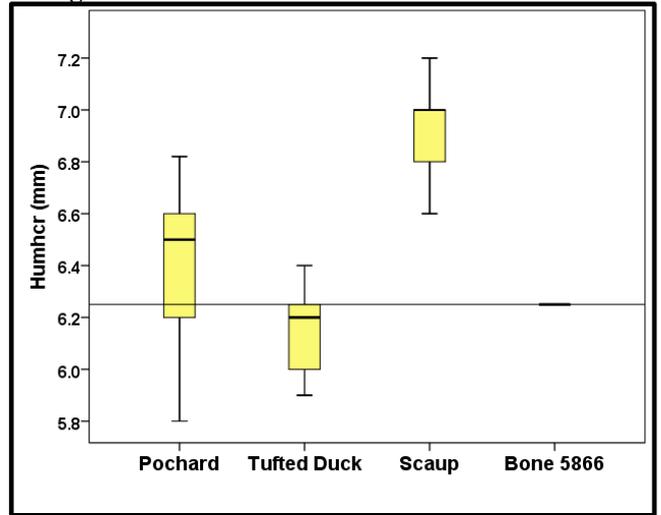
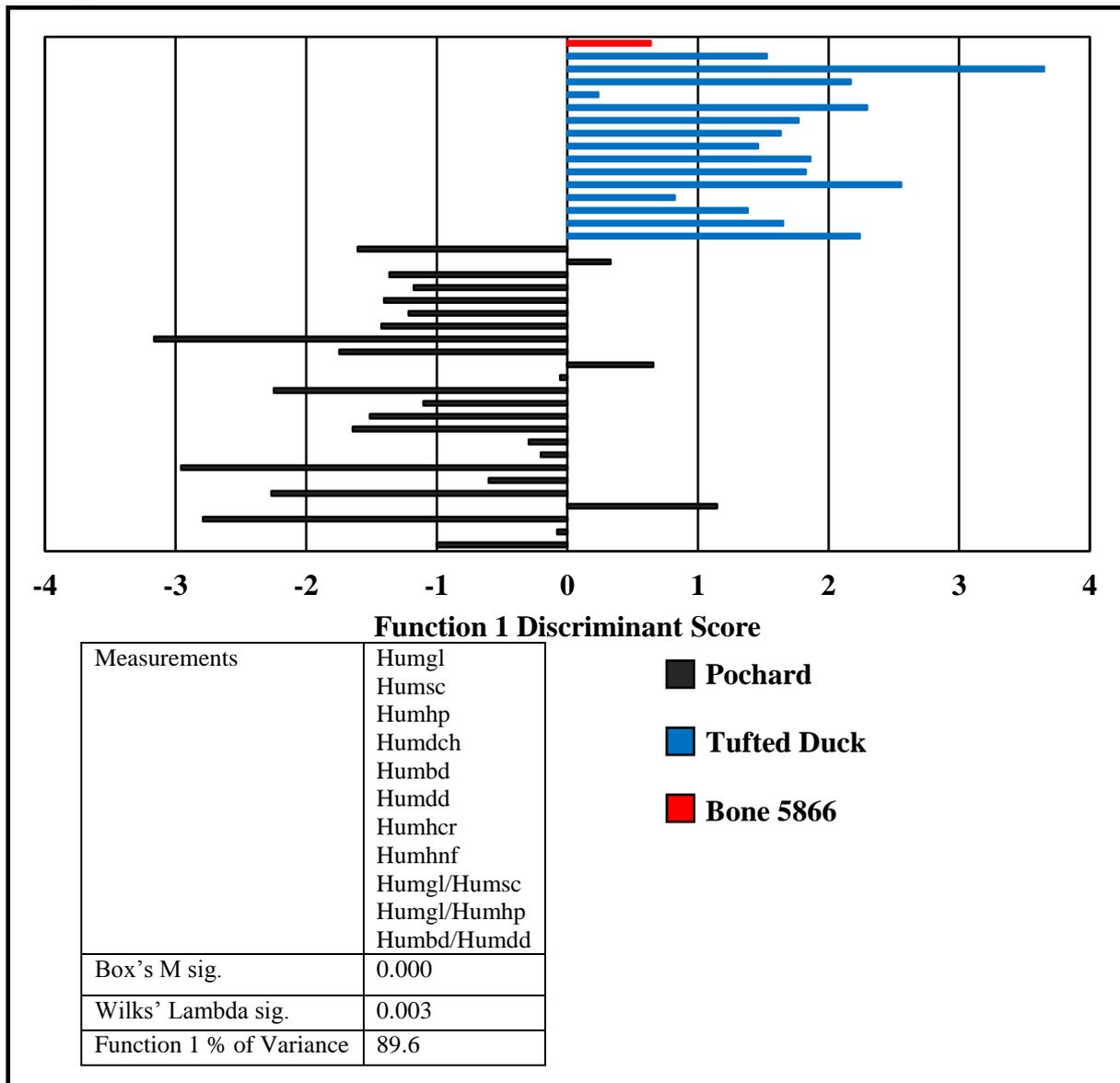


Figure 7.37.



These examples of the identification criteria developed on modern reference specimens show that the process of identification for archaeological bones is linear using a ruling out system. The process is to separate the most distantly related taxa first and then proceed until to the most closely related taxa can be separated. Using this system, the possibility of erroneous identifications is minimised and it is possible to make an identification to at least the genus level in most cases for the archaeological bones. All bones that could be reliably identified as duck or a goose, and met the criteria for recording outlined above, were recorded in the table in Appendix 2, even if only one measurement could be taken on the bone. All bones discussed below were identified using the process discussed above. Where it was not possible to distinguish between two taxa, the bone was identified as belonging to either/or the possible taxa. For example, if an archaeological bone always plotted in the overlap areas of *Anas* and *Aythya* in scatter plots, and not enough measurements could be taken for a discriminant function analysis, then it was recorded as “*Anas/Aythya*”.

The number of identifiable specimens (NISP) was calculated for each taxon by summing the number of identifiable elements for each specimen. Only bones that were 50% complete or more were included to avoid a bone being counted in the NISP twice. In this thesis, the minimum number of individuals (MNI) for a taxon equals the frequency of the most abundant element for that taxon. Here, no distinction was made for left and right but only bones that were 50% complete or higher were included. The NISP and MNI are the only two main quantification methods employed in this thesis as they are frequently used within zooarchaeology and make the results of this thesis easier to compare to other research projects. Further information about each bone, including side and which aspects of the bone are present, is recorded in Appendix 2 for any future researcher that wishes to recalculate the NISPs and MNIs to suit their needs.

## **10 Gresham Street, London**

Tables 7.1 and 7.2 detail the number of identifiable specimens at each of the identification stages by taxon, and then by taxon and element. There were only 14 duck and goose bones that could be identified to any stage using the criteria discussed in chapters 3-5 from a total of 51 duck and goose bones that were identified during the initial assessment of the zooarchaeological material (most bones from this assemblage were either too fragmented, the wrong element, or were from juvenile individuals and so could not be included in this analysis). This means that there is a restricted amount of work that can be done with the data in terms of analysis. However, it is worth pointing out two aspects about the data from this site. Firstly, there were two genera of duck, including three species (*Anas crecca*, *Anas platyrhynchos*, and *Mergus serrator*), and secondly there were two individual goose bones that fell within the modern domestic range, one of which fell outside of the modern wild range (figure 7.38). The sample size is small and it is impossible to say whether these results are representative of the consumption of these animals at the site during the Roman period, but it is worth noting that there is a range of duck species present and that there are two specimens that could be from a Domestic Goose.

**Table 7.1.** NISP and MNI totals for each taxon, at each stage of identification for the 10 Gresham Street assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	7	3	<i>Anas</i>	4	2	<i>Anas crecca</i>	2	1
						<i>Anas platyrhynchos</i>	2	1
			<i>Mergus</i>	2	2	<i>Mergus serrator</i>	2	2
			Indet.	1	-			
<i>Anserinae</i>	7	2	<i>Anser</i>	7	2	<i>Anser anser</i>	2	1
						<i>Anser anser</i> (dom)	1	1
						<i>Anser anser</i> (dom)?	1	1
						Indet. including <i>A. anser</i>	2	-
						Indet. excluding <i>A. anser</i>	1	-

**Table 7.2.** Frequency of each element for each taxon at each stage of the identification process for the 10 Gresham Street assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	1	<i>Anas</i>	Carpometacarpus	1	<i>Anas crecca</i>	Humerus	1
	Humerus	3		Humerus	2		Radius	1
	Radius	1		Radius	1	<i>Anas platyrhynchos</i>	Carpometacarpus	1
	Tibiotarsus	2					Humerus	1
				<i>Mergus</i>	Tibiotarsus	2	<i>Mergus serrator</i>	Tibiotarsus
<i>Anserinae</i>	Carpometacarpus	1	<i>Anser</i>	Carpometacarpus	1	<i>Anser anser</i>	Humerus	1
	Coracoid	1		Coracoid	1		Scapula	1
	Humerus	2		Humerus	2	<i>Anser anser</i> (dom)	Tarsometatarsus	1
	Scapula	1		Scapula	1	<i>Anser anser</i> (dom)?	Coracoid	1
	Tarsometatarsus	1		Tarsometatarsus	1			
	Ulna	1		Ulna	1			



applied. Figure 7.40 shows the frequency of the species identified within the genus *Anas*. Three species were positively identified; *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*. *Anas platyrhynchos* forms the majority of the *Anas* assemblage (79% of the NISP), but that still leaves a significant proportion of the *Anas* assemblage that belongs to other species. There was only one *Anas platyrhynchos* bone (a radius) that plotted within the modern domestic size range, but it was still potentially within the wild range as well (figure 7.41). All five of the *Mergus* bones were identified as *Mergus serrator*, representing an MNI of five as they all belonged to the same element (tibiotarsus).

Within the geese, nearly all of the 66 bones were identified as *Anser* as it was only impossible to determine genus in two cases (tables 7.3 and 7.4). *Anser anser* was the only species of *Anser* that was positively identified (*i.e.* with no other possible species as candidate) and forms the majority of the goose assemblage. *Anser anser* could not be ruled out as the species in all of the other *Anser* bones where there was more than one possible species for the identification (table 7.3). Of the *Anser anser* there were several bones that fell within the modern domestic range, and seven bones that fell outside of the modern wild range and so it is likely that there were at least some domestic geese present at Caister-on-Sea during the Roman period (figure 7.42). What is worth pointing out about these new results is that there was clearly a very different way in which ducks and geese were used at the site, which was not identified in the original analysis (Harman 1993). These new results suggest that whilst a range of wild duck species were utilised, it is possible that only one species of goose was, which may have been the Domestic Goose. There was likely different attitudes towards ducks and geese during the Roman period that reflected the general attitudes of the people that lived at Caister-on-Sea, which is discussed in the next chapter.

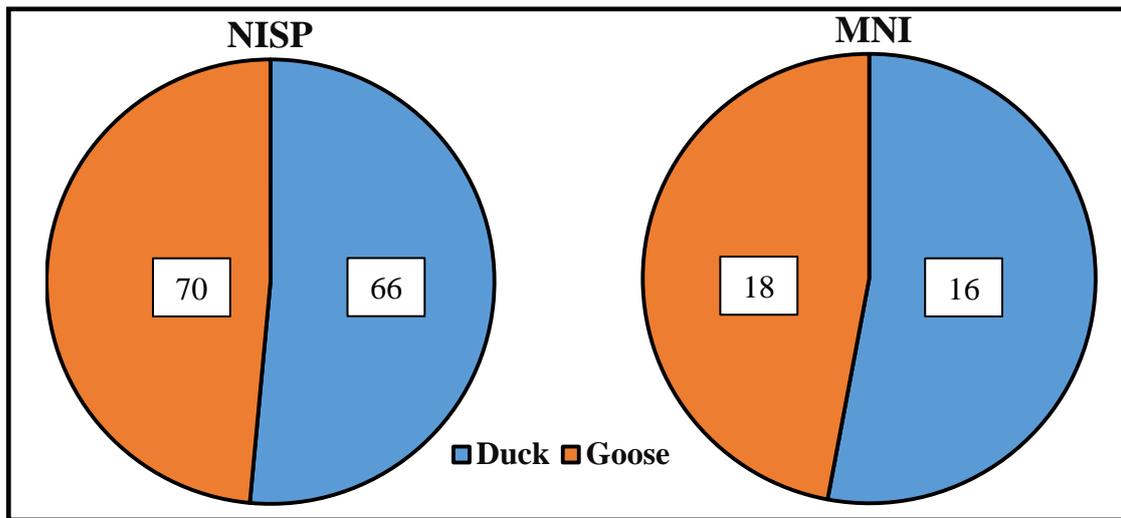
**Table 7.3.** NISP and MNI totals for each taxon, at each stage of identification for the Caister-on-Sea assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	70	18	<i>Anas</i>	48	15	<i>Anas crecca</i>	3	2
						<i>Anas penelope</i>	3	3
						<i>Anas platyrhynchos</i>	36	14
						<i>Anas platyrhynchos</i> (dom)?	1	1
						Indet. including <i>A. platyrhynchos</i>	1	-
						Indet. excluding <i>A. platyrhynchos</i>	4	-
			<i>Mergus</i>	5	5	<i>Mergus serrator</i>	5	5
Indet.	17	-						
<i>Anserinae</i>	66	16	<i>Anser</i>	64	16	<i>Anser anser</i>	13	5
						<i>Anser anser</i> (dom)	7	6
						<i>Anser anser</i> (dom)?	36	9
						Indet. including <i>A. anser</i>	7	-
						Indet. excluding <i>A. anser</i>	1	-
			Indet.	2	-			
Indet.	5	-						

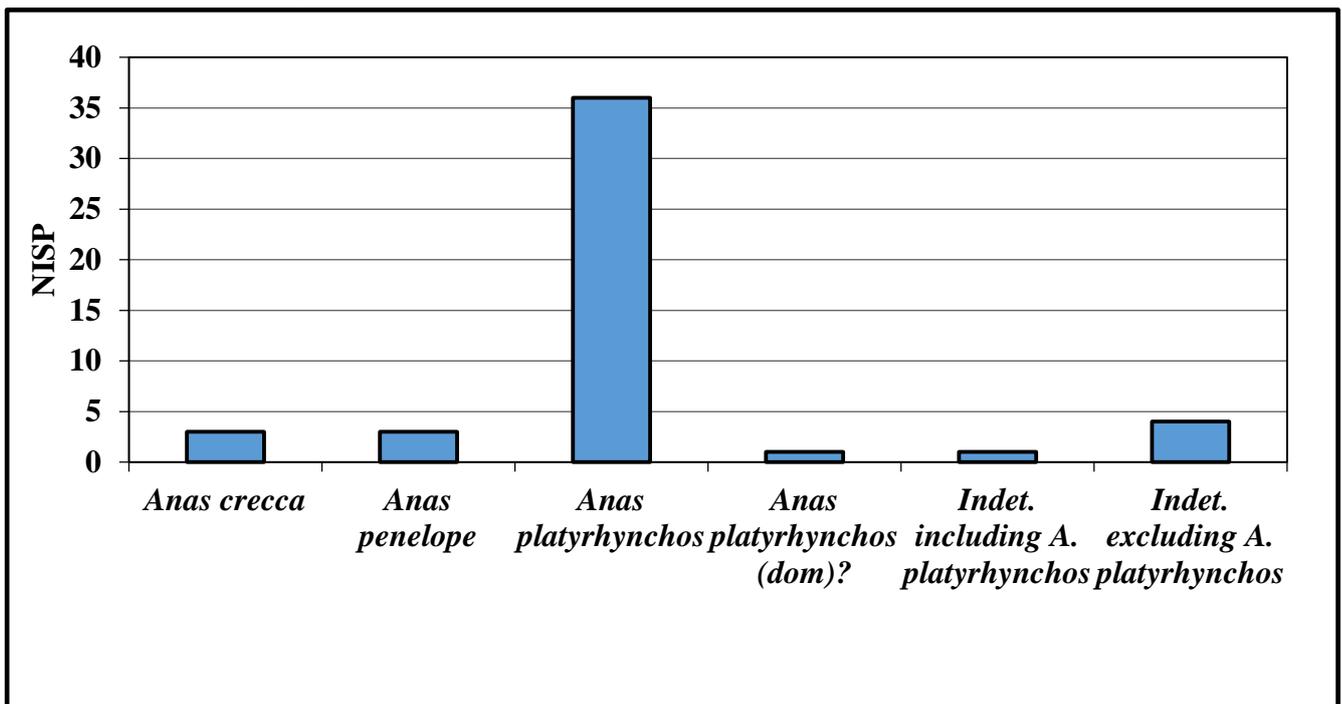
**Table 7.4.** Frequency of each element for each taxon at each stage of the identification process for the Caister-on-Sea assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
Anatinae	Carpometacarpus	9	Anas	Carpometacarpus	4	<i>Anas crecca</i>	Humerus	2
	Coracoid	6		Coracoid	5		Tibiotarsus	1
	Femur	1		Femur	1	<i>Anas penelope</i>	Carpometacarpus	3
	Humerus	13		Humerus	9	<i>Anas platyrhynchos</i>	Coracoid	5
	Radius	7		Radius	6		Femur	1
	Scapula	2		Tarsometatarsus	5		Humerus	5
	Tarsometatarsus	5		Tibiotarsus	3		Radius	5
	Tibiotarsus	9		Ulna	15		Tarsometatarsus	4
	Ulna	18					Tibiotarsus	2
						Ulna	14	
				<i>Anas platyrhynchos (dom)?</i>	Radius	1		
			<i>Mergus</i>	Tibiotarsus	5	<i>Mergus serrator</i>	Tibiotarsus	5
Anserinae	Carpometacarpus	6	Anser	Carpometacarpus	6	<i>Anser anser</i>	Carpometacarpus	1
	Coracoid	3		Coracoid	3		Coracoid	2
	Femur	7		Femur	6		Femur	2
	Humerus	16		Humerus	16		Humerus	5
	Radius	4		Radius	4		Ulna	3
	Scapula	2		Scapula	1	<i>Anser anser (dom)</i>	Tarsometatarsus	6
	Tarsometatarsus	13		Tarsometatarsus	13		Tibiotarsus	1
	Tibiotarsus	10		Tibiotarsus	10	<i>Anser anser (dom)?</i>	Carpometacarpus	3
	Ulna	5		Ulna	5		Femur	4
							Humerus	9
				Radius	4			
				Tarsometatarsus	6			
				Tibiotarsus	8			
				Ulna	2			

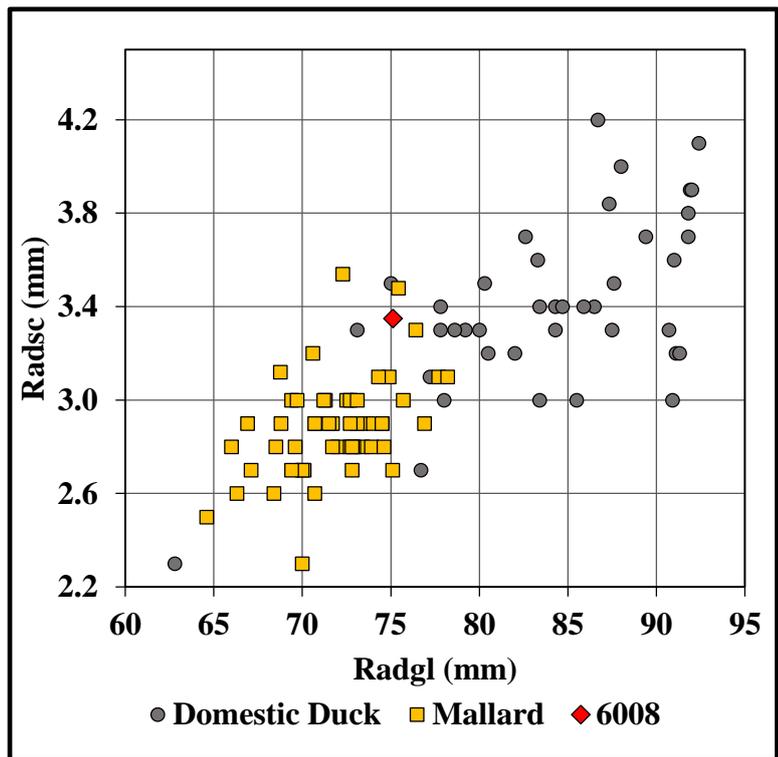
**Figure 7.39.** Pie charts showing the relative frequency of ducks to geese from Caister-on-Sea (sample size indicated in the charts).



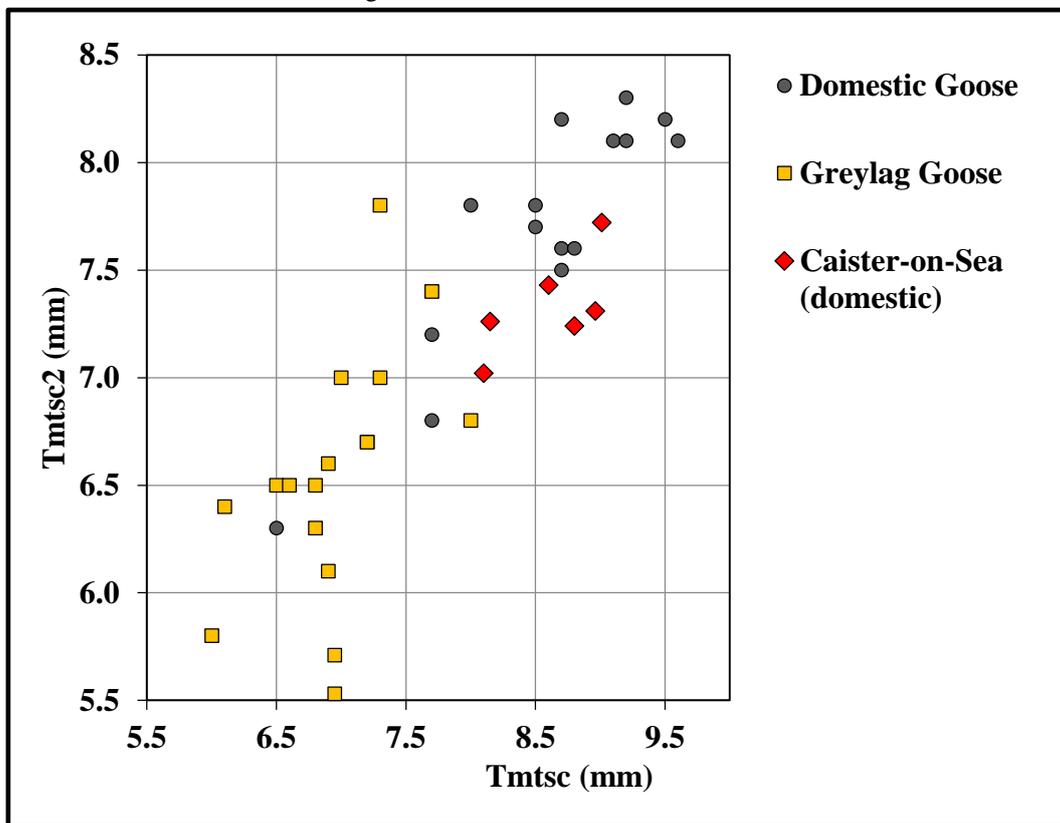
**Figure 7.40.** Bar chart showing the frequency of *Anas* species identified at Caister-on-Sea (sample size indicated in the charts).



**Figure 7.41.** Scatter plot showing Bone 6008 (radius) from the Caister-on-Sea assemblage plotting in the overlap of the modern wild duck cluster and the modern Domestic Duck cluster.



**Figure 7.42.** Scatter plot showing *Anser anser* tarsometatarsi from the Caister-on-Sea assemblage plotting outside of the modern wild goose cluster and with the modern Domestic Goose cluster.



### **Causeway Lane, Leicester**

The sample size of the identifiable specimens from Causeway Lane was similar to that of 10 Gresham Street with 15 identifiable specimens. However, unlike 10 Gresham Street, Causeway Lane is mainly comprised of duck bones, with a ratio of 13 ducks to 2 geese (tables 7.5 and 7.6). The sample size is too small to reliably say that this is indicative of the use of these animals at the site during the Roman period, but does mean that this site may be similar to other sites discussed in this chapter in that ducks were more frequently consumed than geese. The only genera that could be positively identified were *Anas* and *Anser* representing the ducks and geese respectively. No completely reliable identification of the species of goose could be made, but the two goose bones were restricted to belonging to either *Anser anser* or *Anser fabalis* with all other species ruled out. Conversely, a range of duck species were identified showing that even though the sample size was small, the use of the most common species (*Anas platyrhynchos*) was not exclusive. All of the identifiable specimens from this assemblage belonged to a wild taxon according to the identification criteria discussed in chapters 3-5.

**Table 7.5.** NISP and MNI totals for each taxon, at each stage of identification for the Causeway Lane assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	13	3	<i>Anas</i>	8	3	<i>Anas acuta</i>	1	1
						<i>Anas clypeata</i>	1	1
						<i>Anas crecca</i>	2	1
						<i>Anas platyrhynchos</i>	3	2
			Indet. including <i>A. platyrhynchos</i>	1	-			
			Indet.	5	-			
<i>Anserinae</i>	2	1	<i>Anser</i>	2	1	Indet. including <i>A. anser</i>	2	-

**Table 7.6.** Frequency of each element for each taxon at each stage of the identification process for the Causeway Lane assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	1	<i>Anas</i>	Carpometacarpus	1	<i>Anas acuta</i>	Tibiotarsus	1
	Coracoid	3		Coracoid	3	<i>Anas clypeata</i>	Coracoid	1
	Humerus	1		Humerus	1	<i>Anas crecca</i>	Carpometacarpus	1
	Scapula	2		Tarsometatarsus	2		Tarsometatarsus	1
	Tarsometatarsus	2		Tibiotarsus	1	<i>Anas platyrhynchos</i>	Coracoid	2
	Tibiotarsus	3					Tarsometatarsus	1
	Ulna	1						
<i>Anserinae</i>	Femur	1	<i>Anser</i>	Femur	1			
	Humerus	1		Humerus	1			

### **Docklands Light Railway (Monument Street), London**

The assemblage from the site on Monument Street is the largest assessed in this thesis and therefore has the best opportunity for representing the use of ducks and geese on site during the Roman period. Tables 7.7 and 7.8 detail the frequency of each taxon at each stage of the identification process, first just by taxon then by element. The total NISP for the site is 151 with 64% being identified as duck and 36% being identified as goose. However, their MNIs are much more similar with only four more ducks than geese (table 7.7).

Within the ducks, the only genus that could be positively identified (*i.e.* there was no other possible candidate genus) was *Anas*. *Anas* could not be ruled out for any of the bones that could not be identified to a single genus, but *Anas* would still have accounted for the majority of the duck assemblage (84% of the NISP) even if every other bone was not *Anas*. Within *Anas*, three species were positively identified: *Anas clypeata*, *Anas crecca*, and *Anas platyrhynchos*. Of the three, *Anas platyrhynchos* is by far the most frequent and accounts for 77% of the total *Anas* NISP. However, it is worth pointing out that 23% of the *Anas* bones from this site were not *Anas platyrhynchos* (the most common wild duck and the wild progenitor of the Domestic Duck) and actually at least four species are represented (one bone being *Anas acuta* or *Anas strepera*, Appendix 2) meaning that a range of species were utilised. All *Anas platyrhynchos* bones, with the exception of one scapula (figure 7.43), were consistent with the modern wild form with no overlap with the modern domestic range. It is not possible to say that there were Domestic Ducks present on site during the Roman period as only one bone plotted within the modern domestic range. It may be the case that a wild duck was unusually large, and so a single bone cannot be used in isolation to identify the presence of Domestic Ducks on site.

Both genera of goose that are assessed in this thesis were identified within the Monument Street assemblage (*Anser* and *Branta*). Looking at the NISP figures for the

genera, there were around four times as many identifiable *Anser* bones as *Branta*, but the MNI for the genus level of identification shows that there was only a difference of four between the genera (table 7.7). Within the genus *Anser* three species were positively identified: *Anser albifrons*, *Anser anser*, and *Anser fabalis*. Of the three species *Anser anser* was the most frequent and accounted for 30% of the total *Anser* NISP (table 7.7). 50% of the NISP for *Anser* were not *Anser anser* and shows that a range of species were present on site. No goose bone plotted outside of the modern wild range and so it is unlikely that there were any domestic geese present on site during the Roman period. *Branta leucopsis* was the only *Branta* species present, which had an MNI of seven (table 7.7).

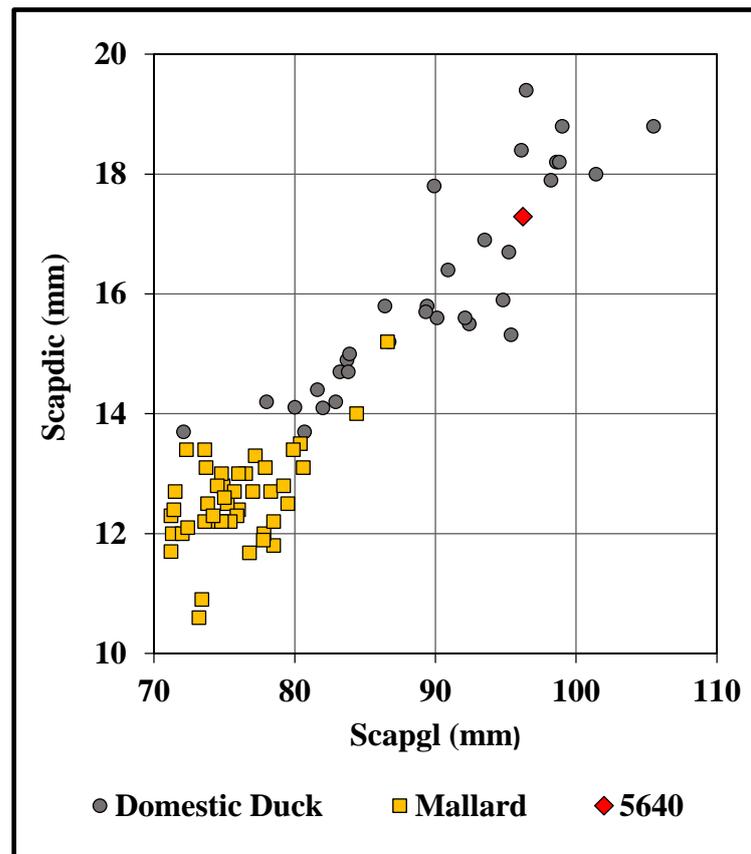
**Table 7.7.** NISP and MNI totals for each taxon, at each stage of identification for the Monument Street assemblage.

<b>Subfamily</b>	<b>NISP</b>	<b>MNI</b>	<b>Genus</b>	<b>NISP</b>	<b>MNI</b>	<b>Species</b>	<b>NISP</b>	<b>MNI</b>
<i>Anatinae</i>	97	19	<i>Anas</i>	81	19	<i>Anas clypeata</i>	1	1
						<i>Anas crecca</i>	8	4
						<i>Anas platyrhynchos</i>	61	15
						<i>Anas platyrhynchos</i> (dom)?	1	1
						Indet. including <i>A. platyrhynchos</i>	4	-
			Indet. excluding <i>A. platyrhynchos</i>	6	-			
			Indet.	16	-			
<i>Anserinae</i>	54	15	<i>Anser</i>	44	11	<i>Anser albifrons</i>	3	2
						<i>Anser anser</i>	13	4
						<i>Anser fabalis</i>	3	3
						Indet. including <i>A. anser</i>	9	-
						Indet. excluding <i>A. anser</i>	16	-
			<i>Branta</i>	10	7	<i>Branta leucopsis</i>	10	7

**Table 7.8.** Frequency of each element for each taxon at each stage of the identification process for the Monument Street assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	9	<i>Anas</i>	Carpometacarpus	9	<i>Anas clypeata</i>	Tarsometatarsus	1
	Coracoid	19		Coracoid	19	<i>Anas crecca</i>	Coracoid	4
	Femur	7		Femur	7		Radius	1
	Humerus	16		Humerus	16		Scapula	1
	Radius	15		Radius	6		Ulna	2
	Scapula	9		Scapula	2	<i>Anas platyrhynchos</i>	Carpometacarpus	8
	Tarsometatarsus	6		Tarsometatarsus	6		Coracoid	12
	Tibiotarsus	7		Tibiotarsus	7		Femur	6
	Ulna	9		Ulna	9		Humerus	15
							Radius	2
				Tarsometatarsus	4			
				Tibiotarsus	7			
				Ulna	7			
				<i>Anas platyrhynchos</i> (dom)?	Scapula	1		
<i>Anserinae</i>	Carpometacarpus	15	<i>Anser</i>	Carpometacarpus	8	<i>Anser albifrons</i>	Coracoid	1
	Coracoid	5		Coracoid	4	Humerus	2	
	Humerus	7		Humerus	7	<i>Anser anser</i>	Carpometacarpus	3
	Radius	8		Radius	7		Coracoid	1
	Tarsometatarsus	6		Tarsometatarsus	5		Humerus	4
	Tibiotarsus	2		Tibiotarsus	2		Tarsometatarsus	2
	Ulna	11		Ulna	11		Tibiotarsus	2
					Ulna	1		
					<i>Anser fabalis</i>	Ulna	3	
				<i>Branta</i>	Carpometacarpus	7	<i>Branta leucopsis</i>	Carpometacarpus
			Coracoid		1	Coracoid		1
			Radius		1	Radius		1
			Tarsometatarsus		1	Tarsometatarsus		1

**Figure 7.43.** Scatter plot showing bone 5640 (scapula) from the Monument Street assemblage plotting outside of the modern wild duck cluster and with the modern Domestic Duck cluster.



### Fishbourne Palace, Sussex

The assemblage from Fishbourne Palace is the third largest analysed in this thesis and presents a real opportunity to investigate the use of ducks and geese at a high status site in Roman Britain. The total NISP for the assemblage is 130 and the NISP and MNI frequencies for each taxon, at each stage of identification, are detailed in tables 7.9 and 7.10. What is immediately evident from the data is that there are many more ducks than geese, according to both NISP and the MNI (figure 7.44), which is similar to some of the other sites assessed in this thesis. Of the ducks, four genera were positively identified; *Anas*, *Aythya*, *Melanitta*, and *Mergus*. *Anas* accounts for the majority of the duck bones with 79% of the total duck NISP. The other three genera only account for 7% of the total duck NISP, but this site has the highest

number of positively identified duck genera from all of the assemblages discussed in this thesis. Of the *Anas* remains, five species were positively identified: *Anas acuta*, *Anas clypeata*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*. *Anas platyrhynchos* accounts for the majority of the *Anas* assemblage with 80% of the NISP, but 16% of the *Anas* NISP are definitely not *Anas platyrhynchos* meaning a significant amount of the *Anas* assemblage does not belong to the wild progenitor of the Domestic Duck. Three bones of *Anas platyrhynchos* plotted within the modern Domestic Duck range and marginally outside of the modern wild range (figures 7.45 and 7.46). However, the evidence is not strong enough to claim with any certainty the occurrence of the domestic form, as the possible incidence of a few larger wild specimens cannot be ruled out. Bone 5911 did not have enough measurements for a discriminant function analysis, and the results were inconclusive for the two humeri.

Of the other genera of ducks identified, just one species from each genus was positively identified; *Aythya fuligula*, *Melanitta fusca*, and *Mergus serrator*. Both *Aythya fuligula* and *Melanitta fusca* have an MNI of one (table 7.9), and *Mergus serrator* has an MNI of five. The possible uses of these birds, and why there is a larger range of species at this site, are discussed in the following chapter.

Of the geese, only bones belonging to the genus *Anser* were identified, but within that two species were identified; *Anser anser* and *Anser brachyrhynchus*. The goose assemblage is much smaller than the duck assemblage with a total NISP of just 17 and *Anser anser* could only be ruled out in two cases (table 7.9). Of the nine positively identified *Anser anser*, six plotted within the modern domestic range and outside the modern wild range (e.g. figure 7.47). Even though this is only a small sample, it does suggest that at least some domestic geese were present at the site during the Roman period. The significance of this is discussed in the next chapter.

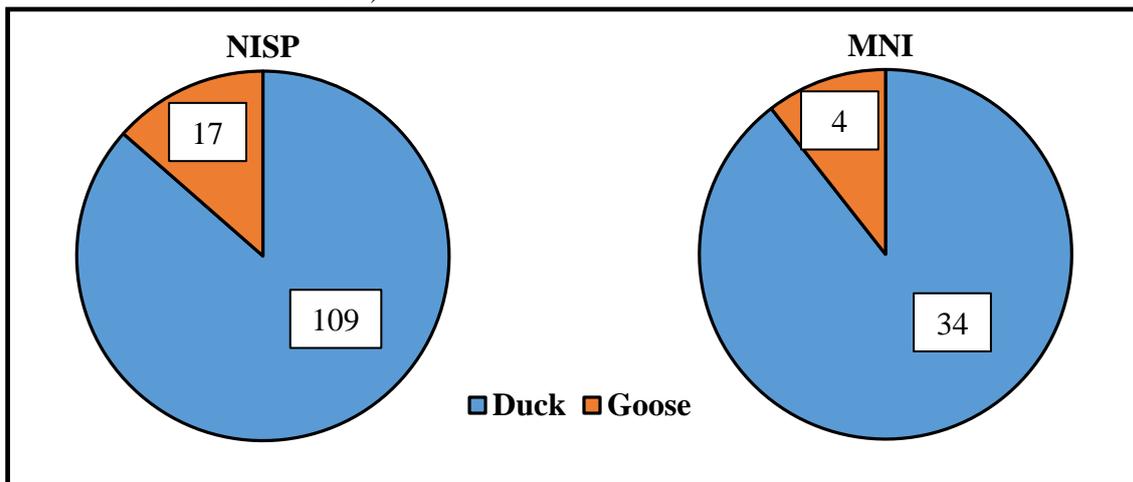
**Table 7.9.** NISP and MNI totals for each taxon, at each stage of identification for the Fishbourne Palace assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	109	34	<i>Anas</i>	86	30	<i>Anas acuta</i>	4	4
						<i>Anas clypeata</i>	2	2
						<i>Anas crecca</i>	3	3
						<i>Anas penelope</i>	3	1
						<i>Anas platyrhynchos</i>	66	20
						<i>Anas platyrhynchos</i> (dom)?	3	2
						Indet. including <i>A. platyrhynchos</i>	3	-
						Indet. excluding <i>A. platyrhynchos</i>	2	-
			<i>Aythya</i>	2	1	<i>Aythya fuligula</i>	2	1
			<i>Melanitta</i>	1	1	<i>Melanitta fusca</i>	1	1
<i>Mergus</i>	5	5	<i>Mergus serrator</i>	5	5			
Indet.	16	-						
<i>Anserinae</i>	17	4	<i>Anser</i>	17	4	<i>Anser anser</i>	3	3
						<i>Anser anser</i> (dom)	6	2
						<i>Anser brachyrhynchus</i>	1	1
						Indet. including <i>A. anser</i>	6	-
						Indet. excluding <i>A. anser</i>	1	-
Indet.	4	-						

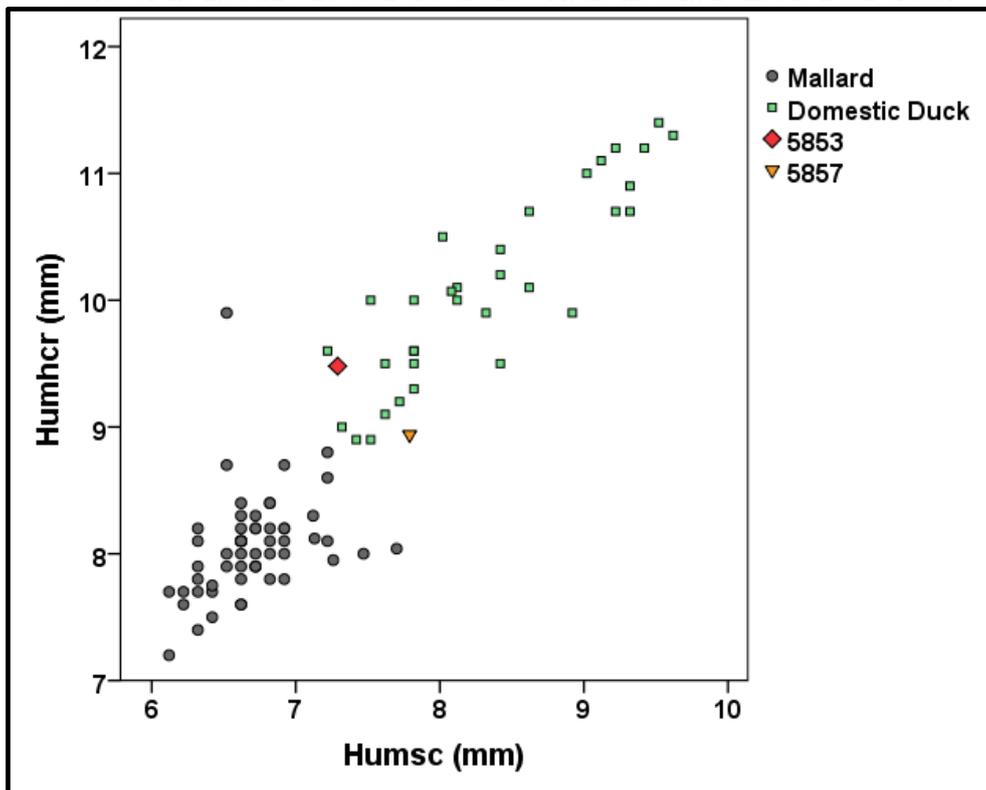
**Table 7.10.** Frequency of each element for each taxon at each stage of the identification process for the Fishbourne Palace assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	20	<i>Anas</i>	Carpometacarpus	20	<i>Anas acuta</i>	Ulna	4
	Coracoid	10		Coracoid	9	<i>Anas clypeata</i>	Ulna	2
	Femur	4		Femur	4	<i>Anas crecca</i>	Ulna	3
	Humerus	14		Humerus	11	<i>Anas penelope</i>	Femur	1
	Radius	6		Radius	4		Humerus	1
	Scapula	2		Tarsometatarsus	6		Tibiotarsus	1
	Tarsometatarsus	6		Tibiotarsus	2	<i>Anas platyrhynchos</i>	Carpometacarpus	20
	Tibiotarsus	13		Ulna	30		Coracoid	8
	Ulna	34					Femur	3
							Humerus	6
							Radius	3
							Tarsometatarsus	5
							Tibiotarsus	1
						Ulna	20	
				<i>Anas platyrhynchos (dom)?</i>	Humerus	2		
					Ulna	1		
			<i>Aythya</i>	Humerus	1	<i>Aythya fuligula</i>	Humerus	1
				Tibiotarsus	1		Tibiotarsus	1
			<i>Melanitta</i>	Humerus	1	<i>Melanitta fusca</i>	Humerus	1
			<i>Mergus</i>	Tibiotarsus	5	<i>Mergus serrator</i>	Tibiotarsus	5
<i>Anserinae</i>	Carpometacarpus	2	<i>Anser</i>	Carpometacarpus	2	<i>Anser anser</i>	Humerus	3
	Femur	2		Femur	2	<i>Anser anser (dom)</i>	Carpometacarpus	1
	Humerus	4		Humerus	4		Humerus	1
	Radius	1		Radius	1		Radius	1
	Tarsometatarsus	3		Tarsometatarsus	3		Tarsometatarsus	2
	Tibiotarsus	1		Tibiotarsus	1		Ulna	1
	Ulna	4		Ulna	4	<i>Anser brachyrhynchus</i>	Tarsometatarsus	1

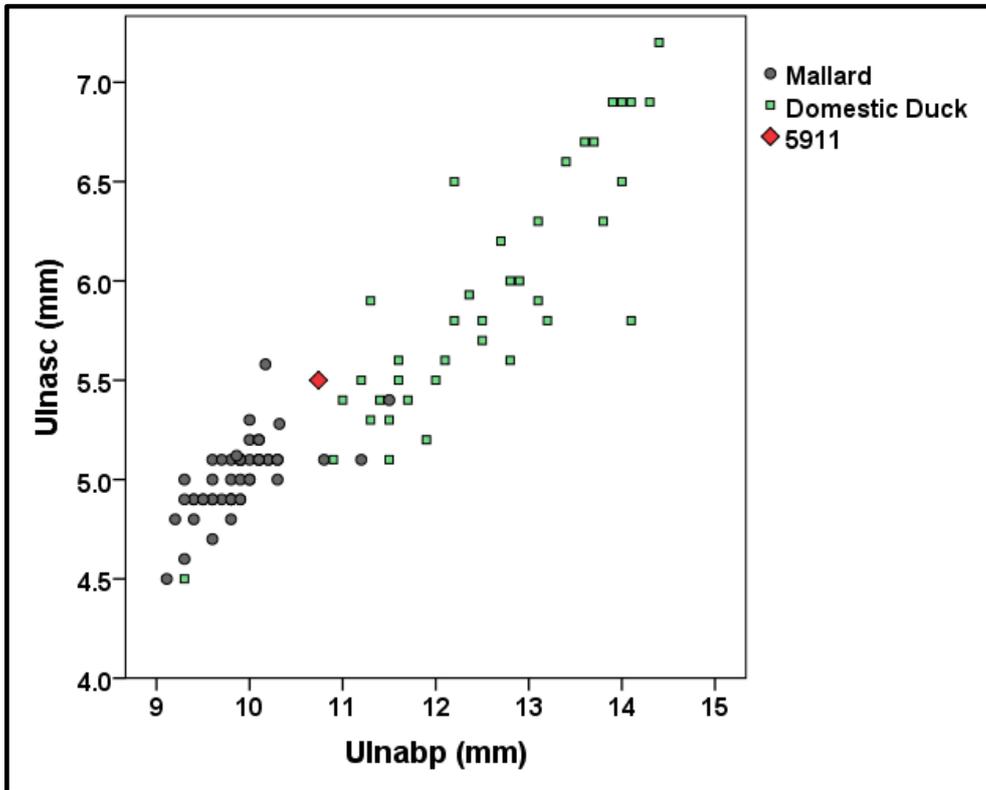
**Figure 7.44.** Pie charts showing the relative frequency of ducks to geese from Fishbourne Palace (sample size indicated in the charts).



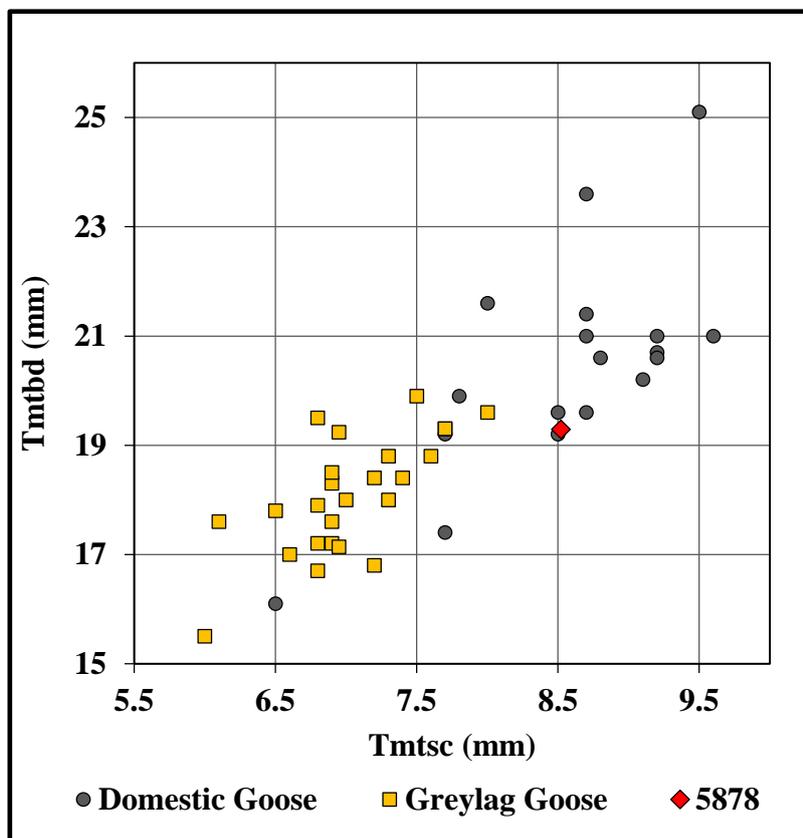
**Figure 7.45.** Scatter plot showing bones 5853 and 5857 (humeri) from the Fishbourne Palace assemblage plotting outside of the modern wild duck cluster and with the modern Domestic Duck cluster.



**Figure 7.46.** Scatter plot showing bone 5911 (ulna) from the Fishbourne Palace assemblage plotting outside of the modern wild duck cluster.



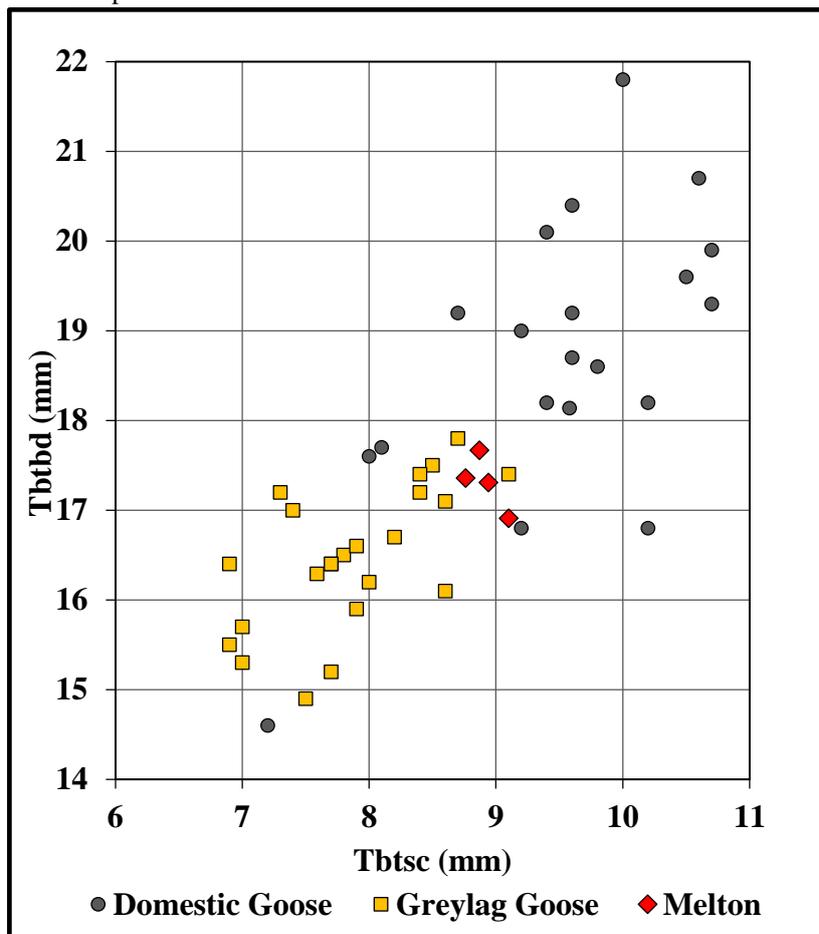
**Figure 7.47.** Scatter plot showing bone 5878 (tarsometatarsus) from the Fishbourne Palace assemblage plotting outside of the modern wild goose cluster and with the modern Domestic Goose cluster.



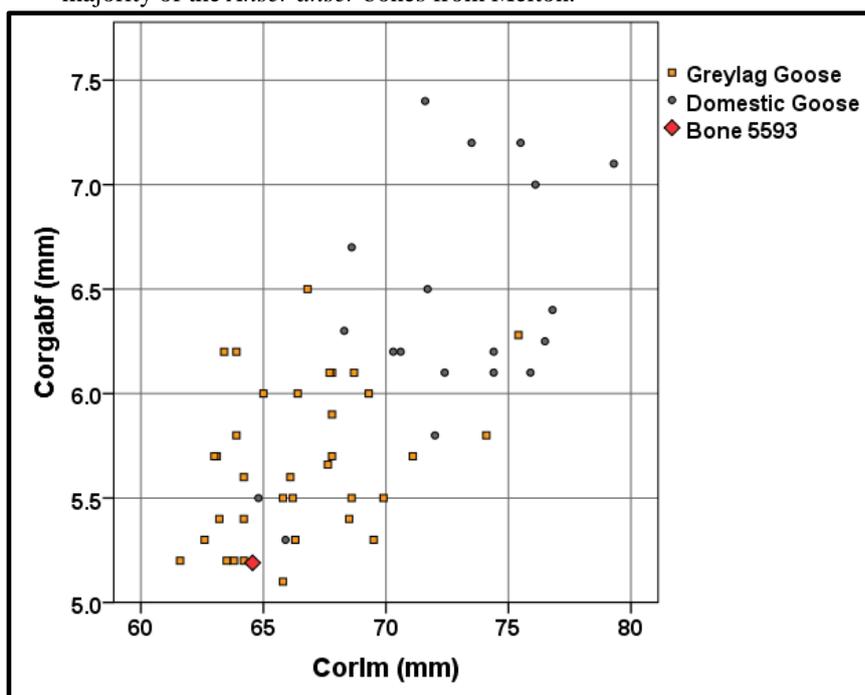
## **Melton, Yorkshire**

Thirty bones from the recently excavated site at Melton were identifiable using the criteria outlined in chapters 3-5 and the results are detailed in tables 7.11 and 7.12. The first aspect of this assemblage to discuss is that no duck bones were identified. It may be the case that duck bones will be identified in the future as more of the animal bone assemblage is analysed, but only the bones that were recovered from the initial excavation were available for analysis for this thesis. At the time of writing this thesis, the animal bone report from Melton had not been written and so it is not possible to see if there were any other anatids present in the assemblage. Of the geese, all bones were identified as belonging to the genus *Anser* with the exception of one coracoid for which the genus could not be determined as the bone was too fragmented (bone number 5569, Appendix 2). Within the *Anser* bones, three different species were identified (*Anser albifrons*, *Anser anser*, and *Anser fabalis*) with all other species ruled out of the identification; *Anser anser* was the most frequent species identified and accounts for the majority of the assemblage. However, it is worth noting here that *Anser anser* was ruled out for the identification of 41% of the *Anser* bones meaning that a significant proportion of the assemblage was not comprised of the most common species of *Anser* in Britain (Yalden and Albarella 2009: 189). Of the *Anser anser* bones, four plotted at the overlap of modern domestic and wild geese, meaning that it is impossible to determine whether they belonged to the wild or domestic form (figure 7.48). The majority, however, plotted outside of the modern domestic range but within the modern wild range (e.g. figure 7.49 - bone 5593).

**Figure 7.48.** Scatter plot showing tibiotarsi (bones 5589-5592) from the Melton assemblage plotting in the overlap area of the modern wild and Domestic Goose clusters.



**Figure 7.49.** Scatter plot showing bone 5593 (coracoid) from the Melton assemblage plotting in with the modern Greylag Geese and away from the modern Domestic Geese. This was the case for the majority of the *Anser anser* bones from Melton.



**Table 7.11.** NISP and MNI totals for each taxon, at each stage of identification for the Melton assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anserinae</i>	30	9	<i>Anser</i>	29	9	<i>Anser albifrons</i>	1	1
						<i>Anser anser</i>	15	4
						<i>Anser fabalis</i>	3	2
						Indet. including <i>A. anser</i>	2	-
			Indet. excluding <i>A. anser</i>	8	-			
			Indet.	1	-			

**Table 7.12.** Frequency of each element for each taxon at each stage of the identification process for the Melton assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anserinae</i>	Carpometacarpus	1	<i>Anser</i>	Carpometacarpus	1	<i>Anser albifrons</i>	Femur	1
	Coracoid	3		Coracoid	2	<i>Anser anser</i>	Carpometacarpus	1
	Femur	4		Femur	4		Coracoid	1
	Humerus	9		Humerus	9		Humerus	4
	Radius	1		Radius	1		Tarsometatarsus	4
	Tarsometatarsus	4		Tarsometatarsus	4		Tibiotarsus	4
	Tibiotarsus	4		Tibiotarsus	4		Ulna	1
	Ulna	4		Ulna	4	<i>Anser fabalis</i>	Coracoid	1
							Humerus	2

### **Owslebury, Hampshire**

Although there were other bones from the site of Owslebury that could confidently be identified as duck or goose, there was only one bone that could be identified using the criteria outlined in chapters 3-5. This was either because the bones were so fragmented that no measurement discussed in chapter 2 could be taken, or because the bone was an element not included in the analysis in this thesis. The one bone that could be recorded was a left humerus of a wild *Anas platyrhynchos* that was broken pre-excavation (Appendix 2). It is of course impossible to infer any kind of meaningful interpretation of the use of ducks at the time of occupation from a single bone, but it may be the case that at this site the use of ducks and geese was uncommon.

### **Plantation House, Chesterfield House (Plantation Place), London**

Tables 7.13 and 7.14 show the frequency of specimens for each taxon at each stage of the identification process, and then by taxon for each element. With a NISP of 24 for all bones the sample size here is too small for any in depth discussion, but the frequency of duck bones compared to geese is similar to some other sites discussed here in that there are many more ducks than geese. *Anas* was the only duck genus that was positively identified, and all four of the goose bones belonged to the genus *Anser*.

Three species of *Anas* were identified showing that there was a range of ducks present on site (*Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*). *Anas platyrhynchos* was the most common duck and accounts for the majority of the duck assemblage. Of the four *Anser* bones identified, one was attributed to *Anser anser* and one was identified as *Anser brachyrhynchus* with the other two bones as having more than one possible species that could not be ruled out for the identification. All duck and goose bones from the Plantation Place assemblage plotted within the modern wild ranges and no bone plotted within the modern domestic ranges.

**Table 7.13.** NISP and MNI totals for each taxon, at each stage of identification for the Plantation House assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	20	5	<i>Anas</i>	17	5	<i>Anas crecca</i>	1	1
						<i>Anas penelope</i>	4	3
						<i>Anas platyrhynchos</i>	12	3
			Indet.	3	-			
<i>Anserinae</i>	4	2	<i>Anser</i>	4	2	<i>Anser anser</i>	1	1
						<i>Anser brachyrhynchus</i>	1	1
						Indet. including <i>A. anser</i>	1	-
						Indet. excluding <i>A. anser</i>	1	-

**Table 7.14.** Frequency of each element for each taxon at each stage of the identification process for the Plantation House assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	2	<i>Anas</i>	Carpometacarpus	2	<i>Anas crecca</i>	Tarsometatarsus	1
	Coracoid	3		Coracoid	3	<i>Anas penelope</i>	Humerus	1
	Humerus	2		Humerus	2		Tarsometatarsus	3
	Radius	2		Radius	2	<i>Anas platyrhynchos</i>	Carpometacarpus	2
	Scapula	2		Tarsometatarsus	5		Coracoid	3
	Tarsometatarsus	5		Ulna	3		Humerus	1
	Tibiotarsus	1					Radius	2
	Ulna	3					Tarsometatarsus	1
						Ulna	3	
<i>Anserinae</i>	Carpometacarpus	2	<i>Anser</i>	Carpometacarpus	2	<i>Anser anser</i>	Tarsometatarsus	1
	Tarsometatarsus	2		Tarsometatarsus	2	<i>Anser brachyrhynchus</i>	Tarsometatarsus	1

## **Tanner Row, York**

Although O'Connor (1988: 76) discussed a relatively large number of goose and duck bones from the Roman phases of the General Accident site, only a small number of the bones are included in the analysis of the assemblage in this thesis. This is for a number of reasons including a relatively high proportion of bones that could not be recorded ('wrong' element, too fragmented, or from a juvenile), the bones were not labelled in a way that made it possible to ascertain their context/phase, or they were missing from the assemblage after the first time they were analysed. However, despite the small sample size, there are some features of the assemblage that are worth mentioning. Tables 7.15 and 7.16 detail the frequency of each taxon at each stage of the identification process and show that goose bones outnumber duck bones. As the sample size is small, it is not possible to infer too much from this assemblage but this pattern is in contrast to most other assemblages discussed in this chapter, apart from Melton which is geographically closest.

The single bone that was identified as a duck was an *Anas platyrhynchos* humerus and only *Anser* was reliably identified for the goose genera. *Anser anser* comprised the majority of the *Anser* bones including four bones that were within the modern domestic range, two of which were outside the modern wild range for *Anser anser* (figure 7.50).

**Table 7.15.** NISP and MNI totals for each taxon, at each stage of identification for the Tanner Row assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	1	1	<i>Anas</i>	1	1	<i>Anas platyrhynchos</i>	1	1
<i>Anserinae</i>	14		<i>Anser</i>	11	3	<i>Anser anser</i>	2	1
						<i>Anser anser</i> (dom)	2	2
						<i>Anser anser</i> (dom)?	2	1
						Indet. including <i>A. anser</i>	3	-
						Indet. excluding <i>A. anser</i>	2	-
Indet.	1	-	Indet.	3	-			

**Table 7.16.** Frequency of each element for each taxon at each stage of the identification process for the Tanner Row assemblage.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Humerus	1	<i>Anas</i>	Humerus	1	<i>Anas platyrhynchos</i>	Humerus	1
<i>Anserinae</i>	Carpometacarpus	3	<i>Anser</i>	Carpometacarpus	3	<i>Anser anser</i>	Radius	1
	Humerus	1		Radius	2		Tibiotarsus	1
	Radius	4		Tarsometatarsus	3	<i>Anser anser</i> (dom)	Tarsometatarsus	2
	Tarsometatarsus	3		Tibiotarsus	2	<i>Anser anser</i> (dom)?	Carpometacarpus	1
	Tibiotarsus	2		Ulna	1		Tarsometatarsus	1
	Ulna	1						



**Table 7.17.** NISP and MNI totals for each taxon, at each stage of identification for the Ware assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	14	5	<i>Anas</i>	11	5	<i>Anas penelope</i>	3	1
						<i>Anas platyrhynchos</i>	7	3
						Indet. excluding <i>A. platyrhynchos</i>	1	-
			Indet.	3	-			
<i>Anserinae</i>	2	2	<i>Anser</i>	2	2	<i>Anser anser</i>	2	2

**Table 7.18.** Frequency of each element for each taxon at each stage of the identification process for the Ware assemblage.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
<i>Anatinae</i>	Carpometacarpus	1	<i>Anas</i>	Carpometacarpus	1	<i>Anas penelope</i>	Coracoid	1
	Coracoid	2		Coracoid	2		Femur	1
	Femur	2		Femur	2		Ulna	1
	Radius	2		Tarsometatarsus	1	<i>Anas platyrhynchos</i>	Carpometacarpus	1
	Tarsometatarsus	2		Ulna	5		Coracoid	1
	Ulna	5					Femur	1
							Tarsometatarsus	1
					Ulna	3		
<i>Anserinae</i>	Radius	2	<i>Anser</i>	Radius	2	<i>Anser anser</i>	Radius	2

## **Results from all sites combined**

This final section of the results chapter looks at the combined results of each site assemblage to try and get a general overview of how ducks and geese were used in Britain during the Roman period. It is appreciated that only ten assemblages are included in this analysis, and the chronological and geographical range of the Roman occupation of Britain is not fully covered, but it is worth exploring any patterns that emerge from this analysis. Tables 7.19 and 7.20 detail the NISP and MNI of each taxon, at each stage of the identification process, for all of the assemblages analysed in this thesis. Figure 7.51 shows that there are many more ducks than geese present on archaeological sites in Britain during the Roman period and that they were recovered in a ratio of about 1.5 : 1.

Within the ducks, four genera were positively identified; *Anas*, *Aythya*, *Melanitta*, and *Mergus*. *Anas* overwhelmingly makes up most of the duck assemblage with 77% of the NISP. 18% of the ducks could possibly be attributed to *Anas*, but at least one other genus could not be ruled out (usually due to the fragmentation of the bone), and *Anas* could only be confidently ruled out in 5% of the duck bones analysed in this assemblage.

Within *Anas*, five species were identified showing that although one species was far more frequent than others (*Anas platyrhynchos* - Figure 7.52), a range of *Anas* were utilised in Britain during the Roman period. The five species represent a range of sizes and so it is not likely that the number of species present has been too adversely effected by preservation or recovery bias, although the actual frequency of each species may have been (discussed in the next chapter). Of the *Anas platyrhynchos*, only five plotted within the modern domestic range. Of the positively identified *Anas platyrhynchos* remains analysed in this thesis only 3% of them could have belonged to a Domestic Duck.

The duck species that belong to genera other than *Anas* only make up a small percentage of the duck assemblage, and *Mergus serrator* accounts for most of those (figure 7.52). With such

a small amount of specimens it is difficult to infer much about the use of these species in the past, but some suggestions for why they are present on site is discussed in the next chapter.

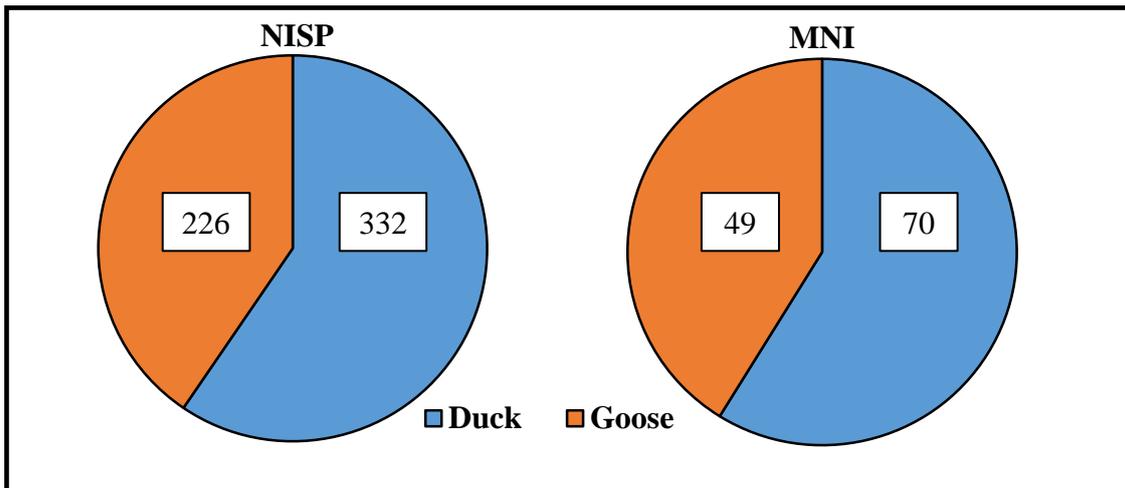
Bones identified as belonging to the genus *Anser* account for 93% of the goose bones with only 4% belonging to *Branta*, and the rest could not be reliably identified to the genus level. Of the *Anser* bones, four species were positively identified on at least one occasion; *Anser albifrons*, *Anser anser*, *Anser brachyrhynchus*, and *Anser fabalis*. Figure 7.53 shows that although *Anser anser* accounts for the vast majority of the *Anser* bones, *Anser anser* was ruled out for the identification in 26% of cases. This is considerably different than the results for the ducks and shows that even though there are fewer geese, there seems to be less focus on one particular species. This is discussed further in the following chapter.

Of the 121 *Anser anser* specimens identified in this thesis, 55 of them plotted within the modern domestic range, and 16 of those plotted outside the modern wild goose range. This may mean that although it was not a common practice, at least in some parts of Britain domestic geese may have been kept during the Roman period. How common a practice this is likely to have been, and what the significance of these geese would have been, is discussed in the following chapter.

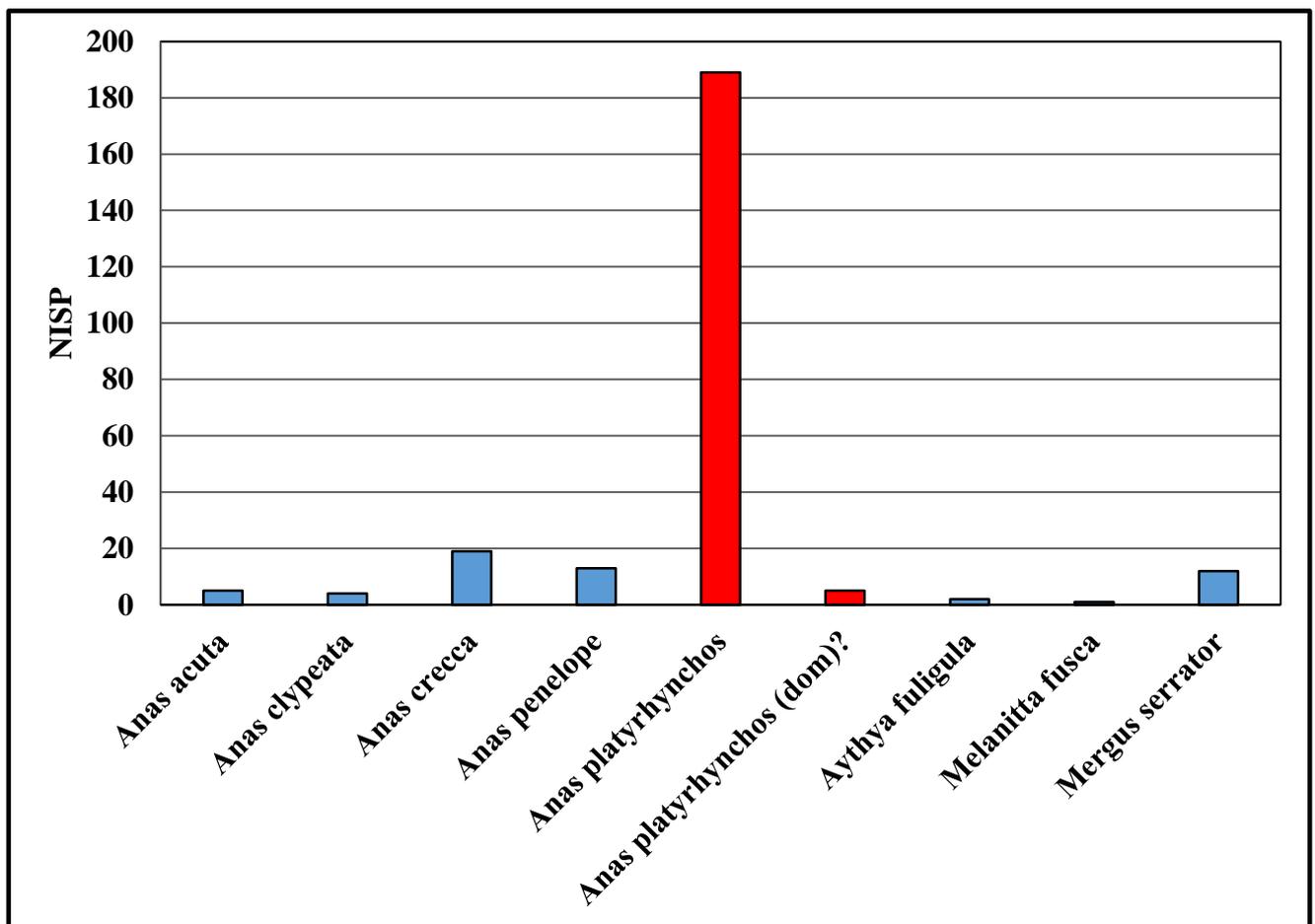
**Table 7.19.** NISP and MNI totals for each taxon, at each stage of identification for all assemblages combined.

Subfamily	NISP	MNI	Genus	NISP	MNI	Species	NISP	MNI
Anatinae	332	70	Anas	257	62	<i>Anas acuta</i>	5	4
						<i>Anas clypeata</i>	4	2
						<i>Anas crecca</i>	19	5
						<i>Anas penelope</i>	13	3
						<i>Anas platyrhynchos</i>	189	47
						<i>Anas platyrhynchos</i> (dom)?	5	2
						Indet. including <i>A. platyrhynchos</i>	9	-
						Indet. excluding <i>A. platyrhynchos</i>	13	-
			<i>Aythya</i>	2	1	<i>Aythya fuligula</i>	2	1
			<i>Melanitta</i>	1	1	<i>Melanitta fusca</i>	1	1
<i>Mergus</i>	12	12	<i>Mergus serrator</i>	12	12			
Indet.	60	-						
Anserinae	226	49	Anser	209	48	<i>Anser albifrons</i>	5	2
						<i>Anser anser</i>	66	21
						<i>Anser anser</i> (dom)	16	11
						<i>Anser anser</i> (dom)?	39	9
						<i>Anser brachyrhynchus</i>	2	2
						<i>Anser fabalis</i>	9	4
						Indet. including <i>A. anser</i>	34	-
						Indet. excluding <i>A. anser</i>	38	-
			<i>Branta</i>	10	7	<i>Branta leucopsis</i>	10	7
			Indet.	7	-			
Indet.	10	-						

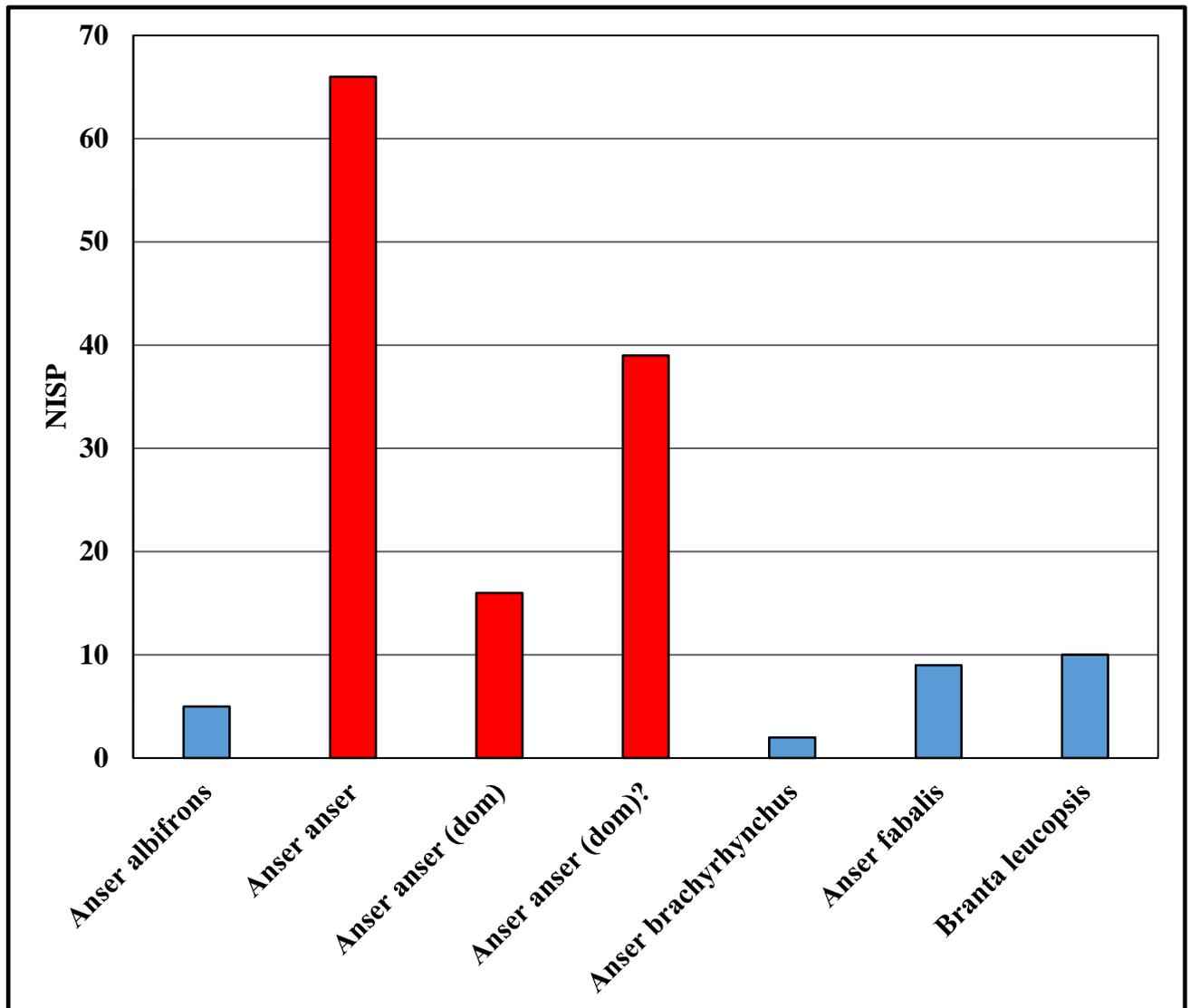
**Figure 7.51.** Pie charts showing the relative frequency of ducks to geese from all analysed Roman assemblages in Britain (sample size indicated in the charts).



**Figure 7.52.** Bar chart showing the frequency of each positively identified duck species from the Roman assemblages analysed in this thesis.



**Figure 7.53.** Bar chart showing the frequency of each positively identified goose species from the Roman assemblages analysed in this thesis.



**Table 7.20.** Frequency of each element for each taxon at each stage of the identification process for all assemblages combined.

Subfamily	Element	Count	Genus	Element	Count	Species	Element	Count
<i>Anatinae</i>	Carpometacarpus	43	<i>Anas</i>	Carpometacarpus	38	<i>Anas acuta</i>	Tibiotarsus	1
	Coracoid	43		Coracoid	41		Ulna	4
	Femur	14		Femur	14	<i>Anas clypeata</i>	Coracoid	1
	Humerus	51		Humerus	43		Tarsometatarsus	1
	Radius	33		Radius	19		Ulna	2
	Scapula	17		Scapula	2	<i>Anas crecca</i>	Carpometacarpus	1
	Tarsometatarsus	26		Tarsometatarsus	25		Coracoid	4
	Tibiotarsus	35		Tibiotarsus	13		Humerus	3
	Ulna	70		Ulna	62		Radius	2
							Scapula	1
							Tarsometatarsus	2
							Tibiotarsus	1
							Ulna	5
						<i>Anas penelope</i>	Carpometacarpus	3
							Coracoid	1
							Femur	2
							Humerus	2
							Tarsometatarsus	3
							Tibiotarsus	1
				Ulna	1			
				<i>Anas platyrhynchos</i>	Carpometacarpus	32		
					Coracoid	31		
					Femur	11		
					Humerus	30		
					Radius	12		
					Tarsometatarsus	16		
					Tibiotarsus	10		
				Ulna	47			

<i>Anatinae</i>			<i>Anas</i>			<i>Anas platyrhynchos</i> (dom)?	Humerus	2		
							Radius	1		
							Scapula	1		
							Ulna	1		
			<i>Aythya</i>					<i>Aythya fuligula</i>	Humerus	1
Tibiotarsus	1									
<i>Melanitta</i>					<i>Melanitta fusca</i>	Humerus	1			
<i>Mergus</i>					<i>Mergus serrator</i>	Tibiotarsus	12			
<i>Anserinae</i>	Carpometacarpus	31	<i>Anser</i>	Carpometacarpus	24	<i>Anser albifrons</i>	Coracoid	1		
	Coracoid	15		Coracoid	12		Femur	2		
	Femur	18		Femur	17		Humerus	2		
	Humerus	49		Humerus	48	<i>Anser anser</i>	Carpometacarpus	6		
	Radius	21		Radius	18		Coracoid	5		
	Scapula	3		Scapula	2		Femur	2		
	Tarsometatarsus	36		Tarsometatarsus	35		Humerus	21		
	Tibiotarsus	23		Tibiotarsus	23		Radius	3		
	Ulna	30		Ulna	30		Scapula	1		
									Tarsometatarsus	11
									Tibiotarsus	11
						Ulna			6	
						<i>Anser anser</i> (dom)			Carpometacarpus	1
									Humerus	1
Radius			1							
Tarsometatarsus	11									
Tibiotarsus	1									
<i>Anser anser</i> (dom)?	Ulna	1								
	Carpometacarpus	4								
	Coracoid	1								
						Femur	4			

<i>Anserinae</i>		<i>Anser</i>		<i>Anser anser (dom)?</i>	Humerus	9		
					Radius	4		
					Tarsometatarsus	7		
					Tibiotarsus	8		
					Ulna	2		
				<i>Anser brachyrhynchus</i>	Tarsometatarsus	2		
				<i>Anser fabalis</i>	Coracoid	2		
					Humerus	4		
					Ulna	3		
		<i>Branta</i>				<i>Branta leucopsis</i>	Carpometacarpus	7
							Coracoid	1
							Radius	1
							Tarsometatarsus	1
					Carpometacarpus	7		
					Coracoid	1		
					Radius	1		
					Tarsometatarsus	1		

## **Chapter 8~**

### **Discussion: The use of ducks and geese in Roman Britain**

This chapter explores the results from the previous chapter and discusses the key research questions about the use of ducks and geese outlined in chapter 1:

- 1. Were domestic geese used in Britain during the Roman period?**
- 2. Were domestic ducks used in Britain during the Roman period?**
- 3. To what extent were wild species used in Roman Britain compared to their domestic counterparts?**
- 4. Were there any differences in the species that were used between different types of site?**

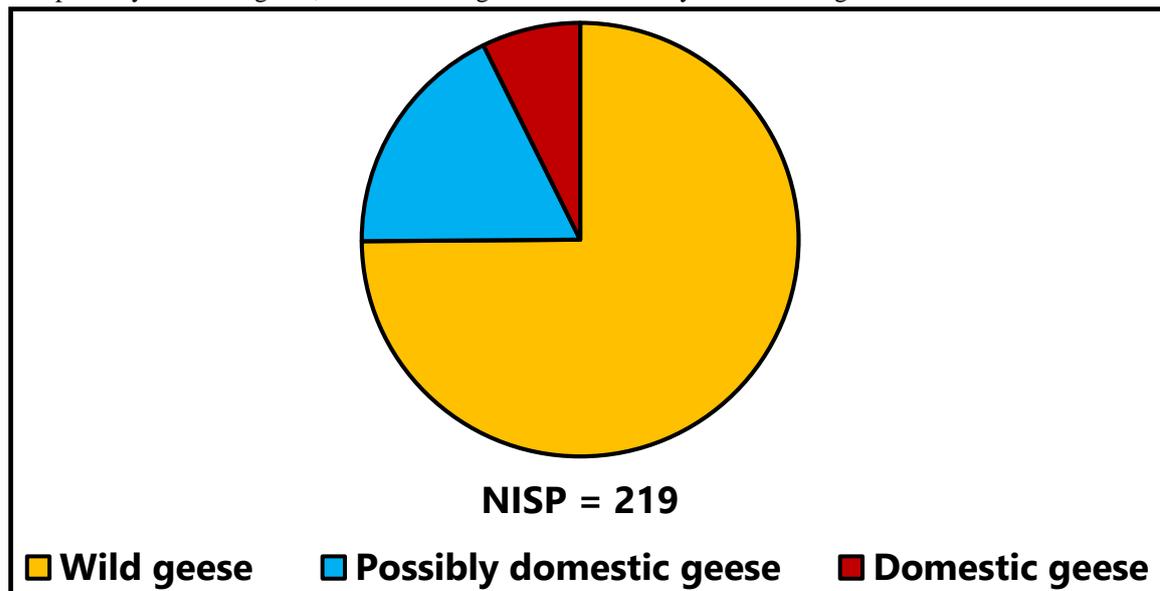
There are many topics that could be discussed in this chapter based upon the results of the previous chapter, but the main focus of this thesis was to present new criteria for the identification of archaeological ducks and geese in Western Europe. Therefore the discussion will focus primarily on the identification of the species present at each site and how this impacts on our understanding of the people who lived at the sites in the past. The structure of this chapter follows the four questions that are listed above and incorporates other information relevant to these discussion points where necessary.

#### **Were domestic geese used in Britain during the Roman period?**

It has long been assumed that domestic geese were present in Britain during the Roman period and that they fulfilled a meaningful, albeit minor, economic role at the time (*e.g.* Serjeantson 2009). This assumption has been questioned (*e.g.* Albarella 2005), but was based upon the size of the geese identified in Roman assemblages and classical texts discussing the use of geese on mainland Europe (O'Connor 1988, Yalden and Albarella 2009). From the previous chapter we can see that there are examples of bones that are very

likely to be from domestic geese from some of the ten assemblages analysed (table 7.19). However, the frequency of these bones compared to wild geese is very low and therefore the rearing of domestic geese could not have been that common compared to the consumption of wild geese (figure 8.1).

**Figure 8.1.** Pie chart showing the relative frequency of bones consistent with modern wild geese, possibly domestic geese, and domestic geese from all analysed sites using the NISP.



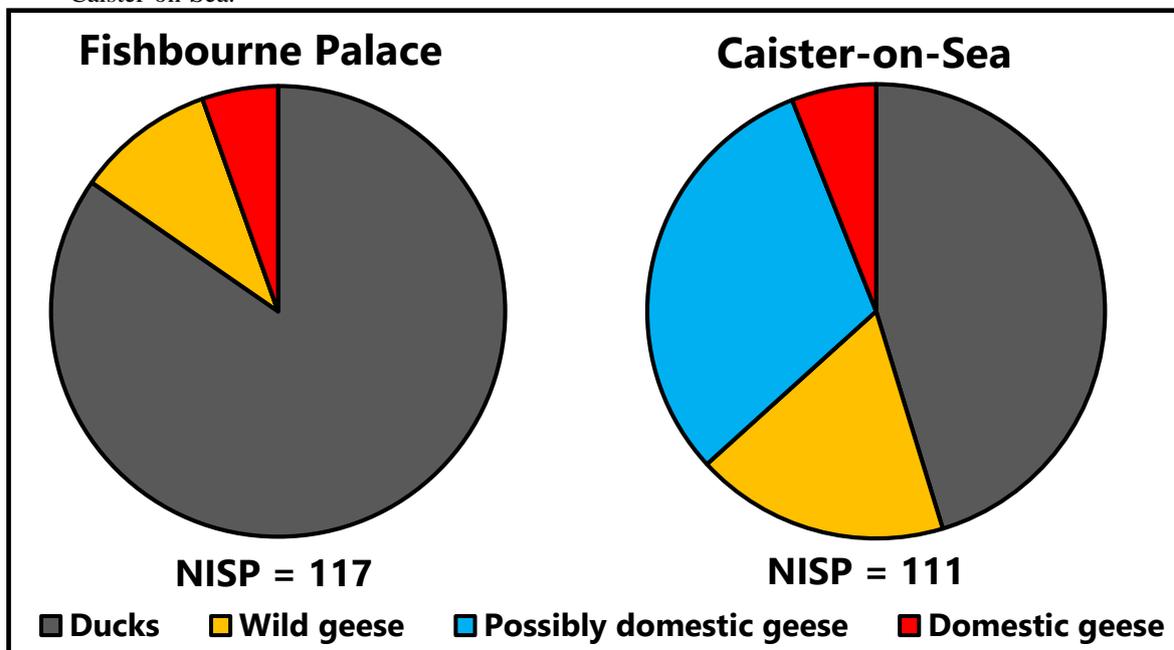
What could be even more interesting from the results of this thesis is that the use and purpose of domestic geese was likely to be different at different sites. This is particularly intriguing when we consider the way these sites functioned and that the identity of the people who lived there was feasibly reflected in most aspects of their life, including their use of minor domesticates. At Fishbourne Palace we can see that there were very few geese present on site, but the geese that were there mostly came from *Anser anser*; or, at least *Anser anser* could not be ruled out as the identified species (table 7.9). Only six of the *Anser anser* bones were identified as likely belonging to the domestic form. This is a small amount of bones, but enough to mean that it is probable that at least some domestic geese were present at the site. There is a range of reasons for keeping domestic geese (discussed in chapter 1) and in most cases researchers have tended to interpret the presence of domestic geese as the product of

economic endeavours. However, this it is unlikely in this case. The small number of geese present could not have provided much income and so there must be another reason for their presence. We know from previous research that Fishbourne Palace was a very high status site where the display of wealth was conspicuous (Cunliffe 1971). We also know that wealth was likely displayed through the animals that were kept at the site. A whole range of animals was kept including imported fallow deer (*Dama dama*) which must have arrived at the site at some expense. The keeping of foreign, or exotic, animals to display wealth is well documented in a number of historical cases and has been suggested in some archaeological cases during the Roman period in Europe (Mackinnon 2006). In this case it is possible that the domestic geese were imported and not bred locally at all. If this is true then they may well have been viewed as an ‘exotic’ domestic (see Sykes 2014 for a discussion of exotic domestic animals) and very much contributed to the way wealth was spent and displayed at the site. It is impossible to discuss the colouration of the geese in this thesis, but if they were a different colour to wild geese (often the domestication process, or post-domestication selective breeding process, causes a change in colouration (Arbuckle 2005)) then they would have been a very striking sight for anyone seeing them walking around the villa complex, even if there was only a handful of them.

At Caister-on-Sea we can see that there were proportionally a lot more geese than at Fishbourne Palace and that seven bones were likely from domesticated birds and domestic goose could not be ruled out in a further 36 bones (figure 8.2). This means that it is probable that domestic geese were kept at the site and that there may even have been a breeding program, albeit on a very small scale. The people at the fort at Caister-on-Sea were unlikely to have been keeping geese, along with other animals, for pleasure or displays of wealth due to the practical nature of the site. The results of the zooarchaeological analysis of the rest of the animal bone assemblage does not suggest an extravagant diet and actually the evidence

suggests that the consumption of animals at the site was similar to other forts in Britain with a focus on heavily butchered cattle (Thomas and Stallibrass 2008). Therefore the keeping of geese may have had a more practical reason than at Fishbourne, such as for their feathers, their fat, their meat, or as guard geese (discussed below). The reason that domestic geese were present at Caister-on-Sea and not at many other sites in Britain may be due to the greater ties with continental Europe (Darling and Gurney 1993) and the relatively late date for the foundation of the fort (3rd century AD).

**Figure 8.2.** Pie charts showing the relative frequency of bones consistent with modern ducks, wild geese, possibly domestic geese, and domestic geese using the NISP from Fishbourne Palace and Caister-on-Sea.



The keeping of domestic geese may have been much more frequent throughout Roman Europe, and indeed seems to have a relatively common in Italy (Corbino *et al.* in prep.). The presence of domestic geese at Caister-on-Sea may have little to do with intentionally changing the way these animals were used locally and more to do with the geese being brought in with the suite of animals and farming practices from mainland Europe.

Whatever the reason for keeping domestic geese, they were not common in Roman Britain and seems to have been a very minor practice at the sites they were kept at. However,

this does not mean that we cannot infer meaning from their presence. Domestic animals are not kept by accident and we should always try to understand the decisions of the people that chose to keep these animals in the past, whether they were driven by economic or socio-cultural reasons. Developing research suggests that the keeping of domestic geese was far more common on mainland Europe compared to Britain during the Roman period (Corbino *et al.* in prep.) and if this is true then it is a topic that will need further investigation in the future. One question that will be interesting to explore will be why the spread of Roman agricultural and livestock management practices in Britain does not include the keeping of domestic geese in more places.

### **Were domestic ducks used in Britain during the Roman period?**

In table 7.19 we can see that there were five duck bones for which domestic duck could not be ruled out for the identification, including four bones that were consistent with modern domestic ducks. However, this does not necessarily mean that domestic ducks were present in Britain during the Roman period. Firstly, this is a very small amount of bones (representing a minimum of just three individuals) and so it may be the case that by chance there were some individual Mallards that were naturally more similar to the modern domestic duck in morphology than modern wild Mallards. Without knowing the full range of sizes and shapes of Mallards in the past it is impossible to say that these were not just at the top of the range for wild ducks at the time. Also, without direct dating, and with such a small amount of material, it cannot be ruled out that these bones are from birds that lived later than the Roman period and somehow became mixed with the Roman material. Therefore it is the opinion of the author that even though these bones are consistent with modern domestic ducks, it is very unlikely that any domestic ducks were present in Britain during the Roman period. The other thing to consider here is that even if these bones did belong to domestic ducks from the

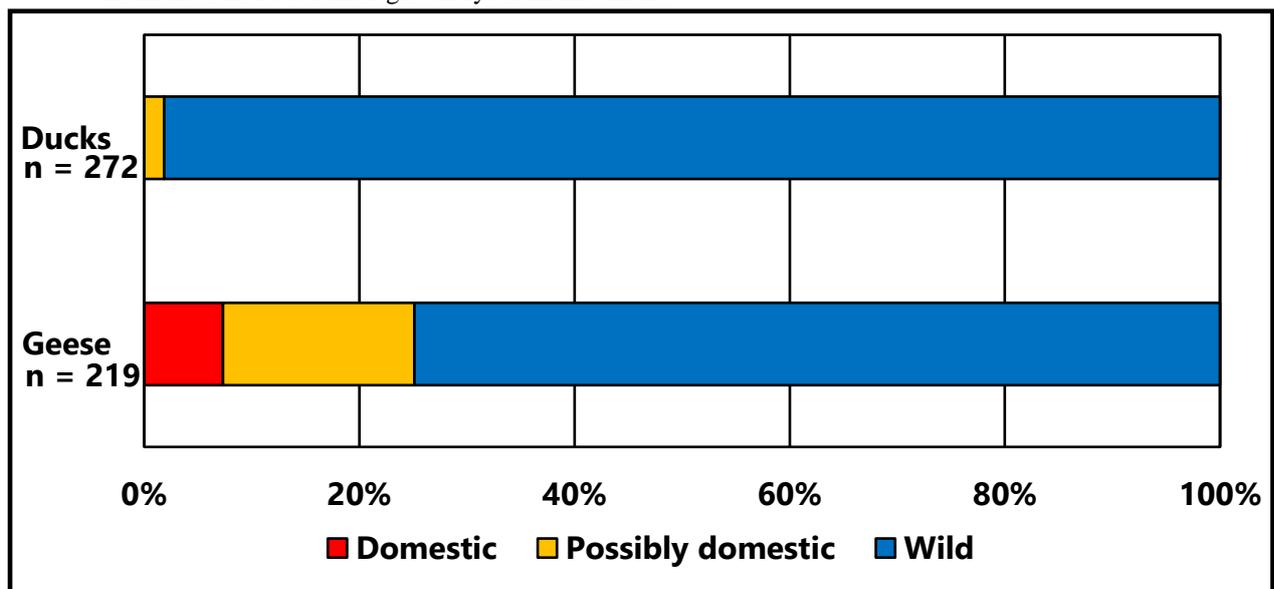
Roman period, they must have been so rare as to have had almost no impact on the use of ducks during the period. Only 3% of the 194 *Anas platyrhynchos* bones could possibly have come from a domestic duck and so their presence, and impact on the people of Britain, must have been miniscule if they were there at all. This conclusion reinforces past research and opinions that it is unlikely that domestic ducks were kept in Britain until at the least the medieval period, and even then may not have been that common until the later medieval period (Albarella 2005). Some researchers have identified Domestic Ducks from Roman contexts in Britain, but this was based upon questionable evidence and these identifications require reconsideration in the future. Forthcoming work on medieval and post-medieval assemblages using the identification criteria outlined in this thesis will help us to define when the keeping of domestic ducks in Britain became common and how the duck has changed morphologically from the Roman period until the modern period (Grau-Sologestoa *et al.* in prep.). Once this has been defined there will be some key questions about the use of ducks including why the keeping of domestic ducks was so much later than domestic geese and why the use of wild duck resources diminished through time.

### **To what extent were wild species used in Roman Britain compared to their domestic counterparts?**

The first thing to consider when discussing the extent and cultural importance of wild resource exploitation is how frequently wild ducks and geese were consumed. Figure 8.3 shows the relative frequency of wild and domestic duck and goose bones identified to the species level for all sites analysed in chapter 7. There were almost no ducks that could have come from a domestic form but 25% of geese could be domestic, with 7% of them most likely to be so. This means that, although generally fewer geese were consumed than ducks during the Roman period in Britain (figure 8.4), there was less of a reliance on wild resources when it came to goose consumption. When you consider the ducks and geese together we can

see that only 12% of all of the bones analysed in this thesis could have come from a domestic bird, provided that domestic ducks and geese during the Roman period were morphologically more similar to modern domestic ducks and geese than to modern wild ducks and geese.

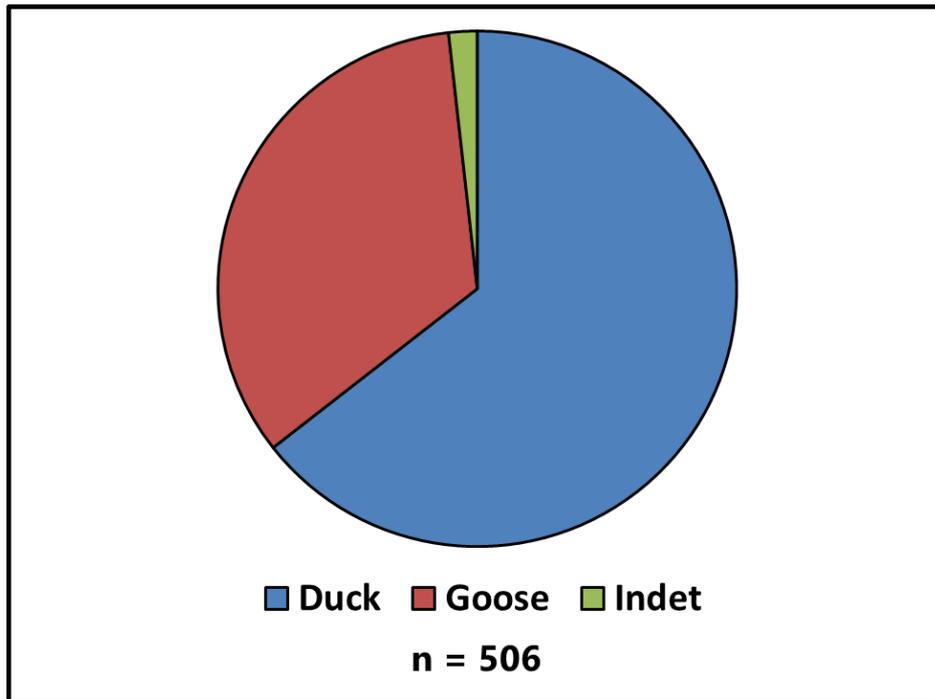
**Figure 8.3.** Relative frequency chart showing the occurrence of bones that were identified to at least the genus level that are consistent with modern wild, possibly domestic, and domestic ducks and geese from the ten site assemblages analysed in this thesis.



It is clear from the results of this thesis that duck and goose consumption in Roman Britain overwhelmingly relied on the collection of wild resources. Whether this was from trapping using nets, hunting, or even raising the birds from hatchlings, it is clear the consumption of domestic anatids was uncommon. The consumption of ducks and geese compared to domestic fowl must still have been a relatively rare occurrence, but the socio-cultural implications of eating wild food must not be underestimated. Often the consumption of wild animals has a higher significance than the consumption of reared animals, both for the hunter/trapper and those consuming the food (Sykes 2014). Whether the wild animal has symbolic meaning, the hunter/trapper is showing off their prowess, or those consuming can show that they can afford food different from the everyday; the public consumption of wild animals always has meaning (Binford 1978). There is of course an argument that could be

made that wild resources are relied upon during periods of food scarcity, but given the contexts of the sites involved in this thesis this an unlikely reason. High status sites, well supplied forts, urban centres, and roadside settlements on trade routes all seem unlikely places for people needing to rely on wild resources.

**Figure 8.4.** Pie chart showing the relative frequency of ducks to geese identified from the 10 Roman British assemblages analysed in this thesis.



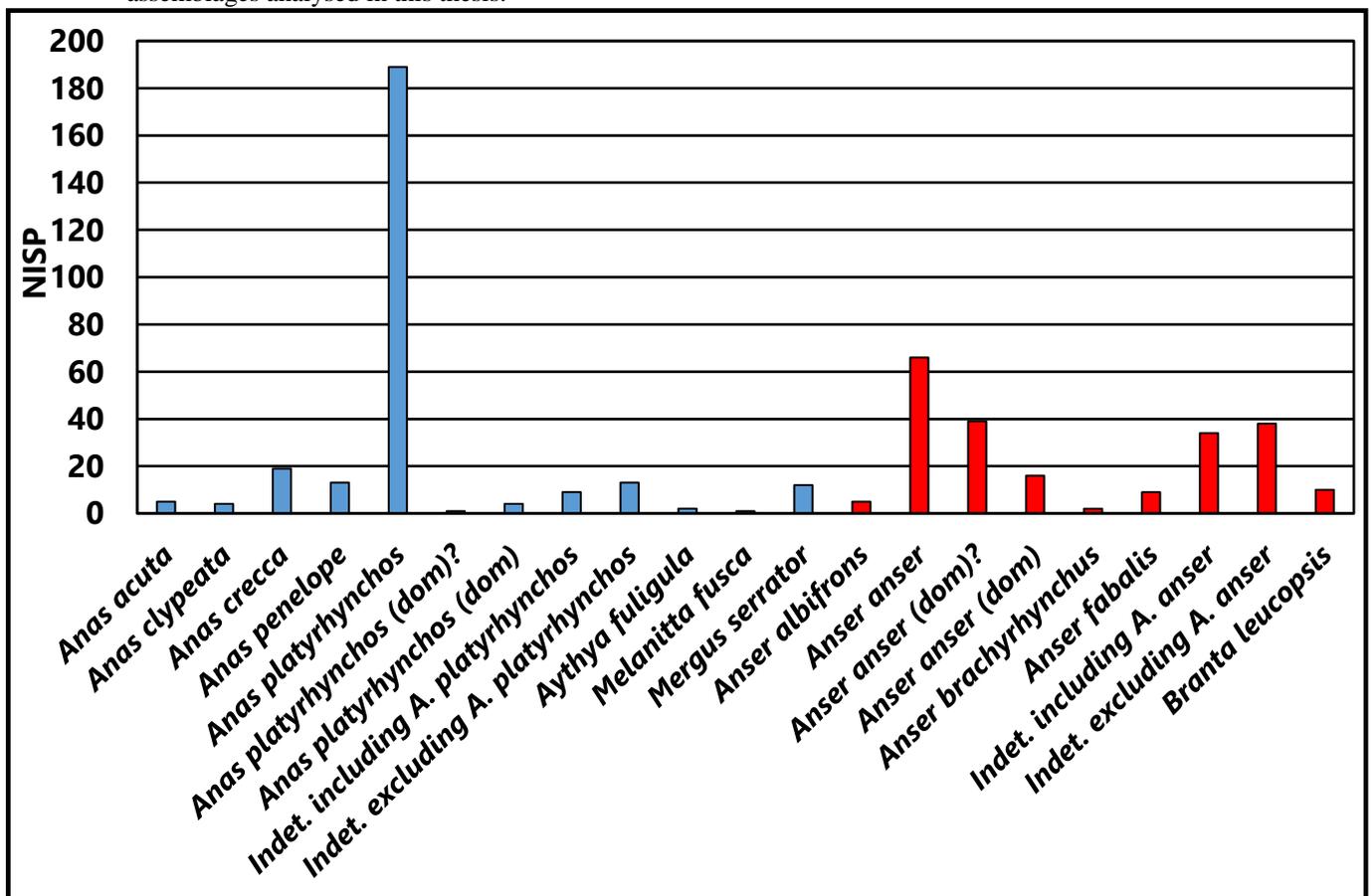
If ducks and geese were consumed in Roman Britain for reasons other than just subsistence, then it must follow that people chose to eat them. What will be interesting in the future is a comparison of consumption practices in Britain compared to the rest of Europe during the Roman period. From some forthcoming work it is clear that not only were far fewer ducks consumed in Italy, but there was much more of a focus on keeping and consuming domestic geese (Corbino *et al.* in prep.). As many of the same species of ducks and geese would be available in the environment in both locations, the difference in their consumption practices must be cultural and this something that needs further exploration in the future. Although the consumption of ducks was more frequent than goose consumption in Britain during the

Roman period, goose consumption (and the use of goose products) became far more frequent than the consumption/use of ducks in later periods in Britain and it will be interesting to explore why there was a shift in practice. Apart from the practical reasons, it will be important to explore whether the change was driven by an indigenous divergence in ideology, foreign influence from abroad, or the influx of new practices from people moving to Britain.

Now that it is established that the consumption wild ducks and geese was much more frequent than the consumption of domestic anatids, the nature of the use of these wild resources must be discussed. There are a range of different strategies that could have been adopted for the acquisition of wild ducks and geese. First and foremost there was a choice of which species to consume; although the concept of species as we understand it may not have existed in Roman Britain, there can be no doubt that people living at the time would have been able to differentiate between the different types of ducks and geese visually based upon colouration and size. Therefore if there was a notion that some ducks or geese were better to eat than others it would have been possible to be selective. Of course, what is good to eat is not just based upon what is palatable, but also there are often rules, customs, and myths surrounding what is good to eat (Binford 1981). There are references to the consumption of ducks and geese from the classical authors, who refer to the consumption of different coloured geese (Columella, *De Re Rustica* Book VIII, XIV [1<sup>st</sup> cent. AD]) and the best parts of the duck, but not which type of duck (Toynbee 1973). Therefore it may be the case that in Roman Britain that there was no preference for the type of duck for consumption. As we now have new and reliable identification criteria, and a dataset of wild ducks and geese in Britain, we can investigate whether there was any selection for particular species. If there was no selection for a particular species then the frequency of species present in the archaeological record would have been proportional to the species that was available in the environment (barring any taphonomic or recovery biases). If there was a selection for a specific species

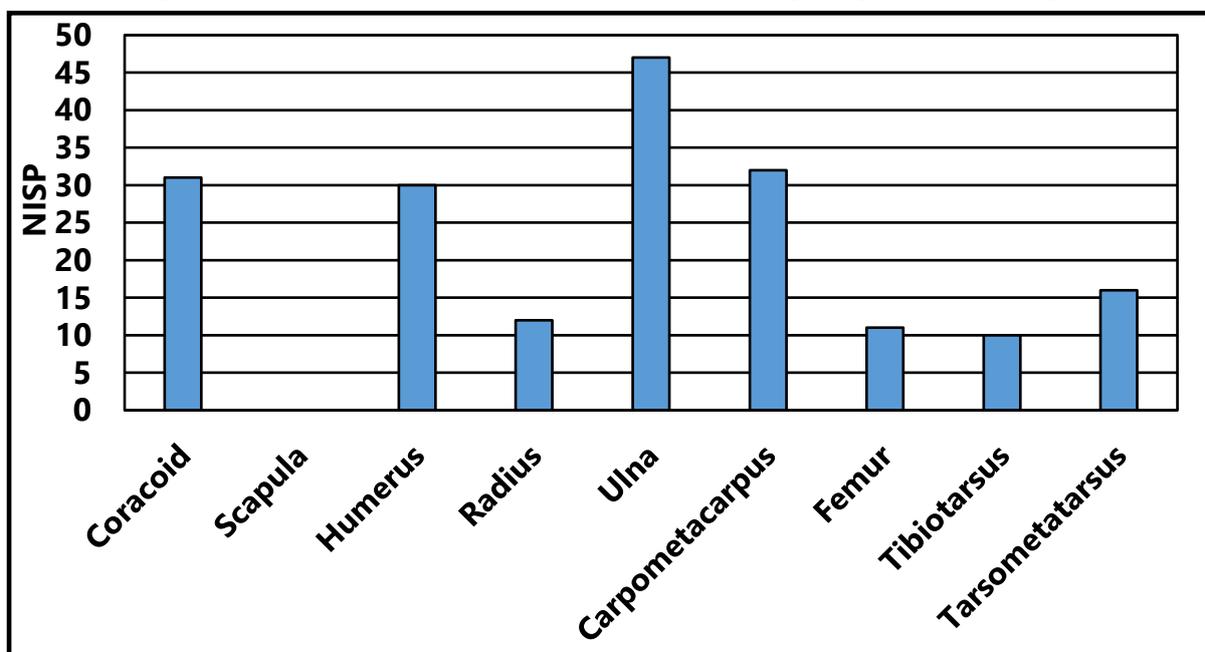
then the frequency of species present in the archaeological record would show a higher frequency of the selected species, disproportional to the frequencies of species that would have been available in the environment. Figure 8.5 shows the frequency of each species positively identified from the 10 sites in Britain. Four genera of duck, including eight species, and two genera of geese, including five species were identified across Britain. This wide range of taxa in itself suggests that generally there was no selection in the type of duck or goose that was consumed as a restricted amount of taxa would be expected if there was a practice of selecting particular birds for consumption. Collecting a number of different taxa in one go would be particularly easy to achieve if nets were used to collect a number of ducks and/or geese at once. Figure 8.5 shows that the most frequent species of duck is *Anas platyrhynchos* and the most frequent species of goose is *Anser anser*.

**Figure 8.5.** Bar chart showing the frequency of NISP for each positively identified species from the ten assemblages analysed in this thesis.



At first glance it may appear that these species were selected for, given their frequency in the archaeological assemblages. However, we have to take into consideration the natural frequency of these animals in the environment and the effect of any biases that may impact on the bones available for analysis today. Firstly, the two most frequent species identified in the archaeological material are by far the most frequent in extant populations in Britain, if we discount introductions such as the Canada goose, *Branta canadensis* (Yalden and Albarella 2009). As there is no reason to assume that these species would not be the most frequent in the past, it is reasonable to say that if there was no selection for species to consume then they would be the most frequent within the archaeological assemblages. Another reason why these two species in particular would be the most frequent within archaeological assemblages is due to taphonomic and recovery biases. Figure 8.6 shows the frequency of elements for *Anas platyrhynchos* (excluding the bones that may be from domestic individuals).

**Figure 8.6.** Bar chart showing the frequency of each element from *Anas platyrhynchos*, from the ten sites analysed in this thesis. There is a higher frequency of the larger/more robust elements meaning that taphonomic and recovery biases cannot be ruled out from impacting on the assemblages.



It is evident that the largest/most robust, elements are the most frequent. This suggests that all assemblages have been subject to preservation and/or recovery biases as the larger and more

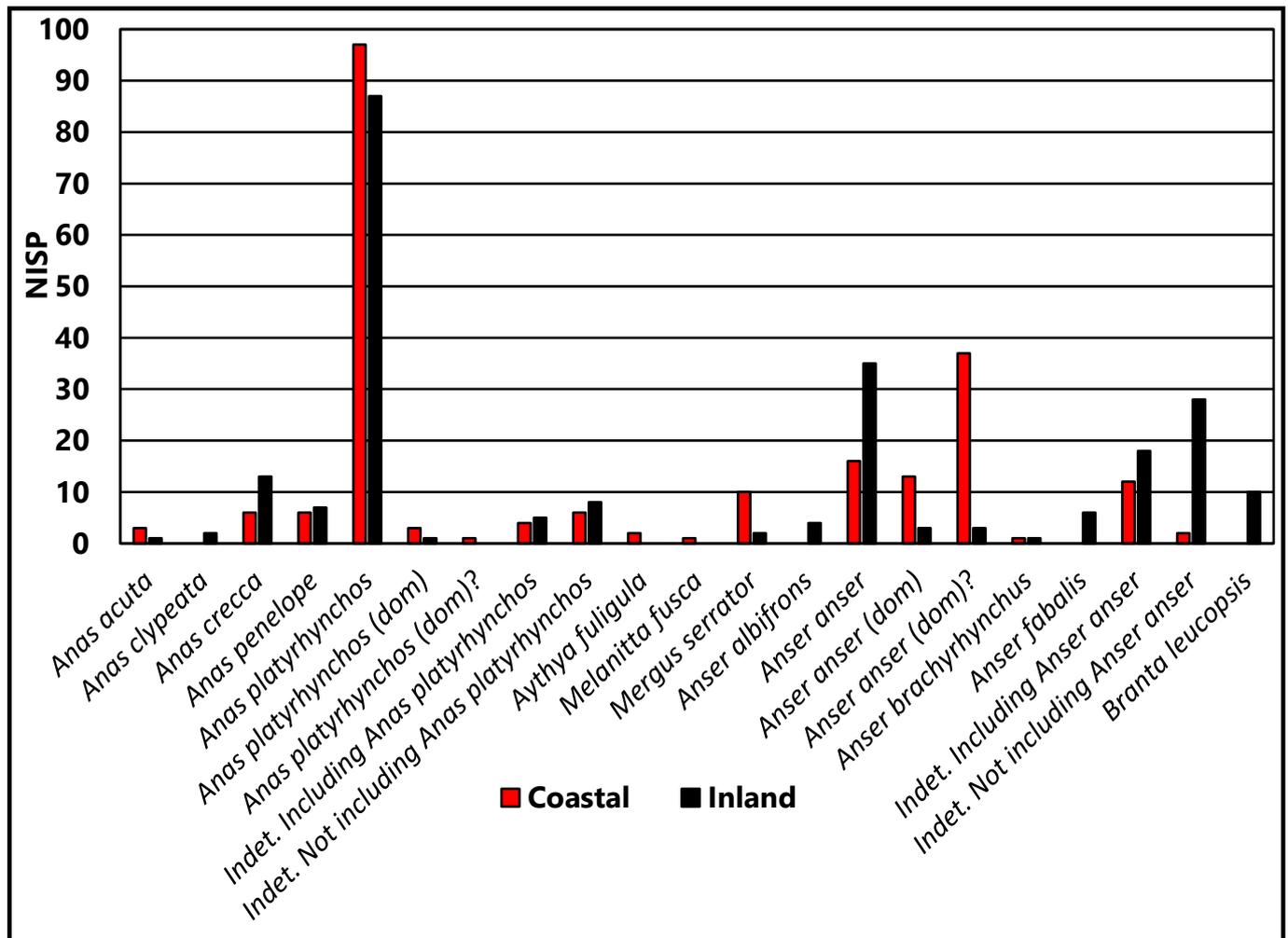
robust bones are more likely to have survived and been recovered (Payne 1973). The higher frequency of wing bones (figure 8.6) could also be an indication of taphonomic bias. It is tempting to think that the higher frequency of wing bones shows a specific practice of collecting the feathers from the wings for fletchings, brushes, or perhaps even quills (MacDonald *et al.* 1993), but it is far more likely that this pattern is a product of taphonomic processes. Wing bones are more likely to stay articulated than the rest of the bones in ducks and geese and so are more likely to be preserved in the archaeological record (Bovy 2012). Given that *Anas platyrhynchos* and *Anser anser* are both the most frequent species in the environment and the largest species of ducks and geese, we can expect that they will be the most frequent in an archaeological assemblage, even if there is no selection for a specific species for consumption. Therefore, the fact that these two species are overwhelmingly the most frequent does not necessarily suggest that they were particularly selected for consumption during the Roman period in Britain. The range of species, and the relative frequency of the species identified, suggests that there was no obvious selection for certain species but that the exploitation of ducks and geese, in general, reflected what was available in the environment. This notion is discussed further below.

### **Were there any differences in the species that were used between different types of site?**

The sites discussed in this thesis are categorised in two ways; firstly by type of site (urban, fort, high status, roadside settlement), then by whether they are coastal or inland. This is to allow for a comparison between the main types of sites to see if there was preferential selection of certain species, or the occurrence of certain species on site was due more to environmental availability than human choices. Perhaps what is easiest to discuss first is a comparison of coastal sites and inland sites, bearing in mind the limitations of dealing with a small number of sites. If there were no selection, then we may expect to see some of the

species that can live in the sea at the coastal sites, but not at the inland sites. Figure 8.7 shows the species present at the coastal sites compared to the inland sites and we can see that for ducks there are some species associated with the sea at the coastal sites (*Aythya fuligula*, *Melanitta fusca*, and *Mergus serrator*) that are almost completely absent from the inland sites. To some extent this is also true for geese, apart from the occurrence of Barnacle geese (*Branta leucopsis*) at an inland site. This species was only identified in London, and although it is an inland site, there is a very clear connection to the coast via the river Thames (Wallace 2014). Perhaps then Barnacle gees were easy to obtain and sold in the market.

**Figure 8.7.** Bar chart showing the frequency (actual NISP) of bones identified to at least the genus level at the Roman coastal and inland sites in Britain analysed in this thesis. Some species of duck that are usually associated with coastal habitats are present in the coastal assemblages but absent from the inland assemblages.



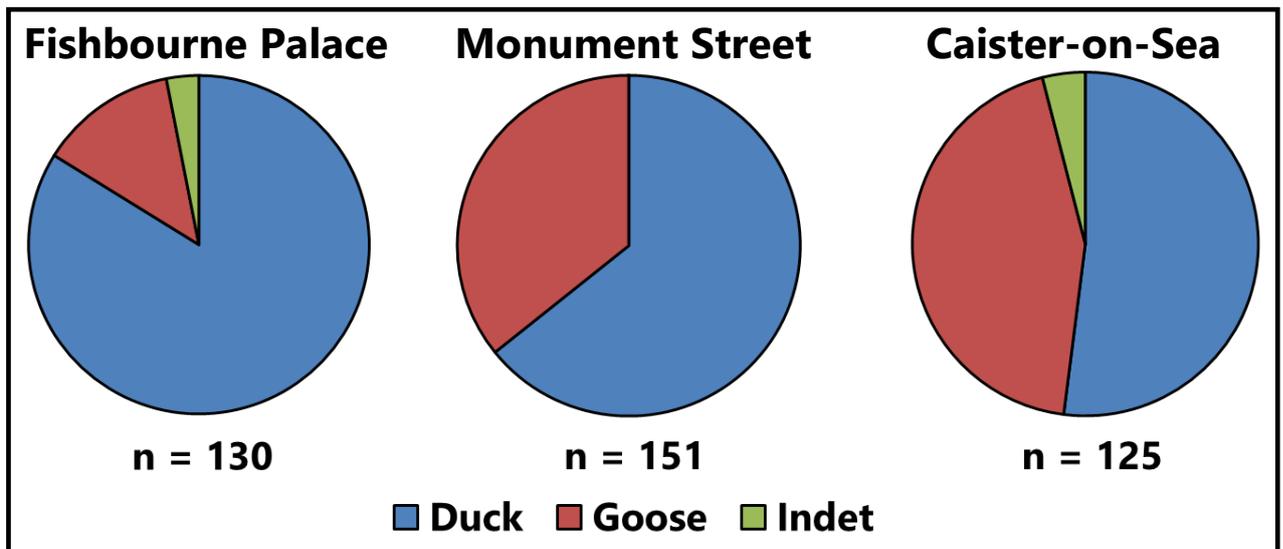
Before comparing the use of ducks and geese at the different site types, there is another pattern within the results that requires attention. The two most northerly sites, York and Melton, have the highest proportion of geese to ducks. It may be the case that this is also a product of what is available locally, but this is unlikely as it is probable that ducks were more frequent than geese in those locations at the time (Yalden and Albarella 2009). It may be the case that for some reason at these sites there is a preference for goose. However, before exploring possible reasons for this it is worth considering taphonomic and recovery biases. These biases would remove the smaller, more fragile bones from the assemblage and so it cannot be ruled out that the proportionally higher amount of geese is the product of biases acting on the assemblage and nothing to do with the choices of the people who lived at the site. Comparing the wet sieved material to the hand collected material at Tanner Row we can see that it is likely that a number of smaller bones have been lost as smaller species are present in the sieved material and not the hand collected assemblage (O'Connor 1988). More duck bones were recovered in proportion to goose bones from the sieved material and so the proportion of duck to goose bones recovered from the whole site is not likely to have been representative of what was there during the Roman period. Therefore it does not appear that there was a particular selection for geese at the northern sites because biases cannot be ruled out for causing the higher proportion of geese.

Three assemblages from the sites analysed are similar in size and so offer an opportunity for meaningful comparison. Fishbourne Palace, Monument Street in London, and Caister-on-Sea all have duck and goose bone assemblages in excess of 100 bones and represent three different site types. Figure 8.8 shows the relative frequency of ducks to geese at the three sites and we can see that many more ducks than geese were consumed at Fishbourne Palace, proportionally more ducks than geese were consumed at Monument Street, and an almost equal number of ducks and geese were consumed at Caister-on-Sea in

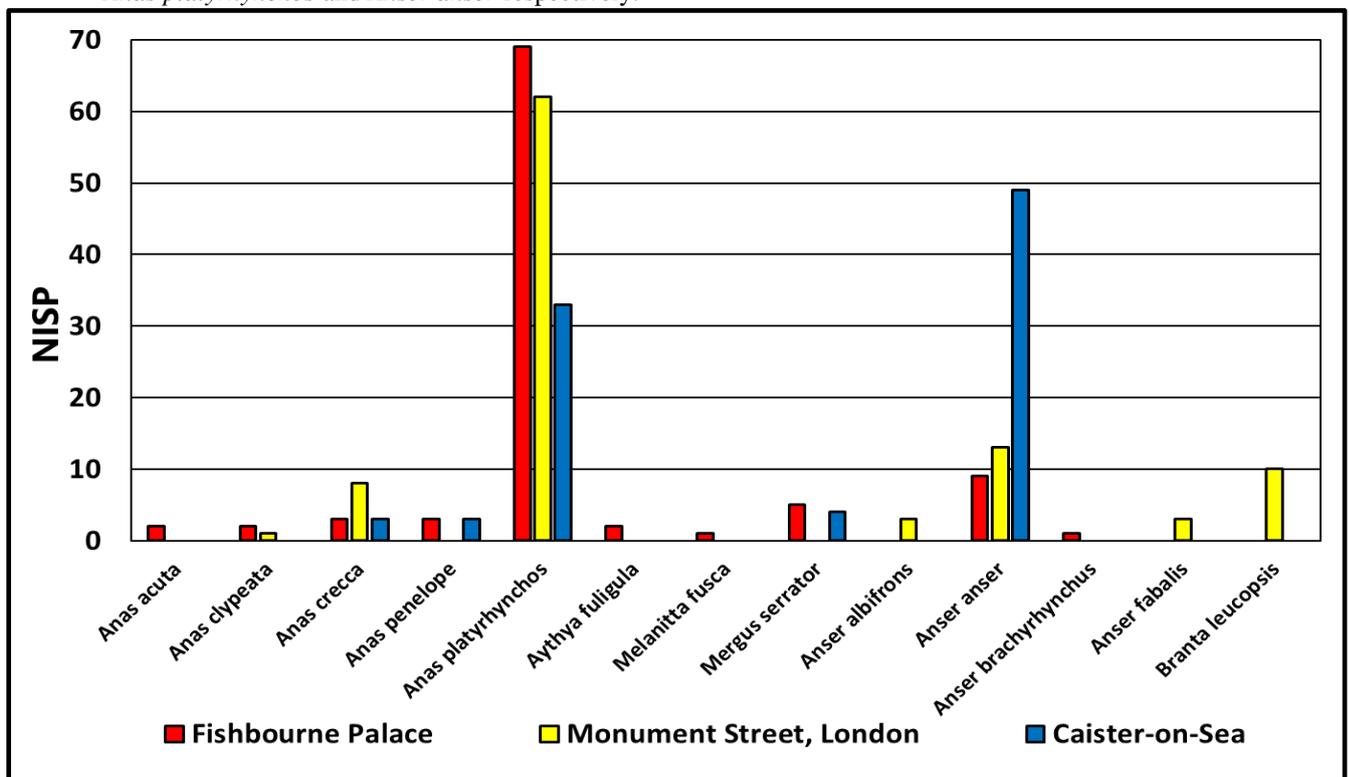
terms of NISP. When we consider the size of geese to ducks it is clear that more goose meat than duck meat was consumed at the fort in Caister-on-Sea. Figure 8.9 shows the relative frequency of the different species at each site, with the domestic (and possibly domestic) individuals separated from the wild individuals.

The highest species diversity is at Fishbourne Palace with at least 10 different species of ducks and geese present. This is interesting for two reasons. Firstly, it shows us the species that are likely to have been in the environment at the time near to the palace and adds to our knowledge of British avifauna in the past and the discussion summarised by Yalden and Albarella (2009). The other reason that this is interesting is that it may well reflect the tastes and attitudes of the people who lived at the palace. It is unlikely that the consumption of wild ducks and geese was necessary for subsistence purposes due to the opulent nature of the site. Therefore there was a choice to consume these birds. We know from work carried out by other researchers that there was a great range of animals consumed at the site, including some exotic animals, and so it seems that variety was a key part of diet at Fishbourne Palace (Allen 2011). Being able to provide a variety of different animals at the table for visitors would have demonstrated the wealth of the people that lived at the palace, and perhaps it was the case that the more unusual, exotic, or colourful the animals served the better. At Monument Street in London seven species of ducks and geese were identified which shows that there was variety on offer at the inn/restaurant, and again there must have been a choice for this variety. One interpretation of the archaeological assemblage from the site is that the well was back filled with the waste from a nearby high quality inn or restaurant (Schofield and Maloney 1998). If this is the case then the range of species found at the site may reflect a taste for variety from the customers of the inn and again may show a display of wealth, particularly in the public inn/restaurant setting.

**Figure 8.8.** Pie charts showing the relative frequency of ducks and geese at Fishbourne Palace, Monument Street in London, and Caister-on-Sea.



**Figure 8.9.** Bar chart showing the frequency of identified species at Fishbourne Palace, Monument Street in London, and Caister-on-Sea by NISP. Bones identified as domestic duck or domestic goose (or could possibly be domestic duck or domestic goose) have been incorporated into the counts for *Anas platyrhynchos* and *Anser anser* respectively.



The higher diversity of goose species at this site, including *Branta leucopsis*, may just reflect what was available locally or easier to acquire at the nearby markets. The site that has the least diversity of the three in terms of ducks and geese is Caister-on-Sea. We can see in figure 8.9 that only five species of ducks and geese were identified, four of which were ducks. At Caister-on-Sea it seems to be the case that the consumption of ducks and geese was different. Ducks appear to have been acquired from the wild, and to some extent may have represented what was available in the environment. However, there are relatively few ducks compared to geese and their consumption does not appear to have been very common. It is plausible that wildfowling was just a pastime for the inhabitants of the fort, or the ducks were occasionally caught to supplement the diet at the fort. Meat consumption may have been relatively monotonous with the main meat overwhelmingly being beef (Harman 1993). An addition of a duck every now and then may well have been a welcome change. When it comes to the geese we see a very different pattern. No other species of goose were positively identified apart from *Anser anser*, and a considerable amount of those bones were identified as the domestic form, or possibly domestic (table 7.3). The geese may have been kept for economic reasons, for example goose fat has been noted as a valuable resource (Kear 1990) and no doubt had many uses in a fort setting. However, another intriguing possibility for keeping geese at the fort is to act as guard geese. Geese are very alert and territorial animals capable of making a great deal of noise if they detect an intruder (Ashton 2012). There are Roman accounts of keeping geese for such a purpose (see Toynbee 1973) and there is the famous example of when geese supposedly saved Rome from a Gaulish sneak attack by rousing the guards when the dogs failed to do so. Whatever the reason for keeping geese at Caister-on-Sea, keeping geese was a different practice from catching the wild ducks at the site and the use of anatids appears to have been different at the fort compared to the high status and urban sites discussed above. Unfortunately the assemblage from York appears to be too small to make a

meaningful comparison with Caister-on-Sea, but it will be interesting to see how similar other forts are in Britain and Western Europe, as more assemblages are analysed using the identification criteria established in this thesis.

### **Summary**

To summarise, it is likely that domestic geese were present in Britain during the Roman period but were not very common. Small numbers of them appear to have been kept at different types of site, at different times during the Roman period, and possibly for different reasons. For example it may be the case that they were kept as a form exotic curiosity at the high status site of Fishbourne Palace and larger amounts of them may have been kept for economic or security reasons at the later fort at Caister-on-Sea. In any case, the numbers of domestic geese kept in Britain during the Roman period must have been very low and it is unlikely that they were a particularly important economic animal at any point during that period of history. Conversely, it is very unlikely that any domestic ducks were kept in Britain during the Roman period. There are only a handful of bones that are consistent with modern domestic ducks compared to the hundreds of wild ducks that have been identified from the ten assemblages from a wide geographical range in Britain. It seems likely that domestic ducks were either not introduced, or not developed and bred, until much later in British history. They certainly do not appear to have been an important animal economically until at least the medieval period.

The consumption of wild ducks and geese does not appear to have involved the selection of any particular species. Rather, the species that are present at each site seems to represent what was available locally. None of the sites discussed in this thesis would have been reliant on wild resources and so the consumption of these wild birds must have been by choice. The consumption of wildfowl would have been a departure from the usual, every day,

meat consumption practices of the people at the sites and so reflects their taste for variety. Regardless of whether the site was a high status site, an urban site, or a fort site, variety in the consumption of wild ducks and geese is the main theme that is evident from the analysis of the Roman archaeological material. The only place that there seemed to have a higher proportion of the consumption of domestic geese was at Caister-on-Sea. This site was the last to be established and is thought to have had particularly strong ties with mainland Europe. Perhaps then this site represents the start of the increase in domestic goose consumption at the expense of duck consumption that has previously been discussed by Albarella (2005). In future it will be interesting to see how our understanding of duck and goose consumption changes as more assemblages from Roman Britain are analysed, as we investigate variation in the use of these birds within Roman Europe, and how we interpret their changing use in Britain from the Roman period into the medieval and post-medieval periods.

## **Chapter 9~** **Conclusions**

The economic and cultural importance of ducks and geese in the past is hardly understood despite many well documented historical references and the frequent recovery of their remains from archaeological sites. This is particularly true when we focus on their use in Britain. There is little understanding of the importance of them as sources of food, providers of secondary products, religious or spiritual symbols, or agents in the human world within their own right. Until relatively recently, we only had a very superficial understanding of the exploitation of wildfowl during the historic and prehistoric periods in Britain. This is not because there is a notion that these animals were unimportant, rather we know that there must have been many uses for these birds and cultural attitudes to them likely reflected the world views of the people who used them (or did not use them) in the past (chapter 1). The reason that the use of these birds in the past is poorly understood is due mainly to a lack of identification criteria that makes it impossible to meaningfully discuss the remains of these birds from archaeological sites. This thesis sought to address this issue and demonstrate how the new identification criteria could be applied to archaeological assemblages to provide meaningful insights into the attitudes and intentions of the people in the past that collected or raised ducks and geese.

The Roman period in Britain was chosen as the study period and location for this thesis as it is during this period that some key changes in the use of ducks and geese in Britain may have started to happen. We know from historical and zooarchaeological sources (Grau-Sologestoa *et al.* in prep.) that the use of domestic ducks and geese was well established by the later medieval period in Britain and that these animals had become a relatively important economic resource. However, we did not know when domestic anatids started to be regularly reared in Britain and at what point their economic importance started

to increase. This thesis aimed to address whether domestic ducks and/or geese were present in Britain during the Roman period to see if the practice of keeping them as an economic resource had started by then. Many researchers have identified ducks and geese in zooarchaeological assemblages from Roman contexts in Britain and there has been many speculations about whether domestic ducks and geese were present in Britain during the Roman period. However, no researcher has been able to say with confidence whether they were present or not. Moreover, most researchers have been completely unable to discuss the use of wild ducks and geese during the Roman period and what that could mean for our understanding of wild resource exploitation strategies and for understanding the local environment at the time. The reason for this is that there has never been any method of reliably identifying the various ducks and geese that are recovered from archaeological sites until now.

### **New identification criteria**

There was a range of options to explore for producing a reliable method of identifying archaeological ducks and geese including traditional morphometrics, ZooMS, genetic analysis, and geometric morphometrics. Ultimately the method that was chosen to investigate was traditional morphometrics using multivariate statistics, as well as simple univariate and bivariate analyses. The reason this method was chosen was because if it worked then it would be relatively inexpensive, easy to adopt by other zooarchaeologists, it is non-destructive, is a relatively quick method, and only requires a set of calipers and easy to obtain statistical software to work. Even if this method was only 90% reliable then it would still be worth exploring for the benefits discussed above. In actuality, traditional morphometrics and multivariate statistics produced a very reliable way of differentiating between the elements selected for study for most taxa. Of the nine elements selected for analysis, a reliable

distinction could not be made in only a handful of cases and this was usually due to sample size, or for elements that only a small number of measurements could be taken (*e.g.* the scapula or radius) and the two taxa were closely related. Chapters 3-5 show how the various taxa, for each element, can be distinguished by just taking a few measurements or morphological observations and plotting/testing them in the graphs and tests described. The way that the identification criteria was tested was to establish the simplest way of differentiating between two taxa. Therefore, if one measurement, or one morphological characteristic, was reliable then this would be used and there would be no need for any further complicated analysis. This was the case in some instances, such as for the distinction between duck and goose radii (chapter 3) and *Anas* and *Aythya* femurs (chapter 4). If two taxa could not be separated using one measurement, then bivariate scatter plots and ratio plots were used to see if different taxa would cluster in different areas of the graph. If taxa did not cluster in different areas then in most cases discriminant function analysis could be used to classify a bone into the correct taxon.

Ducks and geese can often be separated using one or two measurements due to the differences in their size. Ratio plots and discriminant function analysis can also be used to distinguish between ducks and geese, but in most cases this is not necessary (chapter 3). The separation of most genera of ducks cannot be achieved using size alone as the size range of *Anas* overlaps with most genera for most bones (chapter 4). Ratio plots and discriminant function analysis is often required to differentiate between *Anas* and the other genera, but once this is achieved most other genera can be distinguished using bivariate or ratio scatter plots. There are a few examples of morphological characteristics that can be used to distinguish between some genera, (*e.g.* the Cormac2 characteristic for distinguishing between *Aythya* and *Clangula*), but these can only rule out some taxa when making an identification and it is nearly always necessary to analyse the linear measurements to make a final reliable

identification. In most instances, the various species of duck analysed in this thesis can be separated using just one or two measurements as they vary in size within each genus. Ratio plots and then discriminant function analysis can be used to make an identification in most of the remaining cases. In a very small minority of cases, and only for certain elements, a reliable identification cannot be made; this is when an unknown bone plots in the overlap area of the bivariate and ratio plots and there are too few measurements for discriminant function analysis to be used (*e.g.* for the radius or scapula). However, these cases are rare, and positive and reliable identifications can be made in the majority of cases. For most elements the modern wild and domestic *Anas platyrhynchos* could be separated based on size alone. However, there were some shape differences which have not been identified before and can be useful for making an identification. For example, ratio plots show that there is a difference in the shape of the humerus with the domestic ducks being relatively wider in the shaft compared to the length of the humerus (chapter 5). Discriminant function analysis shows that the modern wild and domestic ducks can be classified into two distinct groups with a very high degree of accuracy for all elements with the exception of the radius and scapula (chapter 4). This means that a reliable identification can be made on an archaeological bone, provided that enough measurements can be taken on the bone.

The two genera of goose that were analysed in this thesis can be separated by using one or two measurements as there is no overlap in their size ranges. Ratio plots and discriminant function analysis do work for separating *Anser* and *Branta*, but they are usually unnecessary as simple bivariate scatter plots will distinguish the genera in the majority of cases (chapter 5). Within the genus *Branta*, the two species analysed in this thesis can be separated using just one or two measurements for most elements. Ratio plots did not show a sufficient difference in the shape of the bones to separate the two species, but discriminant function analysis can reliably classify the species provided that enough measurements can be

taken on a bone. Separation using one or two measurements when identifying species within the genus *Anser* can be achieved in some cases, for some elements, but only for distinguishing between the larger and smaller species. Ratio plots show that there is little variation in terms of shape between the different *Anser* species and so it is often necessary to use discriminant function analysis to classify a bone. Although statistically significant results were obtained in most cases, the classification accuracy was lower for species in this genus compared to *Branta* and all of the genera of ducks. This is not to say that it cannot be used to make an identification, but the margin of error may be higher than for the identification of the other species analysed in this thesis. Modern domestic geese and modern wild geese (*Anser anser*) can be separated in bivariate scatter plots or by ratio plots in most cases and for most elements (chapter 5). There are occasions when the clusters of the domestic and wild geese overlap and so it is necessary to use discriminant function analysis to classify an unknown bone if it plots in the overlap area of the scatter plots. This can be highly accurate and reliable, but in some cases the classification accuracy was not as high as it is for the distinction between modern domestic and wild ducks (chapters 4 and 5). This does not mean that the domestic and wild geese cannot be distinguished, it just means that, because there is less variation between the two, the margin of error may be higher than for distinguishing between domestic and wild ducks. As almost nothing within archaeology has 100% accuracy this is not an issue as such and this criterion will still prove to be useful when making identifications to aid with interpreting zooarchaeological geese.

### **Archaeological material results**

The assemblages that the new identification criteria were applied to were chosen for a range of reasons. Firstly, geographical variation between sites was needed so that the impact of environmental availability on the choice of species consumed could be investigated.

Secondly, different types of sites were needed to see if there was a difference in the use of ducks and geese depending on how the sites functioned. Lastly, assemblages were chosen for their sample size, *i.e.* they were large enough to allow for meaningful comparisons between sites or, in two cases, because ongoing research projects were in progress in the department, and their analyses would support the research aims (Owslebury and Ware).

Although there are many research questions that could be explored through the analysis of ducks and geese from Roman Britain, there was a focus on four main research questions in order to address some long running debates and demonstrate the usefulness of the new identification criteria:

- 1. Were domestic geese used in Britain during the Roman period?**
- 2. Were domestic ducks used in Britain during the Roman period?**
- 3. To what extent were wild species used in Roman Britain compared to their domestic counterparts?**
- 4. Were there any differences in the species that were used between different types of site?**

From the analysis of the archaeological material it appears that domestic geese were present in Britain during the Roman period, but were uncommon and may only have been present at certain sites. At Fishbourne, it seems that a small number of domestic geese were kept, along with a whole range of other animals, as curiosities and as a display of wealth. At the later site of Caister-on-Sea it may be that the keeping of domestic geese was a minor but productive activity that was introduced from mainland Europe, along with a suite of other food production practices; alternatively, geese may have been kept for guard purposes. In sum, domestic geese were present in Roman Britain, but made only a minor contribution to the economic life.

It is unlikely that domestic ducks were present in Roman Britain as the vast majority of duck remains identified in this thesis were from wild birds and only a handful are potentially consistent with domestic duck. It seems that the domestic duck was not really kept or developed until later periods and possibly as late as the later medieval period.

Wild ducks and geese were the main anatids that were consumed during the Roman period and it appears that there was no particular selection for species. Due to variation in colouration and size it would have been possible to be selective, but the range of taxa identified at each site suggests that there was no selection. It is likely that there was no cultural or practical reason for being selective and so the taxa found at each site may reflect what was available locally. The other consideration to make is that variety in diet may have been important socially. There was a range of ducks and geese consumed at most sites and this is echoed in the range of other animals consumed in most cases (with the exception of the fort sites). The ability to afford a range of animals, including ducks and geese, may have demonstrated wealth to those that were involved in the consumption. Variety would also have made life more interesting for the person paying for the food, which is always an important consideration worth making.

The inhabitants of some sites, *e.g.* Caister-on-Sea, used more domestic resources relative to the wild resources and this seems to reflect a greater connection to mainland Europe rather than a locally developed practice (this will be an interesting notion to investigate further in the future). What we have to consider though, is why people utilised these wild resources at all. It is unlikely to be the same reason at each site, due to the range of functions they had. For example, the high status site of Fishbourne Palace was unlikely to need additional food resources from the wild for subsistence, and so we must assume they were collected out of choice. Similarly, the forts and urban sites were unlikely to need the wild resources as they were mainly provisioned from other sources. Choice is important to

consider here, and whether it is an ability to show that you can have variety at the dinner table or making welcome changes to the food that was consumed on a daily basis, it is important to realise the significance of wild resources even if they were only occasionally exploited.

### **Future work and recommendations**

The identification criteria produced from the analysis of the modern reference material has shown that it is possible to reliably identify archaeological duck and goose bones using linear measurements and multivariate statistics. It is recommended that the identification criteria presented here are used whenever an identification of an archaeological duck or goose bone is made in north-west Europe. This thesis shows which taxa can be confidently identified using only a few measurements and which taxa require more complex analysis to make an identification due to the similarity of their morphology. When the identification criteria was applied to the archaeological material from Roman Britain, it was evident that ducks were utilised more frequently than geese, that wild birds were consumed more often than domestic birds, that there is little evidence that domestic ducks were present in Britain during the Roman period, and that domestic geese were likely present but were a rare animal in Britain at the time.

Key archaeological questions to examine in the future will be how the domestication process developed, why geese became more popular in later periods, and how similar was Britain to the rest of Europe in terms of the use of these birds during the Roman period. These questions can start to be addressed by analysing more archaeological assemblages in Britain and Europe using the identification criteria established in this thesis and by comparing the results in studies that span larger geographical and chronological ranges. What will be particularly interesting is how our understanding of the economy of ducks and geese develops

as we investigate why there was a transition from mostly wild resources in the Roman period to a much greater focus on domestic birds by the end of the medieval period.

The newly established identification criteria greatly furthers our ability to investigate the use of ducks and geese in the past. However, further work on the database can be carried out to improve the reliability of the identifications for taxa that had low sample numbers (*e.g.* *Anas acuta*, *Anas querquedula*, and *Mergus albellus*). The chronological range that the criteria can be applied to could be extended by adding measurements from other duck and goose taxa. For example, species such as *Branta canadensis* (Canada goose) and *Cairina moschata* (Muscovy duck) were introduced to Britain after the Roman period and so measurements from modern specimens of these taxa could be added to the database to aid with research on assemblages from later periods. Similarly, species from further east or south in Europe, Africa, and Asia could be added to extend the geographical range that the identification criteria could be used in.

The identification criteria presented in this thesis were developed for the purpose of identifying ducks and geese from archaeological sites in north-west Europe. It is anticipated that, even if other methodologies are developed (such as aDNA analysis or ZooMS), this set of criteria will be used for years to come because the method is accurate and reliable in most cases, easy to use, relatively quick and inexpensive, and not destructive. The author hopes that the application of the new identification criteria to archaeological material becomes standard when duck and goose bones are identified in archaeological assemblages in Britain.

Further to an archaeological application of the identification criteria, it is also possible that the criteria will be used by researchers in other fields such as ecology, ornithology, and zoology to investigate bird remains from natural deposits. A wide range of topics could be investigated including biodiversity in the past, seasonality of site occupation, changes in the environment, variation in taxon frequency through time, and anthropogenic impact on animal

species diversity. The author is excited to see how the identification criteria are utilised in the future.

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