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A zooarchaeological study of biometric variation in the cat *Felis silvestris* Schreber

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Abstract

Investigation of modern biometric data indicates that it may be possible to distinguish wildcats from house cats in many instances. Applying the log-ratio (log-difference) technique to archaeological samples from medieval northern Europe, and to mixed samples of wildcats and house cats shows that the differentiation may not always be clear, and the possibility that some samples include hybrids is discussed. The technique is applied to samples from the Orkney islands to demonstrate that single wildcat specimens can be identified in small samples.

Keywords

Cat *Felis silvestris* size-index scaling York Haithabu Orkney

Cats are one of the most widespread and familiar animals of the domestic realm, and their association with people extends at least into the Neolithic period (Vigne *et al* 2004; Davis 1989). Opinions regarding the original domestication of cats range from the view that they were deliberately domesticated by people as useful predators of household vermin (e.g. Zeuner 1963; Kratochvil and Kratochvil 1976; Clutton-Brock 1999) to the behavioural model proposed by Todd (1978), which has cats adopting people as a useful source of food, and being first tolerated then encouraged and fed by people. Serpell (1988; 1996) has made the point that people seem to find benefit in the companionship of other species, quite apart from any resource value those animals may have, and the furry, purry amiability of cats fits them particularly well to the role of companion animal. That being the case, it is remarkable how little research has tackled the archaeology of the relationship between people and cats, compared to, for example, the copious literature on caprines or dogs.

One factor in this relative neglect is that any systematic study would have to differentiate between the bones of wild and domestic cats. The latter term itself may be problematic. For the purposes of this paper, the term ‘house cat’ (c.f. German *Hauskatze*) is used in preference to ‘domestic cat’, as it is purely descriptive and makes no assumptions about the phylogenetic relationship between synanthropic and free-living cat populations. A ‘speciation’ model of animal domestication, such as underlies the attribution of Linnaean binomials to domestic forms (Gentry *et a*l 2004), requires separation of the breeding populations of the domestic animals and their wild precursors; indeed, this is one of the defining aspects of animal domestication. However, house cats are conspecific and sympatric with a particularly widespread and polytypic species, *Felis silvestris*, the modern range of which extends throughout Europe into western Asia and through the entire length of Africa (Sunquist and Sunquist 2002). Breeding between house cats and wildcats is a major conservation problem today in parts of Europe (Daniels *et al.* 2001; Peripaoli *et al* 2003; Yamaguchi *et al.* 2004; Kitchener *et al* 2005; Lecis *et al.* 2006). It is a reasonable presumption that the genetic boundary between the two ecomorphs has always been as blurred as the behavioural boundary. The first point to make about the zooarchaeological data, therefore, is that it may be unrealistic to expect a clear distinction between wildcat and house cat bones because of the probability that hybrid forms existed wherever and whenever the two ecomorphs were sympatric.

The investigation reported here forms part of a larger study of the archaeology of cats. The attribution of cat bones to house cat or wildcat is at the heart of investigating their zooarchaeology, and this paper limits itself to investigating the feasibility of making such attributions with confidence by the use of conventional biometrical techniques, and to investigating inter- and intra-sample variability in ancient and modern samples of cat post-cranial bones. Within European zooarchaeology, it has been the convention to attempt differentiation of wild- and house cats by demonstrating the smaller size of the latter ecomorph (e.g. Harcourt 1979, 154; Johansson and Hüster 1987, 44-7). Whether this apparent size difference derives from a marked difference in selection pressures in synanthropic populations, or reflects the origin of house cats in the more lightly-built African form of *Felis silvestris* (formerly *F. lybica*; see Clutton-Brock 1999), or a combination of both founder effect and several millennia of drift, is a debatable point. For the present purposes, it serves as a starting point for investigation.

Materials and methods

Cat bones typically occur at rather low frequencies in zooarchaeological assemblages: it is unusual for them to constitute more than 1% of an assemblage. Accordingly, it is exceptional for any one element of the cat skeleton to yield a useful biometric sample, making it necessary to combine data from as many elements as is practicable. A technique that allows just such a combination of data is the use of log-ratio or log-difference values (Meadow 1999). Bond and O'Connor (1999) used just such an approach to investigate size variation in cat bones from medieval York, using a single cat skeleton as the 'standard' measure against which to rescale the archaeological data. It is generally better practice to use mean values from a number of skeletons as the standard than to use a single individual that may be atypically proportioned. The largest readily-accessible samples of biometric data pertinent to this paper are those published by Kratochvil (1973, 1976a). The former study investigated size and morphological variation within and between samples of 51 wildcat and 60 house cat skulls, whilst the latter studied the postcranial skeletons of 31 wildcats and 76 house cats. In both studies, the wildcats were from populations in the western Carpathians and the house cats from the Brno region. Kratochvil's aim was to describe and quantify consistent differences between the wildcat and house cat samples, testing and validating criteria proposed by previous authors such as Röhrs (1955) and Schauenberg (1969), and to measure the degree of intra-population variability of different characters. This latter point is important in a zooarchaeological context as Kratochvil's data on variability may help to resolve whether a given archaeological sample represents a rather variable sample of one or other ecomorph or a mixture of the two. The data also show that sexual dimorphism is negligible in the postcranial skeleton and in the cranial skeleton of house cats, but measurable in the cranial skeleton of wildcats (Kratochvil 1976b). Again, this is a valuable observation when trying to explain variation in zooarchaeological samples. Given the lack of sexual dimorphism in postcranial elements, this present study uses Kratochvil's male and female house cat data combined to constitute a 'standard' dataset against which to compare archaeological data using the log-ratio (log-difference) technique (Meadow 1999).

Log-ratio values were calculated using the algorithm

$$\text{Log-ratio} = \log_{10}(\text{observed/standard})$$

The house cat data were used as a standard, in preference to the wildcat data, because the sample size is appreciably larger for Kratochvil's house cat sample, and because a preliminary scan of archaeological data indicated that the great majority of specimens were closer in size to the house cat size range than to the wildcat range. The modern data are summarised in Table 01, which is derived from Kratochvil (1976a). Some of Kratochvil's measurements are not used here, either because they are only rarely available or recorded in zooarchaeological material or because of ambiguity in equating his measurements with those defined and illustrated by von den Driesch (1976) and used by most zooarchaeologists.

Further modern data were acquired from house cats and wildcats in the collections of the author and the University of York (Table 02). The house cats are fully documented as to sex and age at death. The wildcats are not fully documented, but were stated on acquisition to have originated as 'road-kill' specimens in highland

Scotland, and to have pelage characteristics of ‘wild’ *F. silvestris*. Given the uncertainty that surrounds the diagnosis of wild- and house cats in regions of close sympatry (Kitchener *et al.* 2005), it is possible that one or more of these cats is a hybrid (see discussion of the data below). None the less, these data comprise a sample of modern cats from mainland Britain that includes *behaviourally* wild and domestic individuals. All measurements were taken using sliding callipers to a precision of 0.1mm, following conventional zooarchaeological procedures.

Archaeological datasets were acquired from the author’s own records and from published data. Data from sites in York and Lincoln, recorded by the author between 1979 and 1999, have been used to assemble three substantial post-Roman samples:

- YorkVik – York Viking Age (or Anglo-Scandinavian), 10th to early 11th century AD. Specimens from 16-22 Coppergate, assemblages published in O’Connor (O’Connor 1989)
- YorkMed – York High Medieval, 12-13th century. Specimens from 16-22 Coppergate and The Bedern (Bond & O’Connor 1999)
- LincVik – Lincoln Anglo-Scandinavian, 10th to early 11th century. Specimens from Flaxengate timber building phases (O’Connor 1982)

As comparanda for these English samples, further data were acquired from the broadly ‘Viking Age’ assemblage from Haithabu (modern Hedeby; Johansson and Hüster 1987) and from the medieval assemblage from Schleswig (Spahn 1986). These two examples were chosen as the exceptionally large size of the assemblages allows investigation of intra-sample variation.

Further data were acquired from a post-medieval assemblage from Kilton Castle, in the north of England. These cats were part of a mixed assemblage of cats and rodents recovered from the lowest deposits in a well, and apparently derived from 17th century ‘clearing up’ of the castle. The cats are included here as examination of the morphology of cat crania in this assemblage indicates the presence of wildcats and house cats, making the size range and variability of the post-cranial bones particularly relevant to this paper.

Results

To start with an internal comparison, Kratochvil's wildcat sample means were re-expressed as log-ratio values against the house cat standard (Table 01). Unremarkably, all values were positive, indicating the wildcats to be larger on all measured parameters. The log-ratio values were generally lowest for measurements taken on the atlas, axis, pelvis and tarsals; i.e. the difference is most marked in bones of the limbs, ranging from 0.062 (femur SD) to 0.107 (scapula spinus length). From the limb bones, length measurements generally gave larger log-ratio values than breadth measurements. Lengths range from 0.091 (humerus GLC) to 0.102 (fibula GL). Disregarding the length measurements, the forelimb generally gave higher values than the hindlimb: forelimb breadth values range from 0.080 (radius SD) to 0.101 (radius Bp), and hindlimb values from 0.062 (femur SD) to 0.078 (femur Bp, tibia Bp). To summarise, comparisons of length and breadth measurements should be made separately. We may expect limb bones, especially length measurements, to show the clearest differentiation of wild and house cats, and hindlimb breadth measurements to show the least differentiation, though even these measurements show the wildcat sample to be significantly larger than the house cats (t-test analyses on untransformed data are given in full in Kratochvil 1976a).

In order to compare the scale of those log-ratio values with the degree of variability of the house cat sample, four measured variables were investigated in more detail: tibia GL, radius GL, humerus Bd and femur Bd. These four were chosen to give a mix of fore- and hindlimb elements, and of lengths and breadths. The minimum and maximum values given by Kratochvil for each of the four variables were converted to log-ratio values based on the house cat mean values, thus showing the highest and lowest log-ratio values that the house cat sample would have given had the specimens been plotted individually. The results are shown in Table 03. The values for range show that the largest individual house cat specimen would typically have fallen into the wildcat range, though somewhat below the mean. The particularly high maximum values for humerus and femur Bd reflect exceptionally large values for one male house cat. The much narrower confidence limits show that the house cat sample typically has quite tightly-clustered data with a few outliers reflected by the values for the range. Apart from the humerus and femur Bd values, the data would lead us to expect a zooarchaeological sample of house cats to include the odd one or two giving values up to ±0.06, with the great majority well inside this limit. Given that differences in sample means range from 0.062 to 0.107, this internal comparison of Kratochvil's data indicates that it should be possible to differentiate most wildcats from most house cats on log-ratio scaled size alone, but with some overlap between exceptionally large house cats and likewise small wildcats. The same calculations were performed on the numerically smaller wildcat sample (Table 03). The lower values for the range show that there were fewer outliers in the wildcat sample, whereas the slightly higher values for the 95% confidence limits reflect the smaller sample size (hence higher values for the standard error of the mean, hence larger confidence limits). None the less, the wildcat results confirm a generally clear separation of the two samples, if anything indicating that it is more likely that an outlying large house cat would be mistaken for a wildcat than that an exceptionally small wildcat would be grouped with the house cats.

Table 02 lists length data from the additional house cats and wildcats. The three wildcats have separated from the house cats, and specimens from each of the wildcats have grouped together. EAU776 is the largest of the three by some way, and gives values that would place it around mid-range of Kratochvil's wildcat sample. EAU777 and EAU783 are appreciably smaller, particularly the latter. There is no substantial 'break' in the data between the smallest of the wildcats and the largest of the house cats. Given the difficulty of differentiating 'pure' wildcats in modern Scottish populations from pelage characters alone, it is at least possible that EAU783 is actually a hybrid. None the less, this sample usefully shows the range and variance that may be expected of a sample that contains both wild and house cats.

The archaeological sample from Kilton Castle was thought to contain both ecomorphs. Table 04 lists the length data for comparison with Tables 01 and 02. The first point to note is that the largest of the Kilton cats are very large, approaching the maximum values for Kratochvil's wildcat sample given in Table 01. At the other end of the range, the smallest are below the house cat standard values. As with the mixed modern sample in Table 02, there is no discernible 'break' in the data that could be taken to mark the boundary between wild and domestic forms. Fig 01 shows quite clearly the continuity of the Kilton data between the largest and smallest specimens. The Kilton data seem to confirm that the sample contains both wildcats and house cats but the continuity indicates a considerable size overlap, and thus perhaps a degree of hybridisation, between the two ecomorphs.

The medieval archaeological samples were chosen in part as substantial datasets, and in part on the expectation that samples from medieval towns would represent populations predominantly of house cats, with maybe an occasional specimen of wildcat deriving from animals hunted for their fur. Figs 02 and 03 show the log-ratio size distribution of the two York samples, and show a distinct difference in size distribution between two medieval phases in the same city. The Viking age sample, though small in number, shows a size variation either side of the standard, with perhaps two particularly large cats standing out on the breadth measurements (Fig 02). The two specimens exceeding 0.060 in Fig 02 are both ulnae. This value is close to the value discussed above as likely to differentiate most house cats from wildcats, and these two specimens do stand out from the general trend of the distribution in fig 02. The third largest specimen is a radius at 0.048, within the range seen in the reference collection wildcats (Table 02). Pending further discussion below, the two largest specimens can be described as ‘probably wildcat’, with the large radius possibly representing a hybrid or an exceptionally large house cat.

Comparing the York Viking age sample with the medieval sample, the difference is quite striking. On the medieval length measurements, just three specimens are within ±0.01 of the standard, and the remaining 45 are all below. On breadth measurements, just eight are within ±0.01 of the standard and the remaining 58 are all below. The medieval sample is clearly of cats that were substantially smaller than the standard sample: indeed, around 20 of the breadth sample are as far *below* the house cat standard as we might expect wildcat breadth measurements to be *above* the standard. These figures indicate a distinct decrease in the size of cats in York between the Anglo-Scandinavian and High Medieval periods; i.e. either side of the Norman Conquest. Fig 04 shows length and breadth results for the Lincoln sample, and a size distribution more akin to the York medieval sample than to the contemporary 10th-early 11th century sample. One cat stands out in the Lincoln breadth data, a radius at 0.044. This is not a particularly high value, though the specimen is distinctly larger than the remainder of the distribution. Given that, this specimen could be another ‘probable wildcat’. More to the point, the Lincoln data suggest that the size distribution of the York 10th century cats is distinctive to the city, not to the period of time.

Figs 05 and 06 show the distribution of length data from the very large assemblages at Haithabu and Schleswig. The range and distribution of the Haithabu sample is unexceptional, being quite similar to the contemporaneous samples from York and Lincoln. The Schleswig sample, in contrast, shows a remarkable range, from 0.105 to –0.138. The largest specimens overlap with Kratochvil’s wildcat data, with the reference collection wildcats, and with the largest specimens in the Kilton Castle sample. It seems feasible, therefore, that the largest five specimens, at least, in the Schleswig distribution derive from wildcats. Indeed, a graph of humerus GL in the original report shows a distinct ‘shoulder’ of larger cats, though this interpretation is not offered (Spahn 1986, fig 24). However, that does not explain the remarkably *small* specimens in the sample, and the question of intra-sample variability merits further discussion.

Discussion

What becomes clear from a consideration of the modern data, and of the archaeological samples, is that it would be unrealistic to expect a clear differentiation in biometric data between wildcats and their house cat contemporaries. Furthermore, the size distribution of house cat populations varied distinctly from time to time and from place to place. Table 05 summarises the variation observed in length measurements, using the mean log-ratio values for each sample, and the standard deviation of that mean. Although this manipulation of log-ratio values is unconventional, it serves a useful purpose here in summarising both the overall size difference between samples in this investigation, and giving us a measure of the degree of intra-sample variation. The mean values show that the largest average size occurs, not surprisingly, in the reference collection sample known to contain both wildcats and house cats, and in the Kilton Castle sample inferred to contain both. That result, at least, tends to support the interpretation of the Kilton sample. Apart from

Schleswig, the other archaeological samples show a consistency in their standard deviation values, those values being lower than in the two ‘mixed’ samples. With more conventional data, the standard deviation values could be converted to a coefficient of variation (V = 100*std dev/mean). However, as the mean values from these data range either side of zero, such calculation would be meaningless (i.e. for the reference collection sample, V = 100*0.038/0.000 = ∞). Indeed, the absolute numerical value of the calculated standard deviations are of little significance, but the results at least confirm that ‘mixed’ samples tend to show a higher intra-sample size variation than do archaeological samples arguably predominantly composed of house cats. Schleswig is therefore highly anomalous, with a mean value in the same range as the other Viking and medieval archaeological samples, and a size distribution consistent with the other archaeological samples (Fig 06), but a far higher standard deviation than even the ‘mixed’ reference sample.

It has been argued above that the largest few cats in the Schleswig sample may have been wildcats, but that does not explain the high overall variance. The Schleswig sample spans an appreciable period of time, from the later 11th century into the 14th century. Although some distinction is made in the published report between ‘young’ and ‘old’ phases within that period, the biometrical data are not subdivided. It is clear that cat bones were about equally distributed between the two phases, and that there was no substantial change in the spatial distribution of cat bones between the phases (Spahn 1986, 15-17). What we have for Schleswig, therefore, is a pooled sample spanning several centuries. It is quite possible that some size change occurred in house cats during this period of time, greatly increasing the intra-sample variability. The very small size of some of the cats is notable, suggesting quite strong selection pressures acting on adult body size (e.g. see Spahn 1986, fig 25, which illustrates two skulls at either end of the size range). Whether those pressures favoured smaller body size, or whether we are seeing a relaxation of pressures that would normally favour a larger body size, is not apparent. With a medium-sized animal such as the cat, it is difficult to predict the direction in which body size would tend to move given a relaxation of the selection pressures associated with a ‘wild’ lifestyle.

It remains to ask whether the results of this investigation have any practical application in the diagnosis of cat bones from archaeological samples, given that these generally occur in small numbers, precluding the analysis of intra-sample variation that has been possible here. Table 06 lists measurements of cat limb bones from Late Iron Age structures overlying the broch at Howe, Orkney (Smith 1994). One radius stands out from the remainder, sufficiently so to suggest that this could perhaps be a small wildcat, the remaining specimens deriving from house cats. The log-ratio values for length and breadth measurements on the large radius are not clearly in the modern wildcat range, but do approach the range of values seen in larger samples in which the presence of wildcat is either known (e.g. Table 02) or suspected (Table 04). This specimen lies just outside the 2σ range of the York Viking sample. Perhaps of more significance is the apparent confirmation that the majority of specimens are from house cats. Orkney is well beyond the sphere of Roman influence and therefore, even given the 'post-Roman' 4th to 8th century AD date of the Orcadian Late Iron Age, the Howe specimens are inconsistent with the oft-repeated assertion that house cats 'came to Britain with the Romans', at the northern end of a distribution that began with domestication in Middle or New Kingdom Egypt (e.g. see Kratochvil and Kratochvil 1976; Teichert 1977; Serpell 1988; Malek 1993). A second example is given in Table 07, which lists measurements of cat bones from the high-status late Viking Age site at Earl's Bu, Orkney (Batey *et al.* 1993). Again, one specimen, a humerus, stands out as being well within the range to be expected of wildcat, with the remaining specimens all being typical of rather small house cats in the range seen at York and Haithabu.

Finally, limb bone measurements from a cat recovered from the Roman site at Quseir el-Qadim, Egypt, have been tested against the house cat standard. This cat was reported by von den Driesch and Boessneck (1983), who draw particular attention to its size; "extremely large for a house cat" (*ibid*., 208). By adding this egregious cat to the analysis, the aim was to test the limitations of the procedure. Conversion of limb bone lengths and breadths to log ratio values against the house cat standard gave a range of strongly positive values, from 0.043 (radius Bd, though note 0.026 for calcaneum GL) to 0.079 (femur GLC). On the face of it, this is a wildcat-sized cat, though calculations of log-ratio values against Kratochvil's wildcat sample means (Table 01) gave consistently negative values (-0.013 tibia Bp to –0.047 radius Bd). Von den Driesch and Boessneck are quite confident that this is a house cat, citing morphological traits of the cranium and mandible, and the photographs that accompany their paper clearly show a shortened angular process on the mandible, typical of house cats. Furthermore, the context of the burial, wrapped in linen and lain on woollen textile (appropriately of tabby weave) in a niche within a major building, strongly suggests ‘domestic’ status, whatever the morphology. The same authors have drawn attention to the often large size and ‘wild’ proportions of house cats in ancient Egypt (Boessneck and von den Driesch 1982). Evidently, any investigation of house cats from Roman or earlier Egyptian sites would need to play close attention to context as well as to biometry.

Conclusions

This investigation has demonstrated that differentiation of wildcat and house cats may be feasible using a conventional and relatively unsophisticated biometric technique. However, examination of intra-sample range and variation within large zooarchaeological samples shows that it maybe unrealistic to expect a clear size distribution break between the two ecomorphs, a result that is consistent with modern observations that sympatric wildcats and house cats interbreed freely to produce a continuum of hybrid forms. None the less, application of the results to two typically small samples has shown that specimens of wildcat may be identified in samples consisting largely of house cats, albeit with differing degrees of confidence. The Quseir el-Qadim cat was an exceptional beast, and serves as a warning that the context of the finds should be taken into consideration. The next step is to attempt the converse, namely to identify scarce house cats among samples that largely consist of wildcats (O’Connor, in prep.). Acquiring the data for such an analysis is more difficult than accessing the substantial medieval samples used in this paper, but further investigation is essential if our knowledge of the domestication and adoption of this most familiar of companion animals is to proceed on a more sound evidential basis.

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References

Batey CE, Harry RC and Morris CD. 1993. *Excavations at the Earl’s Bu, Orphir, Orkney 1993*. Glasgow University Archaeological Research Division: Glasgow

Boessneck J and von den Driesch A. 1982. Studien an subfossilen Tierknochen aus Ägypten. *Münchner Ägyptologische Studien* 40: 1-172.

Bond JM and O'Connor TP. 1999. *Bones from medieval deposits at 16-22 Coppergate and other sites in York.* York Council for British Archaeology Archaeology of York15/5.

Clutton-Brock J. 1999. *A natural history of domesticated mammals*. (2nd ed.) Cambridge University Press: Cambridge

Daniels MJ Beaumont M. Johnson PJ Balharry D Macdonald DW and Barratt E. 2001. Ecology and genetics of wild-living cats in the north-east of Scotland and the implications for the conservation of the wildcat *Journal of Applied Ecology* 38: 146-161

Davis SJM. 1989. Some more animal remains from the Aceramic Neolithic of Cyprus. In *Fouilles récentes à Khirokitia (Chypre) 1983-1986*., Le Brun A (ed.) ADPF Edition Recherches sur les Civilisations: Paris; 189-221

Driesch A von den and Boessneck J. 1983. A Roman cat skeleton from Quseir on the Red Sea coast. *Journal of Archaeological Science* 10: 205-211

Gentry A Clutton-Brock J and Groves CP. 2004. The naming of wild animal species and their domestic derivatives. *Journal of Archaeological Science* 31: 645-51

Harcourt RA. 1979. The animal bones. In G*ussage All Saints. An Iron Age settlement in Dorset*., Wainwright GJ. Dept of Environment Archaeological Report no 10. Her Majesty's Stationery Office: London; 150-160

Johansson F and Hüster H. 1987. *Untersuchungen an Skelettresten von Katzen aus Haithabu (Ausgrabung 1966-1969)*. Berichte über die Ausgrabungen in Haithabu 24. Karl Wachholtz: Neumünster

Kitchener AC Yamaguchi N Ward JM and Macdonald DW. 2005. A diagnosis for the Scottish wildcat (*Felis silvestris*): a tool for conservation action for a critically-endangered felid. *Animal Conservation* 8: 223-237

Kratochvil Z. 1973. Schädelkritieren der Wild- und Hauskatze (*Felis silvestris silvestris* Schreb. 1777 und *F. s. f.catus* L. 1758). *Acta Scientiarium Naturalium Brno* 7(10): 1-50

Kratochvil Z. 1976a. Das postkranialskelett der Wild- und Hauskatze (*Felis silvestris* und *F. lybica f. catus*). *Acta Scientiarium Naturalium Brno* 10: (6) 1-43

Kratochvil Z. 1976b. Sex dimorphism of the domestic cat (*Felis lybica f. catus* L.) on the skull and on the mandible. *Acta Veterinaria Brno* 45: 159-67

Kratochvil J and Kratochvil Z. 1976. The origin of the domesticated forms of the genus *Felis* (Mammalia). *Zoologické Listy* 25(3): 193-208

Lecis R Perpaoli M Birò .S Szemethy L Ragni B Vercillo F and Randi E. 2006. Bayesian analysis of admixture in wild and domestic cats (*Felis silvestris*) using linked microsatellite loci. *Molecular Ecology* 15: 119-131

Malek J. 1993. *The cat in Ancient Egypt*. British Museum Press: London

Meadow RH. 1999. The use of size-index scaling techniques for research on archaeozoological collections from the Middle East. In *Historiae Animalium ex Ossibus*. Becker C Manhart H Peters J and Schibler J (eds). Marie Leidorf Verlag: Rahden; 285-300

O'Connor TP. 1982. *Animal bones from Flaxengate c. 870-1500.* Council for British Archaeology, Archaeology of Lincoln18/1: London

O'Connor TP. 1989. *Bones from Anglo-Scandinavian levels at 16-22 Coppergate*. Council for British Archaeology, Archaeology of York 15/3: London

Pierpaoli M Birò ZS Herrmann M Hupe K Fernandes M Ragni B Szemethy L and Randi E. 2003. Genetic distinction of wildcat (*Felis silvestris*) populations in Europe and hybridization with domestic cats in Hungary. *Molecular Ecology* 12: 2585-2598

Röhrs M. 1955. Vergleichedne Untersuchungen an Wild- und Hauskatze. *Zoologische Anzeige* 155: 53-69

Schauenberg P. 1969. L'identification du Chat forestier d'Europe Felis s. silvestris Schreber 1777 par une méthode ostéométrique. *Revue Suisse de Zoologie* 76(2): 433-441

Serpell JA. 1988. The domestication and history of the cat. In *The domestic cat. The biology of its behaviour* Turner DC and Bateson P (eds), Cambridge University Press: Cambridge;151-8

Serpell JA. 1996. *In the company of animals. A study of human-animal relationships*. Canto edition. Cambridge University Press: Cambridge

Smith BB. (ed.) 1994. *Howe: four millennia of Orkney prehistory. Excavations 1978-1982*. Society of Antiquaries of Scotland: Edinburgh

Spahn N. 1986. *Untersuchungen an skelettresten von Hunden und Katzen aus dem mittelalterlichen Schleswig. Ausgrabung Schild 1971-1975*. Karl Wachholz; Ausgrabungen in Schleswig Berichte und Studien 5: Neumünster

Sunquist M and Sunquist F. 2002. *Wild cats of the world.* University of Chicago Press; Chicago

Teichert M. 1977. Fundnachweise von Wild- und Hauskatzenknochen aus ur- und frühgeschichtlicher Zeit. *Hercynia Leipzig* 14: 212-6

Todd NB. 1978. An ecological behavioural genetic model for the domestication of the cat. *Carnivore* 1: 52-60

Vigne J-D Guilane J Debue K Haye L and Gérard P. 2004. Early taming of the cat in Cyprus. *Science* 304: 259

Von den Driesch A. 1976. *A guide to the measurement of animal bones from archaeological sites*. Peabody Museum Bulletin no 1 Harvard.

Yamaguchi N Driscoll C Kitchener AC Ward JM and Macdonald DW. 2004. Craniological differentiation between European wildcats (*Felis silvestris silvestris*) African wildcats (*F. s. lybica*) and Asian wildcats (*F. s. ornate*): implications for their evolution and conservation. *Biological Journal of the Linnaean Society* 83: 47-63

Zeuner FE. 1963. *A history of domesticated animals*. Hutchinson: London

		House cat			Wildcat			Log(Wild/ House)
		mean	s.d.	n	mean	s.d.	n	
Atlas	GL	17.1	1.13	61	19.46	1.19	19	0.056
Atlas	BFcr	22.00	1.29	61	25.44	1.09	19	0.063
Atlas	BFcd	15.55	1.00	61	17.79	1.07	19	0.058
Atlas	GB	34.16	2.77	61	38.91	2.78	18	0.057
Axis	LCDe	23.78	1.81	57	27.83	1.43	19	0.068
Axis	SBV	11.45	0.89	61	12.57	0.72	19	0.041
Scapula	DHA	63.25	4.39	61	80.88	4.6	19	0.107
Scapula	HS	68.19	4.61	61	85.96	5.04	19	0.101
Scapula	SLC	12.02	0.80	61	14.13	0.89	19	0.070
Scapula	GLP	13.7	0.95	61	16.74	1.08	19	0.087
Scapula	LG	11.48	0.77	61	14.5	1.06	19	0.101
Scapula	BG	9.03	0.65	61	11.08	0.71	19	0.089
Humerus	GL	96.46	4.89	62	119.08	6.17	19	0.091
Humerus	Dp	20.32	1.31	62	24.66	1.85	19	0.084
Humerus	SD	6.64	0.68	62	8.04	0.52	19	0.083
Humerus	Bd	17.91	1.16	62	22.18	1.63	19	0.093
Radius	GL	92.17	4.86	61	115.96	5.14	19	0.100
Radius	Bp	8.05	0.62	63	10.16	0.6	19	0.101
Radius	SD	5.24	0.44	62	6.3	0.5	19	0.080
Radius	Bd	12.51	0.79	61	15.39	1.08	19	0.090
Ulna	GL	108.9	5.65	63	134.47	6.25	19	0.092
Ulna	DPA	11.08	1.03	63	13.16	0.95	19	0.075
Ulna	BPC	8.74	0.7	63	11.16	0.83	19	0.106
Sacrum	GL	25.18	1.66	58	30.09	2.15	15	0.077
Sacrum	GB	28.3	1.91	57	32.28	1.88	18	0.057
Pelvis	GL	43.59	2.59	63	52.7	2.49	20	0.082
Pelvis	LAR	10.96	0.81	63	12.92	0.79	20	0.071
Pelvis	SH	10.9	0.9	63	13.18	0.94	20	0.082
Femur	GLC	105.58	5.98	63	132.7	6.77	19	0.099
Femur	Bp	20.1	1.23	63	24.03	1.58	19	0.078
Femur	DC	9.74	0.6	63	11.51	0.78	19	0.073
Femur	SD	8.28	0.8	63	9.55	0.57	19	0.062
Femur	Bd	18.42	1.15	63	21.87	1.43	19	0.075
Tibia	GL	111.32	5.65	63	140.19	5.82	19	0.100
Tibia	Bp	19.35	1.22	63	23.18	1.46	19	0.078
Tibia	SD	7.21	0.68	63	8.4	0.7	19	0.066
Tibia	Dd	9.4	0.58	63	10.97	0.8	19	0.067
Fibula	GL	103.72	5.63	62	131.04	5.17	18	0.102
Astragalus	GH	15.81	0.79	62	17.82	1.57	19	0.052
Calcaneus	GL	29.22	1.78	62	34.44	1.6	19	0.071

Table 01. Sample means, standard deviation and number of cases for house cat and wildcat samples derived from Kratochvil (1976) with codes following von den Driesch (1976)

				GL(C)	GLlog
RefColl	EAU776	wild	Fibula	122.2	0.071
RefColl	EAU776	wild	Tibia	130.6	0.069
RefColl	EAU776	wild	Radius	107.0	0.065
RefColl	EAU776	wild	Femur	122.0	0.063
RefColl	EAU776	wild	Ulna	124.0	0.056
RefColl	EAU776	wild	Humerus	109.0	0.053
RefColl	EAU777	wild	Tibia	122.7	0.042
RefColl	EAU777	wild	Radius	101.0	0.040
RefColl	EAU777	wild	Ulna	118.7	0.037
RefColl	EAU777	wild	Femur	113.3	0.031
RefColl	EAU783	wild	Radius	98.3	0.028
RefColl	EAU783	wild	Fibula	109.6	0.024
RefColl	EAU783	wild	Tibia	117.2	0.022
RefColl	EAU783	wild	Femur	111.0	0.022
RefColl	EAU783	wild	Humerus	101.4	0.022
RefColl	Hobbit		Humerus	100.0	0.016
RefColl	Hobbit		Radius	95.0	0.013
RefColl	Hobbit		Ulna	112.2	0.013
RefColl	Hobbit		Femur	108.5	0.012
RefColl	Hobbit		Tibia	114.0	0.010
RefColl	Hobbit		Fibula	105.7	0.008
RefColl	Juno		Humerus	95.9	-0.003
RefColl	Juno		Radius	91.4	-0.004
RefColl	Juno		Tibia	109.0	-0.009
RefColl	Juno		Fibula	101.5	-0.009
RefColl	Juno		Ulna	106.0	-0.012
RefColl	Vicki		Tibia	108.1	-0.013
RefColl	Vicki		Radius	89.4	-0.013
RefColl	Vicki		Fibula	100.4	-0.014
RefColl	Vicki		Ulna	105.3	-0.015
RefColl	Juno		Femur	102.0	-0.015
RefColl	Vicki		Femur	101.3	-0.018
RefColl	Vicki		Humerus	92.5	-0.018
RefColl	EAU129		Humerus	89.4	-0.033
RefColl	EAU129		Tibia	102.8	-0.035
RefColl	EAU129		Ulna	100.2	-0.036
RefColl	EAU129		Fibula	95.3	-0.037
RefColl	EAU129		Radius	83.9	-0.041
RefColl	Omega		Ulna	97.7	-0.047
RefColl	EAU129		Femur	94.4	-0.050
RefColl	Omega		Radius	82.0	-0.051
RefColl	Omega		Fibula	91.7	-0.053
RefColl	Omega		Tibia	98.0	-0.055
RefColl	Omega		Humerus	84.3	-0.059
RefColl	Omega		Femur	91.7	-0.061

Table 02. Length measurements and corresponding log-ratio values for wild- and house cat specimens from University of York (EAU numbers) and author's reference collections. Specimens designated 'wild' were attributed on pelage characters. The specimens have been sorted by size. Note that 'wild' specimens have separated entirely from the remainder and that specimens from the same individual mostly cluster together. Of the house cats, Hobbit was an intact male; the others were all female.

	Range	95% CI
Tibia GL	-0.058 to 0.064	±0.006
Radius GL	-0.060 to 0.056	±0.006
Humerus Bd	-0.054 to 0.095	±0.007
Femur Bd	-0.050 to 0.091	±0.007

Range and 95% Confidence Intervals for four house cat sample parameters converted to log-ratio values with respect to the house cat sample mean.

	Range	95% CI
Tibia GL	-0.028 to 0.032	±0.008
Radius GL	-0.035 to 0.032	±0.009
Humerus Bd	-0.049 to 0.029	±0.015
Femur Bd	-0.054 to 0.035	±0.013

Range and 95% Confidence Intervals for four wildcat sample parameters converted to log-ratio values with respect to the wildcat sample mean.

Table 03. Log-ratio values for maximum minimum and 95% Confidence Interval values for house and wildcat data from Kratochvil (1976a).

	Context		GL(C)	GLlog
Kilton	<28	Radius	114.9	0.096
Kilton	28-30	Radius	114.9	0.096
Kilton	28-30	Tibia	136.2	0.088
Kilton	<28	Ulna	133.0	0.087
Kilton	<28	Femur	128.6	0.086
Kilton	28-30	Ulna	132.5	0.085
Kilton	28-30	Tibia	135.0	0.084
Kilton	28-30	Femur	127.6	0.082
Kilton	28-30	Radius	105.3	0.058
Kilton	28-30	Tibia	126.6	0.056
Kilton	28-30	Tibia	126.1	0.054
Kilton	no depth	Femur	118.4	0.050
Kilton	28-30	Femur	118.2	0.049
Kilton	no depth	Ulna	121.8	0.049
Kilton	<28	Humerus	104.7	0.036
Kilton	28-30	Femur	112.9	0.029
Kilton	<28	Tibia	118.4	0.027
Kilton	28-30	Ulna	113.5	0.018
Kilton	<28	Ulna	113.4	0.018
Kilton	<28	Fibula	103.6	-0.001
Kilton	<28	Tibia	111.0	-0.001
Kilton	<28	Humerus	96.0	-0.002
Kilton	28-30	Tibia	104.2	-0.029

Table 04. Length measurements and corresponding log-ratio values for cat bones from post-medieval deposits at Kilton Castle, Yorkshire, sorted by size.

Sample	*Mean GL log*	*Std Dev*	*n*
Reference Collection	0.000	0.038	45
Kilton Castle	+0.048	0.036	23
York Viking Age	-0.012	0.028	8
Haithabu	-0.015	0.023	248
Schleswig	-0.026	0.054	208
Lincoln Viking Age	-0.028	0.024	21
York medieval	-0.053	0.027	48

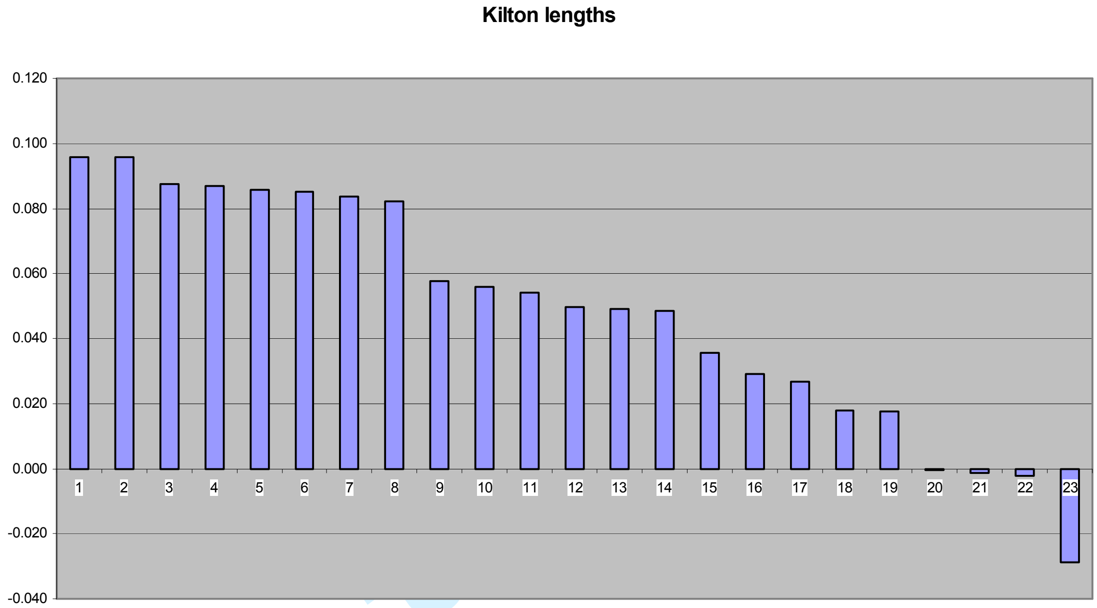
Table 05. Sample mean values of log-ratio length measurements and standard deviations of those mean values.

		GL(C)	Bp	SD	Bd	GL log	Bp log	Bd log
Howe	Radius	102	9	6	14	0.044	0.048	0.049
Howe	Radius	95	8	6	13	0.013	0.003	0.017
Howe	Radius	93	8	6	12	0.004	0.003	-0.018
Howe	Femur	104	20	0	17	-0.007		-0.035
Howe	Femur	104	19	0	17	-0.007		-0.035
Howe	Tibia	109	19	0	14	-0.009	-0.008	

Table 06. Howe Orkney. Measurements of cat bones from Late Iron Age Phase 8 as given in Smith (1994) with log-ratio values relative to the house cat standard.

			log-ratio value
EB	humerus	BD=17.7	-0.005
EB	humerus	BD=21.5	0.079
EB	radius	Bp=7.6	-0.025
EB	tibia	Bp=17.9	-0.034
EB	astragalus	GH=14.2	-0.046
EB	astragalus	GH=15.5	-0.008
EB	calcaneum	GL=27.8	-0.022
EB	calcaneum	GL=27.7	-0.023

Table 07. Earls Bu Orkney. Measurements of cat bones from Viking Age deposits with log-ratio values relative to the house cat standard. Data courtesy of J.F. Harland.



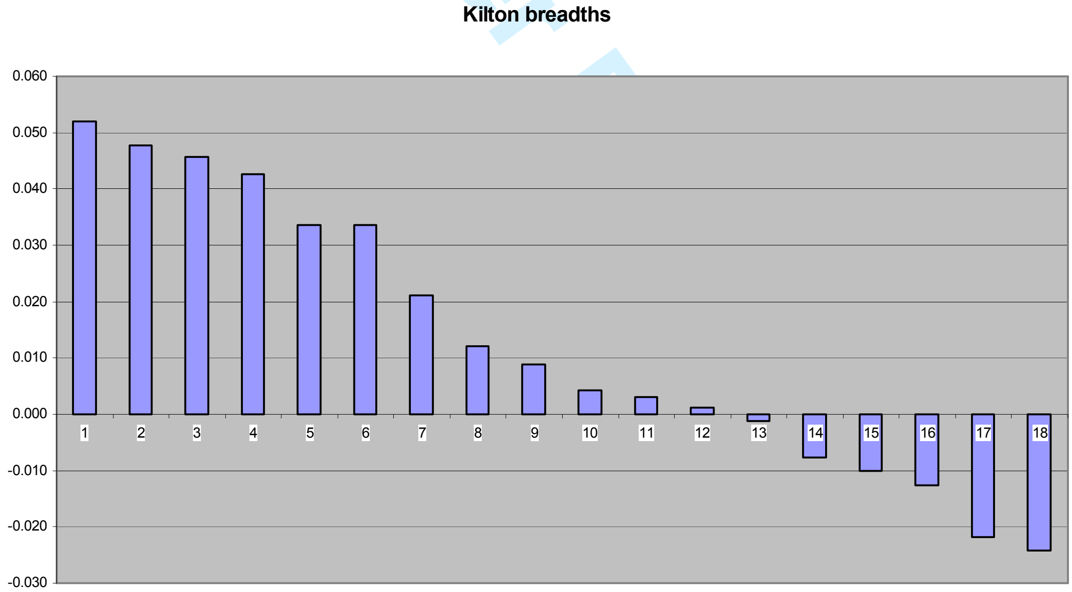


Fig 01. Kilton Castle length and breadth measurements against house cat standard. Note the high log-ratio values for the largest specimens, and the lack of any clear break in the data between the largest and smallest specimens.

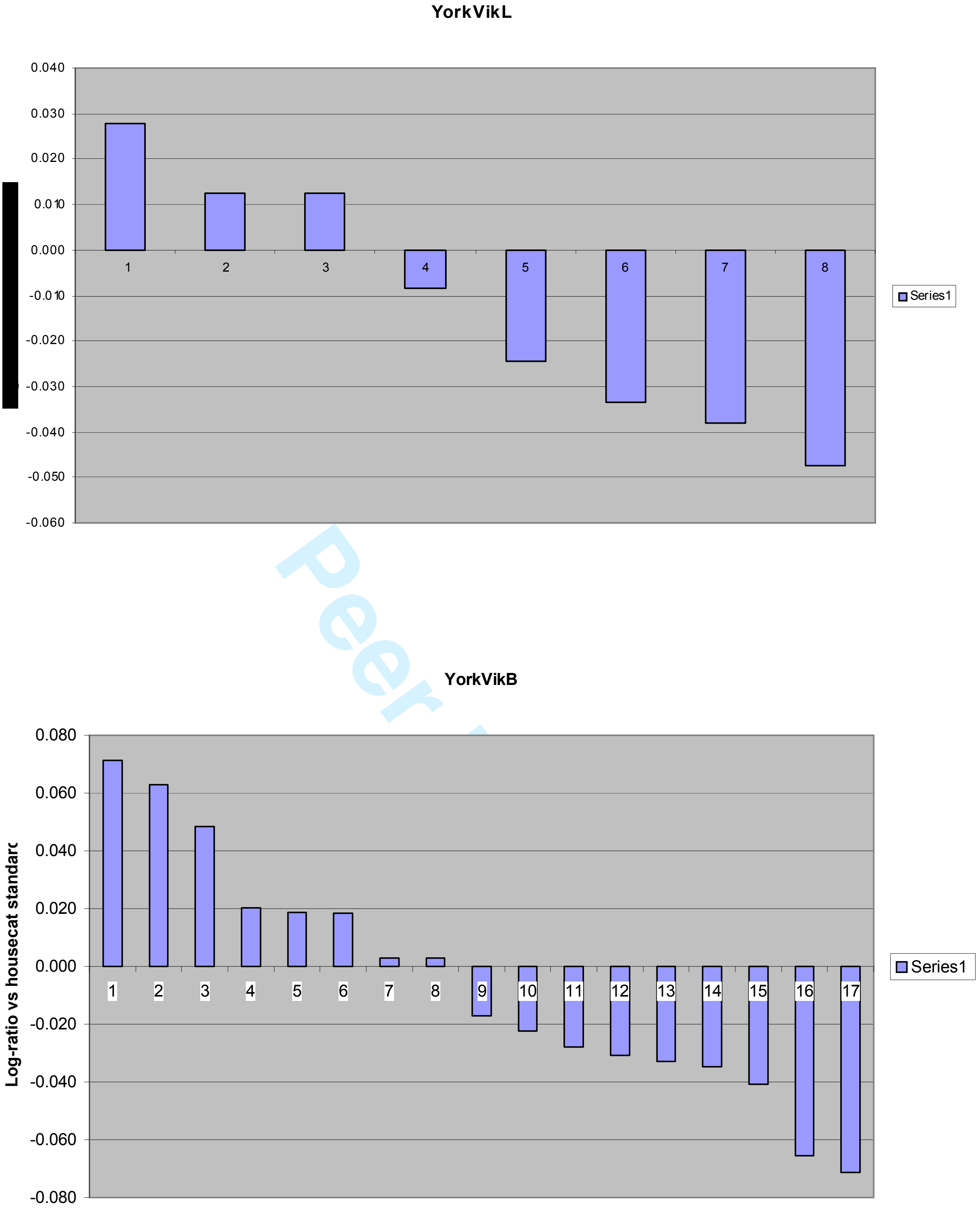


Fig 02. Log-ratio length and breadth distributions for York 10th to early 11th century cats.

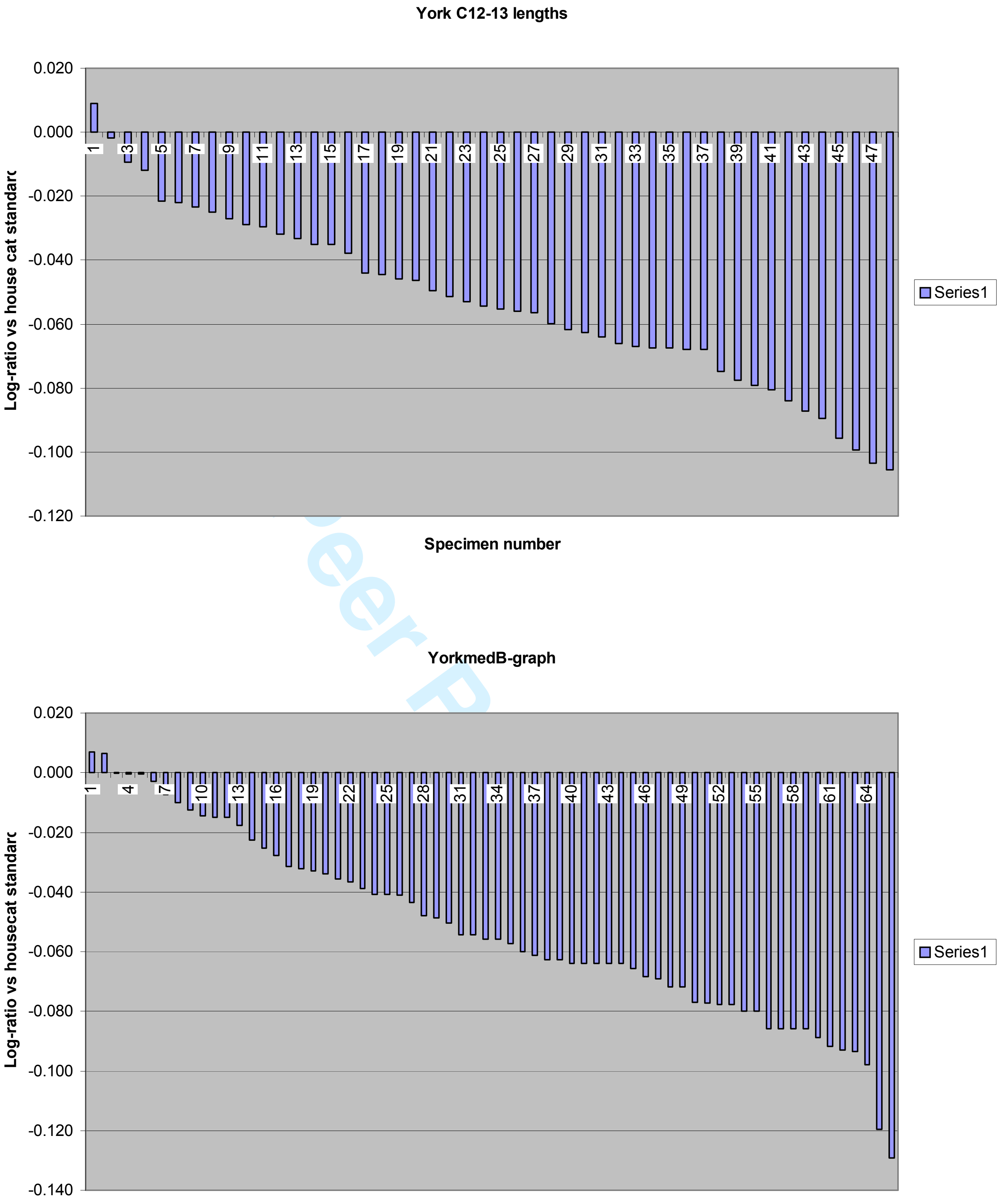


Fig 03. Log-ratio length and breadth distributions for York 12th to 13th century cats.

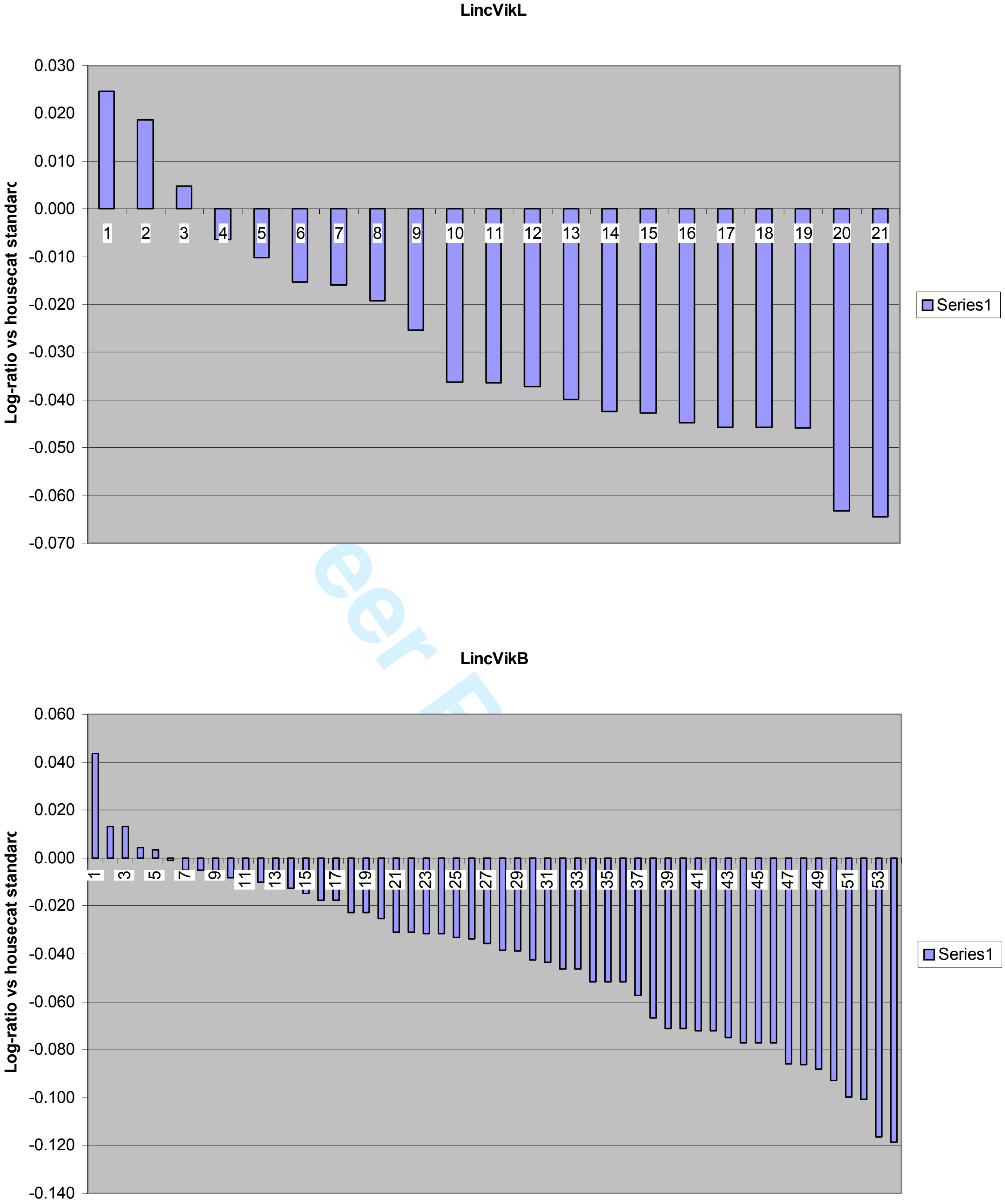


Fig 04. Log-ratio length and breadth distributions for Lincoln 10th to early 11th century cats.

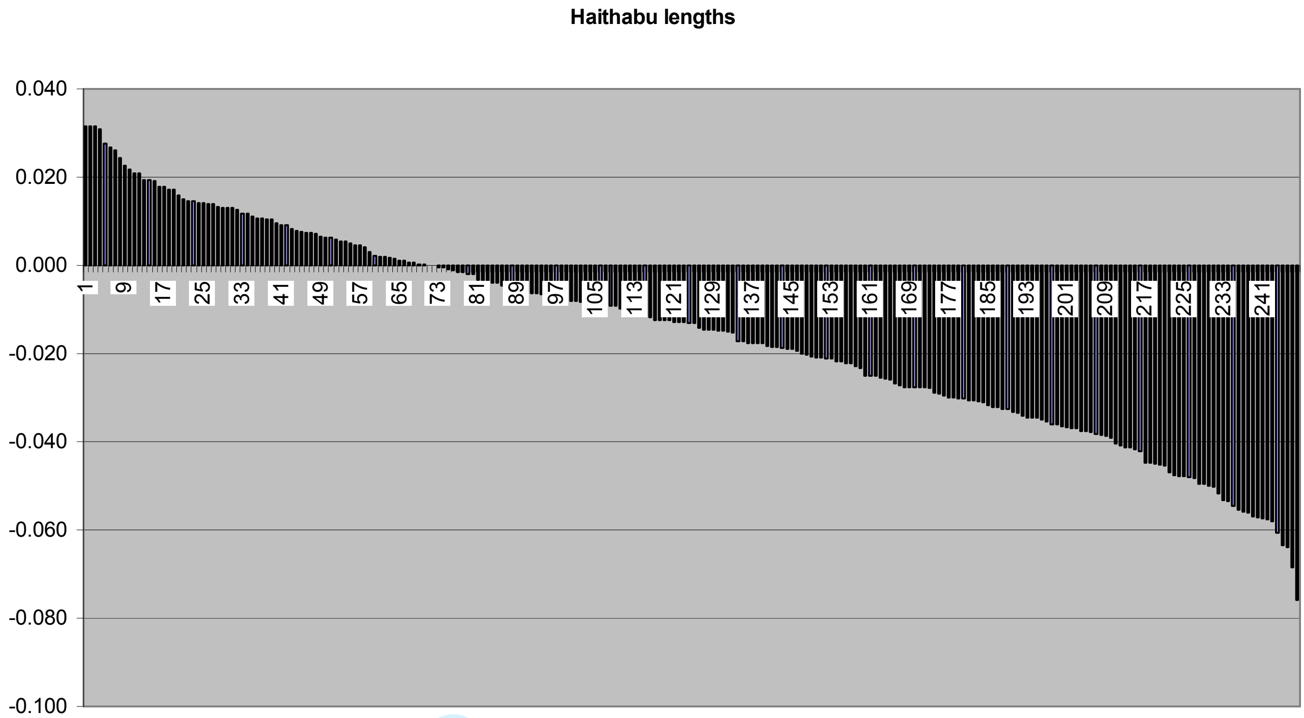


Fig 05. Haithabu cat lengths against house cat standard

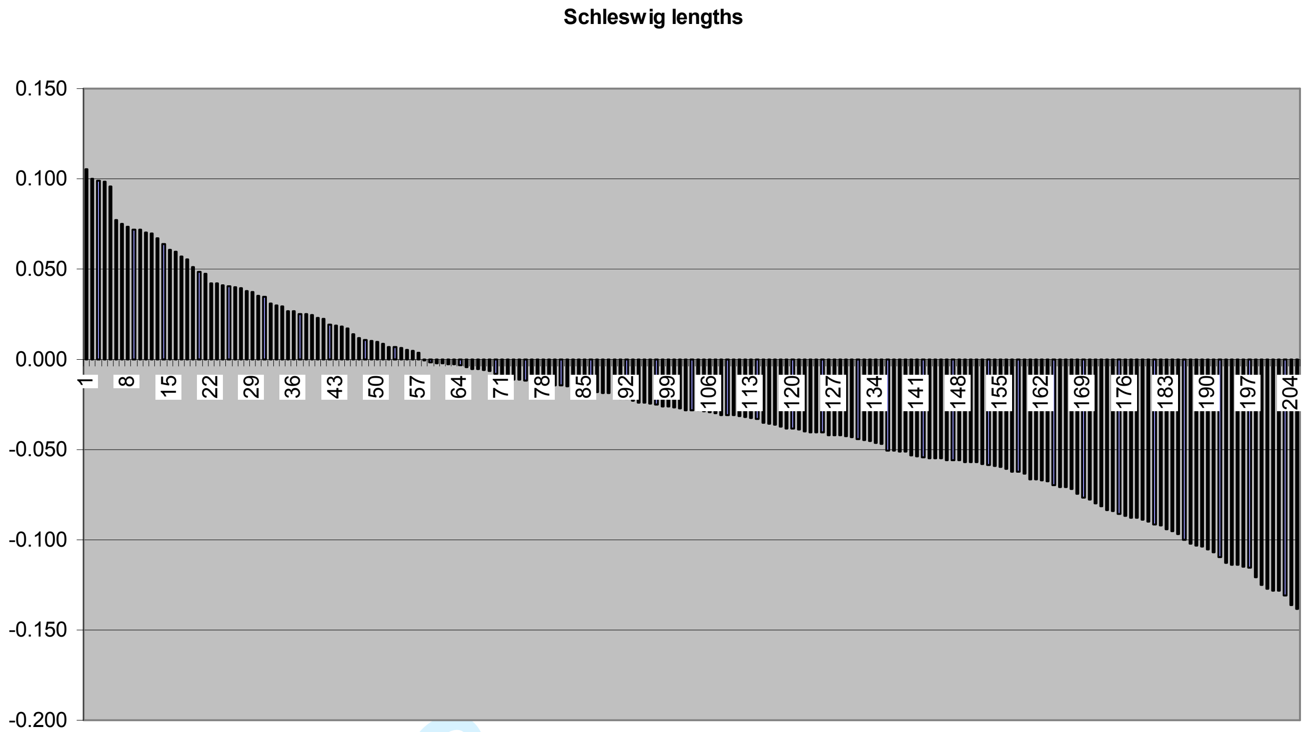


Fig 06. Schleswig cat lengths against house cat standard. Note the exceptionally high and low values at the extremes of this range.