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Intervention and Analysis

Jewel Tower, Abingdon Street, Westminster, London SW1P 3JX
A Cat Skull from Jewel Tower (88381813)

Fay Worley

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SUMMARY
A skull from an adult domestic cat, probably female, is reported. Raw osteometric data was recorded and is compared to reference specimens in the Historic England Zooarchaeology Reference Collection and published data from elsewhere. The date and provenance of the skull are unknown, beyond that it is from Jewel Tower, Westminster. It is probably related to 1950s excavations at the site and therefore may be 17th century, the date of the majority of finds. The skull is green-coloured; pXRF analysis is used to suggest that the pigment may be a copper alloy solution derived from brass. The majority of the skull is green, however the pigmentation does not cover the entire surface within the cranial cavity. The discolouration may reflect the burial or storage environment, or might have been intentionally applied.

CONTRIBUTORS
David Dungworth conducted pXRF analysis

ACKNOWLEDGEMENTS
James Morris kindly provided measurements for post-medieval cat skulls from London recorded at Museum of London Archaeology. Angela Middleton helped translate German language papers to English. Clara Stefen kindly allowed the skull metric convention diagram (Figure 5) to be reproduced.

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INTRODUCTION

This report considers a green-coloured cat skull from English Heritage archives, which is labelled as from Jewel Tower 88381813. No further provenance is known.

The following information is taken from the Tower's PastScape record (http://www.pastscape.org.uk/hob.aspx?a=0&hob_id=1102544, accessed 20/01/2015) and excavation reports.

The Jewel Tower was built in the mid-14th century as a treasury at Westminster Palace, becoming a Parliamentary records store in the mid-17th century and later having other administrative uses. The tower was damaged during the Second World War and, following restoration, was then opened to the public. The tower has been subject to excavation on three occasions: the moat was excavated in 1948-59; a section of earlier quay and associated structures, along with material from a 17th century drain were excavated in 1963-4; and lastly test pits were excavated in 1994-5, identifying medieval garden soils. It is not clear whether the skull is associated with any of these events, although the curators suggest that it may relate to the first excavation and 17th century deposits. It is not mentioned in the report of the 1960s excavation, which focusses on medieval assemblages (Green 1976).

METHODS

The skull was examined by the author at Fort Cumberland, Portsmouth. Osteometric data was recorded following Stefen and Heidecke (2011) and von den Driesch (1976). Raw data is provided in the appendix. Cranial volume was measured by filling the cranium with small puy lentils, and measuring their volume to the nearest cm^3 with a measuring cylinder. This was repeated four times and the average (mean) measurement recorded. The skull was examined under a low power microscope to check for the presence of any fine carcass processing marks. The skull was also investigated through portable X-ray fluorescence (pXRF) by David Dungworth and photographed for 3D digital modelling by Jon Bedford. The skull will be returned to the English Heritage archive once all examinations are complete.

RESULTS

Completeness and condition

The skull is in very good condition with no evidence for abrasion or erosion of the cortical surfaces. It is almost complete, only the left and right lacrimal bones and the left zygomatic bone are missing. Both permanent fourth premolars are

present, but all other teeth are missing, all except a second premolar probably having been lost since death.

Identification

There are two cat species native to Holocene England, the wildcat (*Felis silvestris*) and Lynx (*Lynx lynx*). In addition domestic cats (*Felis catus*) have been present since at least the Iron Age, possibly earlier (Kitchener and O'Connor 2010, 90) and were common in medieval towns (eg Fairnell 2014). Lynx are relatively large animals compared to wildcats and domestic cats and can be excluded from consideration here. Although wildcats can be larger than domestic cats, the two taxa have overlapping size ranges and domestic cat size changes over time (see O'Connor 2007). Wildcats and domestic cats can also interbreed. These factors make distinguishing species problematic in zooarchaeologial assemblages.

The skull is similar in size to the smallest adult domestic cats and smaller than all adult wildcats in the Historic England Zooarchaeology Reference Collection (4 wildcats and 8 domestic cats). Raw osteometric data for the skull can be found in Table 1 and comparison with data for seven measurable Historic England domestic cat reference specimens in Table 2 and Figure 1. The skull is also similar in size to a small number of cats from medieval and post-medieval London for which data are available (see Table 3).

The identification of the skull as domestic cat is supported by the cranial volume (cranV = 27cm^3) and the cranial index (greatest total length of skull: cranial volume = 3.18) both of which are within the range for domestic cats and different to that for wildcats (Stefen and Heidecke 2011 and 2012, both citing Piechoki 1990 and Schauenberg 1969). Additional morphological and metric criteria for distinguishing domestic cats and wild cats (Stephen and Heidecke 2011) are not applied here.

Age at death and sex

The pattern of tooth sockets and surviving teeth indicate that the cat was over seven months old at death (permanent premolars and molar were erupted) (Miles and Grigson 1990:339, citing Habermehl 1975).

The frontoparietal ridges are not pronounced and do not form a sagittal crest between the parietals as seen on the only two certain male cat skulls in the Historic England collection (both are domestic). This criteria may not be diagnostic to sex - O'Connor (2007, 582) notes that domestic cat skulls do not show clear sexual dimorphism. However, Stefen and Heidecke (2011) found

statistically significant differences in some measurements between males and females in a population of German domestic cat skulls. Using a selection of measurements that Stefen and Heidecke found to be significant, the Jewel Tower cat skull is compared to modern[1] domestic cat skulls from the Historic England Zooarchaeology Reference Collection in Figure 1. The Jewel Tower skull is more similar to the female than male cats. While the Jewel Tower skull is from a different population to both that displaying statistically significant sexual dimorphic variation in these measurements and to those in the Historic England Zooarchaeology Reference Collection, and the number of known sex individuals in Figure 1 is small, the comparison suggests that the skull may be female.

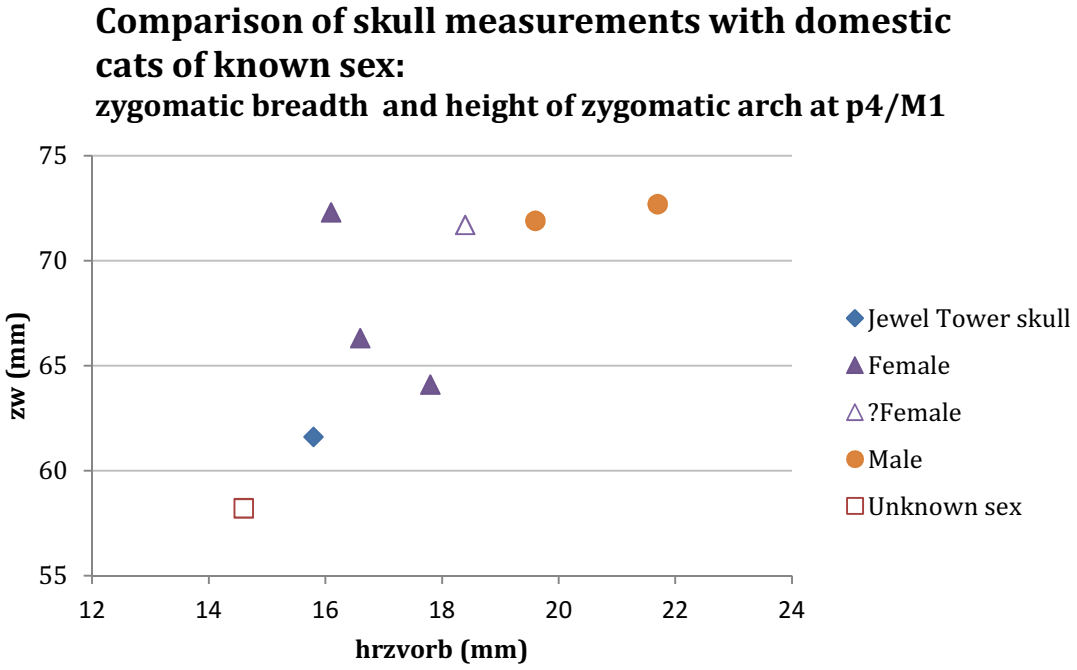

Figure 1 Metric comparison of the skull with those of domestic cats in the Historic England Zooarchaeology collection (see raw data in Table 3). The Historic England cats fall within the size range Stefen & Heidecke (2011) recorded for German domestic cats: zw = 39.7 to 74.9; hrzvo = 9.0 to 27.6.

Variations

The skull shows some pathology. There is a socket for the left second premolar, and a slight scar in its place on the right side, suggesting that the right tooth was

[1] The majority of the domestic cats were acquisitioned as complete carcasses and had died between the mid-1970s and 2008, a '?Female' (Figure 1) was found as a mummified carcass in a 17th century coaching inn. Its sex was assessed as 'probably female'.

lost some time before death and the socket healed over, rather than it being absent through genetic non-metric variation. There is no difference in the length of the tooth row, or the distance between the canine and third premolar on either side. However, also on the right side of the maxilla, the infra orbital foramen is much reduced, compared to the left side. This feature could perhaps be associated with soft tissue infection at the time the second premolar was lost.

Modifications

There is one possible transverse cut on the right parietal bone, which may have been inflicted whilst skinning the cat, but is more likely to be a natural feature of the skull. There is some damage to the presphenoid bone, with a linear shaped fragment missing. This damage may represent a trauma to the skull from a narrow object, and the zygomatic bone may also have been lost as a result of the same blow. It is likely to be post-mortem, and may be recent.

A notable modification to the skull is its green colour (Figure 1). Portable XRF analysis (Figures 2 and 3) by David Dungworth suggests that the green pigment is rich in copper (Cu) and zinc (Zn), with some lead (Pb) and nickel (Ni), but contains no tin (Sn). This elemental composition is consistent with staining from brass. The calcium (Ca), strontium (Sn) and phosphorus (P) peaks represent the bone itself.

> "Traditional green pigment was often made from verdigris (copper acetate) by placing copper alloy sheets in acetic acid (eg vinegar). If the alloy was a brass (copper and zinc) then both copper acetate and zinc acetate would be produced in the pigment" (David Dungworth pers comm 15th October 2015)

Interestingly, the green discolouration extends over most of the skull. It is not uncommon for small patches of green colouration to be found on archaeological bones that have been buried next to copper alloy objects (eg see Baker and Worley 2015, Figure S3.3), but it is unusual for the colouration to extend over the majority of the specimen.

The discolouration is not uniform. The left and right maxillae anterior to the zygomatic bone, much of the orbits (especially the dorsal side of the maxillae), the posterior retroarticular processes and adjoining zygomatic process of the temporal bones, and patches of the parietals, frontals, nasals and palate are less green and sometimes a orange-brown colour. The internal surface of the skull is not discoloured away from the opening of the foramen magnum and other major foramena.

Figure 2 The Jewel Tower cat skull

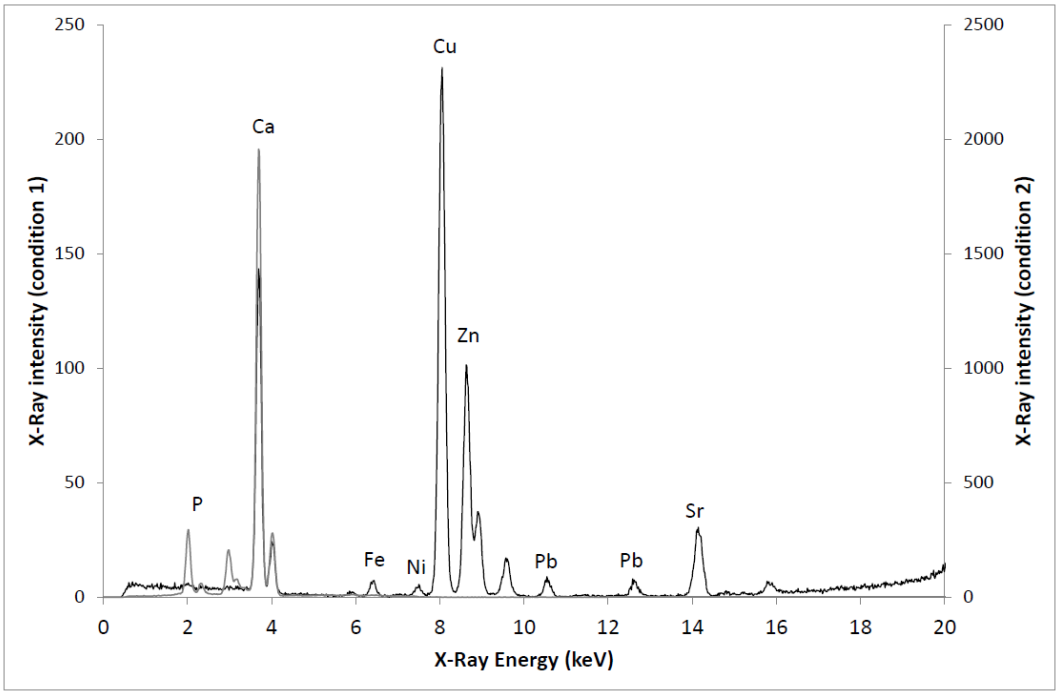

Figure 3 XRF Spectra (analysis: D Dungworth)

Figure 4 David Dungworth using portable XRF to test the elemental composition of the green pigment (photo: G Campbell)

Two hypotheses can be offered for the discolouration. Firstly, the skull may have been immersed in a copper alloy solution, or solution-soaked sediment, while incompletely de-fleshed, thus preventing the discolouration reaching all areas. The darker, brown-coloured areas tend to be recessed, and may represent areas where soft tissues remained at the time of discolouration, although the nasals and palate are likely to expose relatively quickly during decomposition, as they do not have a thick flesh covering. The lack of discolouration within the deeper areas of the brain case suggest that the skull was certainly not immersed in a copper alloy rich liquid. A second interpretation is that the skull may have been intentionally 'painted' with the green pigment, with none applied inside the brain-case.

Without further contextual information or a date for the cat skull, it is difficult to evaluate either interpretation as an explaination for the skull's green colour.

The status of cats in medieval towns is unclear. Many died while immature, at less than 18 months old, and this has been interpretaed as evidence that they were most likely feral, and perhaps intentionally killed for their skins, the latter interpretation also supported by butchery marks and the recovery of complete skeletons (see discussion in O'Connor 1992; Fairnell 2014). No comparative green-coloured skulls are known, although cats are often associated with folklore and cat remains are sometimes given unusual treatments, for example being bricked into house walls or displayed (for example, Merrifield 1987, 129-31; also see blog post about post-medieval cats in London buildings https://guildhalllibrarynewsletter.wordpress.com/tag/cats/).

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APPENDIX 1 – RAW DATA

Table 1 Cranial measurements

Code*	**Measurement definition***	**Data (mm)**
gsl	greatest skull length, shortest distance from inion (point where the two superior nuchal crests meet in the sagittal plane) to prosthion (maxillary bone at alveoles of incisors in sagittal plane) [inion is marked as akrokranion in von den Driesch (1976)]	85.9
cbl	condylobasal length (condylion, furthest extension of condyles to inion)	72.8
zw (23)	zygomatic width, maximum	61.6
zwM1	zygomatic width at M1. Measured from ventral	Cannot measure
nucr (18)	maximum width across nuchal crest	40.5
hsb (22)	maximum cranial width (maximum across squamosum)	42.6
dtempr	distance between frontoparietal ridges at their intersection with frontoparietal sutures	c. 11.6 - ridges not clear
iob	interorbital width measured between grooves of angularis occuli veins	Position not clear
bn	width of nasal bones at premaxilla/maxilla/nasal sutures	4.8
nasapw	maximum internal width of nasal aperture	10.7
nasaph	maximum internal height of nasal aperture (might be oblique)	9.8
cranh	cranial height from porion (dorsal most point of auditory meatus) to bergma (intersection of frontoparietal sutures at sagittal plane)	39.9
lsagcr	potential length of sagittal crest, from intersection of frontoparietal sutures to inion	40.1
bop (24)	width across orbital processes	47.3
pob (28)	width across postorbital constriction	31.4
skullh	skull height from the condyles to inion	29.2
ln_1	length of nasal bones at the midline [measured along facial profile]	20.7

ln_2	maximum length of nasal bones [measured along facial profile]	c. 23.4
facl	facial length, from prosthion to nasion (caudal end of nasals)	32.4
facl vertorb	maximal vertical diameter of orbit [measured along facial profile]	c.21.5
hororb	horizontal diameter across orbit	24.2
hrzvorb	vertical distance from orbital to maxillary bone between P4 and M1	15.8
bCa (27)	width of maxillary bone at canines	21.0
bCi	distance between canines	13.6
rostb	rostral breadth, maximal width of snout	26.2
pw	palate width measured between M1 (tips of callipers in between palate and M1 from distal in ventral view)	32.4
acbull	width across bullae from porion to porion [measured at midpoint]	c32.7
formw (20)	maximal width of the foramen magnum	13.8
formh (≈21)	height of foramen magnum (occasionally occurring high notches of the foramen are not included in the measurement)	12.1
cond (19)	maximal width across occipital condyles	21.6
npalno	distance from internal nares to anterior palatal notch	22.1
palnobull	distance from anterior palatal notch to depression of the tympanic bulla at base of styloid process	26.6
bulll (16)	length of tympanic bulla	19.2
bullw (17)	width of tympanic bulla [measured at midpoint]	c10.6
bullh	height of tympanic bulla, from top of auditory meatus to maximal ventral extension of bulla	8.8
ozrl	length of maxillary tooth row from distal canine to distal P4 [left side measured]	20.8
lP4 (14)	length of P4 crown	Cannot measure
bP4	width of P4 crown	Cannot measure
Csuph / Ch	height of crown of maxillary canine from alveole to tip	Cannot measure
Csupl / Cl	length of crown of maxillary canine	Cannot measure
afor	distance between foramen lacerum and foramen ovale [location of foramen lacerum unknonwn in cats]	Definition not clear
shbull	height of skull measured vertically above bullae tympanica	40.2
y4	distance from prosthion to middle of infraorbital foramen	19.6
y17	greatest width across both P4	36.6
y6 (12)	length of tooth row from P2-P4 [left measured]	18.7
kliob (25)	interorbital breadth measured at shortest distance between orbits	16.9
cranV (33)	cranium volume, measured to the nearest 0.5 cm^3 using glass beads of 1 mm diameter [see methods for application here]	27cm^3
(1)	(total length: akrokranion – prosthion) [measured horizontally, rather than following profile]	83.3
(2)	(condylobasal length: aboral border of the occipital condyles - prosthion)	81.7
(3)	(basal length: basion - prosthion)	71.4
(4)	(basicranial axis: basion - synsphenion)	23.7
(5)	(basifacial axis: synsphenion - prosthion)	47.5
(6)	(neurocranium length: basion – nasion. Can be taken only with curved callipers)	Not taken
(7)	(upper neurocranium length: akrokraion – frontal midpoint) [measured as a horizontal measurement is 49.5, recorded	51.6

	measurement follows profile]	
(8)	(viscerocraniumm length: nasion - prosthion) [measured following profile, illustration is mislabelled]	32.4
(9)	(facial length: frontal midpoint - prosthion) [measured following profile, illustration is mislabelled]	46.8
(10)	(lateral length of "snout": oral border of the orbit of one side - prosthion)	22.4
(11)	(median palatal length: staphylion - prosthion)	33.3
(13)	(length of premolar row)	18.6
(26)	(greatest palatial breadth)	37.3
(29)	(facial breadth between the infraorbital foramina (least distance))	34.4
(30)	(greatest inner length of orbit: ectorbitale - entorbitale)	26.4
(31)	(greatest inner height of orbit)	24.9
(32)	(height of occipital triangle: akrokranion - basion)	25.0

* Codes and definitions follow Stefen and Heidecke (2011, 2012; also see Figure 4) and von den Driesch (1976). Von den Driesch codes and definitions are given in round brackets, Worley's comments in square brackets. In some cases the language has been amended.

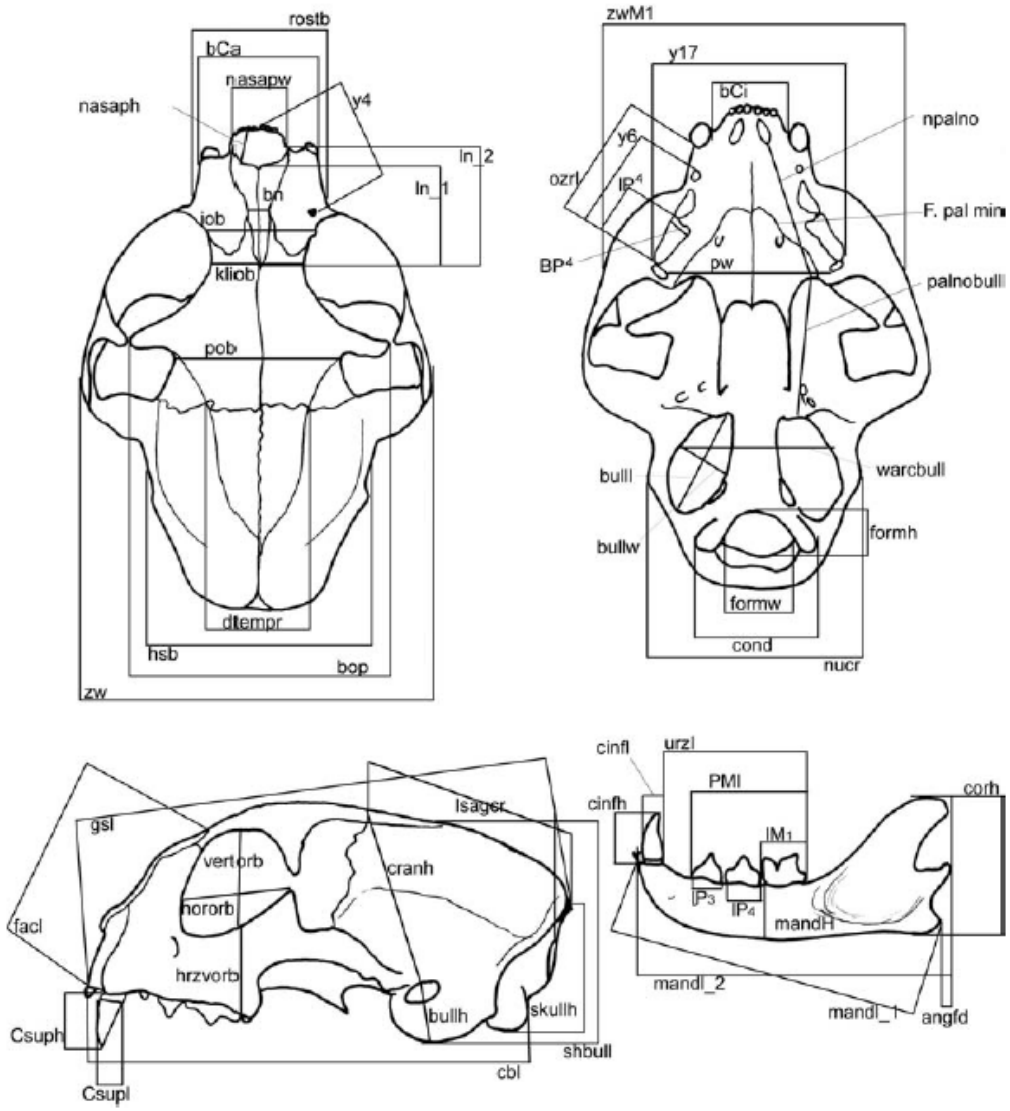

Figure 5 Illustration of measurement points (from Stefen and Heidecke 2011, Fig 1)

Table 2 Metric data compared to domestic cats in the Historic England Zooarchaeology Reference Collection.

Specimen	Sex	hrzvorb	gsl	nucr (18)	zw (23)	skullh	facl	nasapw	nasaph	Nasvol (facl x nasapw
Jewel Tower	?	15.8	85.9	40.5	61.6*	29.19	32.4	10.7	9.8	3397
HE 2027	?	14.6	83.3	38.8	58.2	23.98	32.8	10.7	10.9	3825
HE 2848	Female	17.8	88.3	40.4	64.1	28.96	29.3	11.5	10.9	3673
HE 3066	Female	16.6	93.6	41.0	66.3	28.8	33.2	11.7	11.2	4351
HE 3227	Female	16.1	99.5	43.4	72.3	30.02	36.7	12.7	12.6	5873
HE 2212	?Female	18.4	100.9	45.3	71.7	29.77	37.5	12.2	13.3	6085
HE 4162	Male	19.6	97.2	46.1	71.9*	30.68	37.4	13.5	12.2	6160
HE 4012	Male	21.7	99.7	45.7	72.7	31.67	39.5	12.8	13.3	6724

*damaged. But measurement probably not significantly affected

Table 3 Metric data compared to medieval and post-medieval cat skulls from other London sites (data provided by J Morris).

Measurement (see Table 1)	Jewel Tower	Holywell Priory (BGX05-175)	Holywell Priory (BGX05-670)	Guildhall (GDH85-419)	London Bridge (TYT98-1043)
(1)	83.3	86	-	88.7	88.2
(2)	81.7	-	78.8	84.8	-
(4)	23.7	-	24	-	-
(6)	-	-	-	-	67.2
(7)	51.6	-	-	-	51.2
(8)	32.4	-	-	-	50.2
(9)	46.8	-	-	33.7	32.8
(11)	33.3	-	-	34.4	34.3
y6 (12)	18.7	-	-	20.7	22.3
lP4 (14)	-	-	9.1	9.9	-
nucr (18)	40.5	-	37.7	40.8	40
hsb (22)	42.6	-	39.1	41.5	41.8
zw (23)	61.6	-	-	60.3	64.1
bop (24)	47.3	-	-	46	46.7
kliob (25)	16.9	-	-	16.8	17
(26)	37.5	-	-	34.6	38.3
bCa (27)	21.0	-	20.6	22.5	24.8
(32)	25.0	-	23.8	-	-

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