Walking on Eggshells: A Study of Egg Use in Anglo-Scandinavian York Based on Eggshell Identification Using ZooMS

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Walking on eggshells: a study of egg use in Anglo-Scandinavian York

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Abstract

Eggshell is a potentially common archaeological resource, but it has tended to be underused. The recent development of ZooMS (zooarchaeology by mass spectrometry) as a rapid and robust system for taxonomic identification of preserved eggshell fragments has facilitated new insights into patterns of egg use in the past. This paper presents a case study of egg use at two sites in Anglo-Scandinavian York (Hungate and Coppergate). The results described below suggest that the relative prevalence of goose eggshell may become a useful indicator of status, consistent with other characteristics of the two sites, and also demonstrate an apparent lack of exploitation of wild eggs in York during the Anglo-Scandinavian period. These results highlight the interpretative potential of eggshell, which can now begin to be more fully explored.

1: Introduction

1.1: Introduction & overview

Bird eggs have formed a substantial component of the diets of many people, as well as serving a wide range of other functions such as raw material for artefacts (Kightly 1984; Orton 2008; Baldwin 2009, 2010; Serjeantson 2009). Egg production is either an important focus or a highly beneficial by-product of keeping most domestic birds, while the eggs of wild birds (particularly seabirds) represent a major seasonal resource in many areas (e.g. Hunn et al., 2003; McGovern et al., 2006; Baldwin 2009, 2010; Serjeantson 2009). The collecting season for wild birds is usually quite narrow, but eggs can be stored for a number of months even without modern technology and domestic species may have a longer or repeated laying interval (Baldwin 2009, 2010; Serjeantson 2009). Although domestic species (particularly chicken) provide all of the eggs consumed by most people today, documentary records describe the exploitation of a wide range of species by British coastal communities even into the latter part of the 20th century, and egg collecting remains an important activity in many traditional societies (Kightly 1984; Hunn et al., 2003; Baldwin 2009, 2010; Serjeantson 2009).

Despite the long history of exploitation, substantial ethnographic and historical evidence of the importance of eggs, and the abundance of the material at many archaeological sites (section 1.2), surprisingly little is known of egg use in past societies from the archaeological record. For example, in the recent edition of *Cambridge Manuals in Archaeology on Birds* (Serjeantson, 2009) only 16 of 450 pages are devoted to eggs and eggshell. Previous work by Keepax (1981) and Siddell (1993a; b), whilst significant, did not initiate a wider appreciation and investigation of excavated eggshell. This paper will exploit a recently published technique for identification of archaeological eggshell fragments (Stewart et al., 2013) and the large eggshell collections excavated from two significant urban sites (Hungate and Coppergate) to conduct a case study of egg exploitation in Anglo-

Scandinavian York. The aims of this case study are to begin to establish the range of bird species exploited for their eggs in York during this period, the relative prevalence of wild and domestic species, and to begin to shed some light on how the eggs of different species were perceived (e.g. the relative status of the eggs of different species).

1.2: Eggshell in the archaeological record

Avian eggshell is composed primarily of calcite. It also incorporates a substantial organic phase (3.5-4% by weight in chicken eggshell), which initiates and mediates deposition of the mineral phase (Becking 1975; Arias et al., 1993; Dennis et al., 1996; Gautron et al., 1997; Hincke et al., 1995, 2010; Lakshminarayanan et al., 2002; Nys et al., 2004; Freeman et al., 2010, 2011). Calcite is the most stable crystalline form of calcium carbonate at normal temperatures and pressures, and so eggshell is extremely durable at the neutral to alkali pH ranges found at many archaeological sites. Despite the archaeological potential of eggshell, extensive studies of the material are rare. One reason for this is that eggshell is difficult to recover during excavation. It is usually highly fragmented, requires sieving of sediments using at least a 5mm (preferably 2mm) mesh, and separating eggshell fragments out from other small fragments of bone and mollusc shell can be very time consuming. Secondly, the fragmented preservation state of eggshell renders it difficult to identify the material taxonomically based on morphology.

Despite efforts by a number of researchers (Keepax, 1981; Sidell 1993a, 1993b; Eastham & Gwynn 1997), there has been no rapid and robust system for identification of these fragments capable of analysing the large assemblages often found at archaeological sites (Stewart et al., 2013). Even where it has been recovered, eggshell is often archived and never taxonomically identified. The length of time and amount of labour required to identify eggshell fragments often precludes analysis

of whole assemblages, which may comprise hundreds (even thousands) of fragments. As there is no way of reconstructing the number of actual eggs represented in the assemblage, this presents a major barrier to meaningful interpretation.

The technique used in this study (ZooMS; Zooarchaeology by Mass Spectrometry) is able to yield accurate taxonomic information on thousands of eggshell fragments (Stewart et al., 2013). It can therefore be used to analyse whole assemblages; this increases the archaeological value and interpretative power of eggshell (Stewart et al., 2013). Previous research has demonstrated that ZooMS can taxonomically identify heavily fragmented bone (Buckley et al., 2009, 2010; Richter et al., 2011), as well as providing a means for high-throughput analysis of eggshell assemblages (Stewart et al., 2013).

1.3: The sites

The two sites discussed in this study are described below. Over 2750 eggshell fragments were recovered from these sites, and were analysed using the new technique. Analysing this volume of material would not be practicable using previously available techniques.

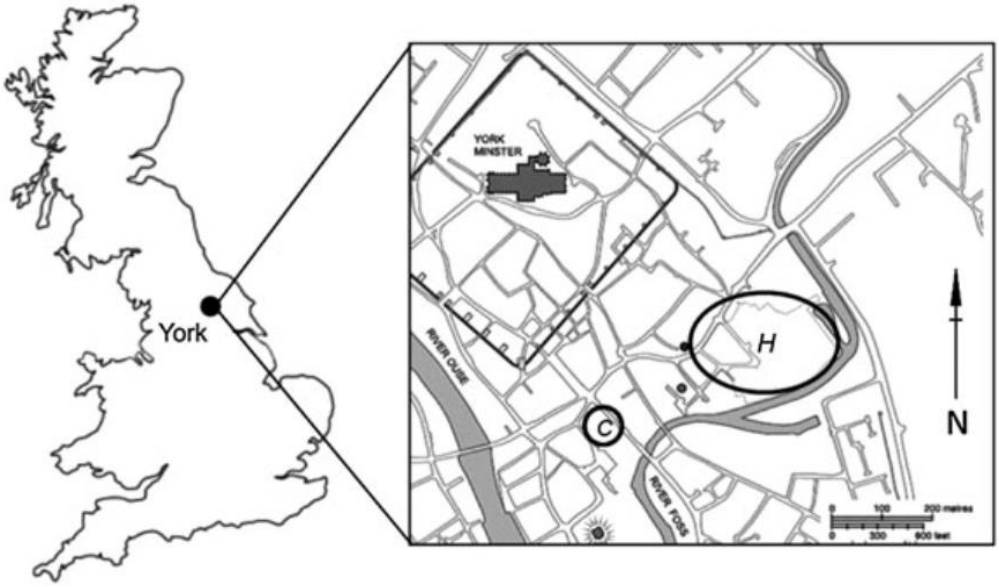

Figure 1. Location of Hungate (H) and Coppergate (C) sites. Reproduced courtesy of York Archaeological Trust. Based on the Ordnance Survey mapping

1.3.1: Hungate

Hungate is located near the centre of York, abutting the north bank of the River Foss (Figure 1). The site is a large multi phase site, and the Dig Hungate excavations conducted by York Archaeological Trust (YAT) began in late 2006 and will be completed in line with the Hungate (York) Regeneration Ltd. development schedule. The source of the material used in this study, Block H, was excavated between 2007 and 2011. Most of the contexts evaluated in this paper are provisionally assigned to Anglo-Scandinavian age activity (unless stated otherwise). Structural and artefact evidence, and topographical position, suggest that during the Anglo-Scandinavian period (late 9th – mid 11th centuries), the site was of relatively low-status compared with the contemporaneous Coppergate site a few hundred metres to the south-west (see below). Over 2000 fragments of eggshell were recovered from the Hungate excavation by 5mm and 1mm sieving, which YAT excavators performed routinely on samples of most types of deposit.

1.3.2: Coppergate

Coppergate, which is located around 350 m to the south-west of Hungate (Figure 1), was excavated by YAT between 1976 and 1981. A site of activity during the Roman period, Coppergate was apparently deserted during the post-Roman period, and became active once more with the onset of the Anglo-Scandinavian period (mid-9th Century) (O'Connor 1989). During the early Anglo-Scandinavian period, there is evidence for glass working and possible structures; these were definitely established at the site by the mid-10th Century (Hall 1989). There is also evidence of iron working at the site during this period (Hall 1989).The areas to the rear of these structures contained a large number of pits, in which organic preservation was often excellent (Kenward and Hall 1995). Relative to Hungate, Coppergate is considered a high-status site on the basis of the type of industrial activities, finds and structures excavated. 758 fragments of eggshell were recovered from the site by YAT excavators, and were analysed using the technique described in section 2.

2: Methodology

2.1: Extraction procedure and analysis by MALDI-ToF mass spectrometry

The extraction procedure follows that developed by Stewart et al (2013). Fragments were cleaned by sonication in ultra-pure water. Residual dirt was then removed by hand, and samples were left to air-dry. A small piece of each fragment was then removed using fine tweezers, weighed into sterile 2 mL Eppendorf ftubes, and exposed to strong bleach (sodium hypochlorite, 12% w/v) at a concentration of 50 µL/mg sample for 7 days in order to oxidise inter-crystalline proteins (Penkman et al., 2008, 2011; Stewart et al., 2013). This isolates an intra-crystalline protein fraction, and is an established approach in studies of the protein fraction of biominerals (e.g. Berman et al., 1988; Collins et al., 1991; Collins & Riley, 2000; Penkman et al., 2008, 2011; Sykes et al., 1995). The fragments were then thoroughly rinsed in ultra-pure water, briefly suspended in HPLC-grade

methanol, air-dried, and the calcite partially dissolved in dilute (0.6M) hydrochloric acid (HCl) at 4°C over seven days to extract a fraction of the intra-crystalline proteins. This approach left a non-dissolved eggshell core to buffer the solution at pH ≈ 7, yet still released a sufficient volume of proteins for mass spectrometry.

Internal disulphide bonds on cysteine residues were reduced using 0.01M dithiothreitol (DTT) at a concentration of 1 µL per 2 µL sample solution at 60°C for one hour and subsequently alkylated using 0.05M iodoacetamide (IAA) at a concentration of 1 µL per 3.3 µL sample solution at room temperature in dark conditions for 45 minutes. Proteins were digested with 4 µL of 0.4 µg/µL porcine trypsin (Promega, Southampton, UK) in trypsin re-suspension buffer (Promega, Southampton, UK) at 37°C in order to produce peptides in the detection range of the mass spectrometer used in analysis. Digestion was stopped after 24 hours by addition of trifluoroacetic acid (TFA) at a concentration of 0.5-1% of the total solution.

Solid phase extraction was performed on BioVyon C18 10mg 96 well plates (Porvair, Fareham, UK) conditioned (as per manufacturer's instructions) with 50% acetonitrile (ACN) in 0.1% TFA, and equilibrated with 0.1% TFA in aqueous solution. Samples were then loaded and the unbound fraction washed off in 0.1% TFA in ultra-pure water, before the peptides were eluted in 75µL of 50% ACN in 0.1%TFA. 1 µL of this eluate was spotted in triplicate on an MTP384 Bruker ground steel target plate. On each spot, 1 µL of matrix (α-cyano-4-hydroxycinnamic acid; 10 g/L in 50% ACN in 0.1%TFA) was mixed with the sample.

Samples were analysed in positive mode on the Bruker Ultraflex III MALDI-ToF (Matrix-Assisted Laser Desorption/Ionisation – Time of Flight) mass spectrometer with the following parameter settings:

ion source, 25 kV; ion source, 21.4 kV; lens voltage, 9 kV; laser intensity, 35-40%; and mass range, 800–4000 Da. Peptide masses below 650 Da were suppressed. Final mass spectra were externally calibrated against an adjacent spot containing 6 peptides (des-Arg^1-Bradykinin, *m/z* = 904.681; Angiotensin I, 1296.685; Glu^1-Fibrinopeptide B, 1750.677; ACTH (1-17 clip), 2093.086; ACTH (18-39 clip), 2465.198; ACTH (7-38 clip), 3657.929). FlexAnalysis software 3.3 (Bruker Daltonics) was used to baseline subtract, normalize spectra and determine peak *m*/*z* values and intensities in the mass range of 800−4000 *m*/*z*.

2.2: Taxonomic identification

Both approaches to identifying eggshell fragments described below rely upon comparison of mass spectra obtained from archaeological material with a reference database obtained on specimens of known species. This has been drawn mostly from museum material, and currently comprises 56 species in 13 orders (Stewart et al., 2013). One approach is based on identification of potentially diagnostic peptide masses. These were identified by screening peptide masses found in each species against the entire reference collection (Signal/Noise ratio (S/N) ≥ 6). This approach provided a reference list of peptide masses which were potentially useful as taxonomic indicators, although the level of resolution achieved varies between markers; in some cases, convergent peptide masses in different taxa limit this method to constraining the possible range of taxa present (Table 1).

Rather than identifying specific markers, the second approach uses peptide mass fingerprinting (PMF); the whole list of peptide masses is compared with reference spectra in order to derive taxonomic information (e.g. Henzel et al., 1993; Hollemeyer et al., 2007, 2008; James et al., 1993; Pappin et al., 1993). For all archaeological samples, matching of mass spectra to species based on comparison with reference spectra was performed using an in-house Microsoft VB application

(ChickenHawk) (Stewart et al., 2013). This software searches a reference database constructed of known peptide masses and reports both the number of matches between observed peptide masses and data in the reference collection, and the percentage of peaks observed in each species which are observed in the sample (an example of output (Appendix S1) is provided in supplementary information). It also screens the data for the presence or absence of potentially diagnostic peptide markers.

The level of resolution of this approach varies between taxa due to (a) differences in the extent to which taxa are represented in the reference collection; and (b) the degree to which the peptides observed in different members of the taxa differ (for example, there is no way of distinguishing confidently between different members of the closely-related and highly speciated family Laridae). ChickenHawk will identify which species in the reference collection is the closest match, but cannot always extrapolate this into definite species identification; identification to family or order is more realistic in some cases. The major advantages of this approach are that it is applicable to all species, is very fast, and can be very accurate if the relevant sections of the reference collection have good coverage.

3: Results

3.1: Success of technique

In total, over 2750 separate eggshell fragments were analysed. Successful taxonomic identifications were achieved for eggshell from 35 of 39 sampled contexts at Hungate (89.7%), and all 29 sampled contexts at Coppergate. At Coppergate, the success rate of the technique by fragment was 98.33% (12 of 758 fragments remain unidentified). An exploration of possible reasons for this disparity is provided below (section 4.1). Where no identification was made, this was due to poor quality mass spectra rather than inability to match good spectra to the reference database.

3.2: Relative composition of eggshell assemblage at Coppergate and Hungate

The percentage representation of the species identified in an eggshell assemblage, whilst it gives some indication of the prevalence of use of that species, should not be taken as a proxy quantified measure of the absolute abundance of eggs of that species in the sampled deposit or original refuse. This analysis does not account for differential pathways of egg fragmentation, which are unknown and probably impossible to quantify with any degree of confidence. For example, if the relative abundance of taxa in shell fragments from Coppergate (Figure 2) were taken at face value, it might be deduced that goose eggs were barely used.

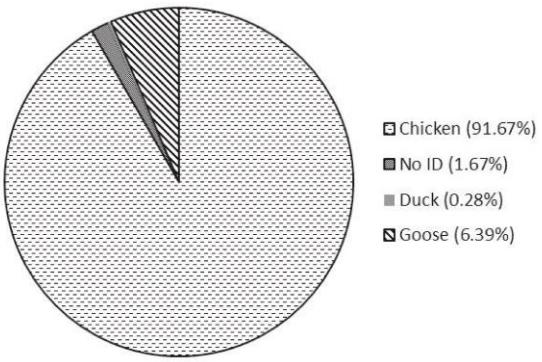

Figure 2: taxonomic composition of Coppergate eggshell assemblage (n = 758)

As it is not possible to relate the number of fragments recovered to the number of eggs originally present, assessing only the *presence* or *absence* of each species in each context is a more appropriate method of quantification. Three taxa were identified: chicken, goose and duck. A cross-context comparison of the two sites shows that goose eggshell is present in a high proportion (41%) of contexts at Coppergate (Figure 3). The breakdown of the data presented in Figure 3 by context is also given below (Table 2). Chicken is equally ubiquitous at both sites, but goose is far more prevalent at Coppergate (see section 4.2). The only occurrence of duck eggshell is also found at Coppergate (context 34726). The percentage representation per context is calculated as the

proportion of the contexts in which successful identification was achieved, i.e. in all 29 contexts from Coppergate, and 35 from Hungate.

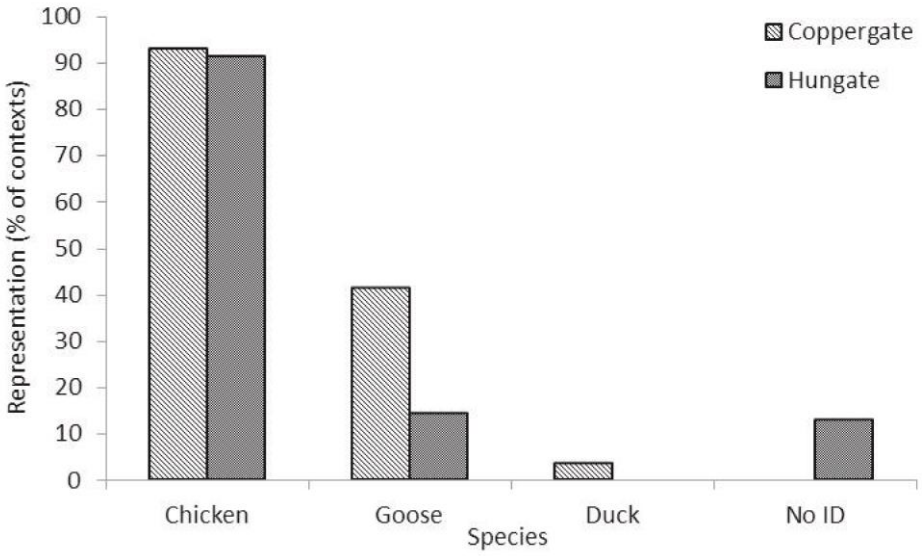

Figure 3: cross-context comparison of eggshell assemblage composition at the two sites. The Hungate data represent all contexts, including those known to post-date the Anglo-Scandinavian period. Limiting the contexts represented to only those from this period does not affect the pattern observed.

4: Discussion

4.1: Success of the technique

There are several non-mutually-exclusive factors which may explain the disparity in successful identification rate between the sites. A simple age effect may seem a logical explanation, but some of the Hungate contexts from which no identification was made are among the youngest at the site. Other factors which may contribute to this disparity include better organic preservation in general at Coppergate; improvements in resolution and execution of the technique between the two analyses; possible burning of some shell fragments at Hungate; and misidentification of very small fragments of plaster or mollusc shell as avian eggshell at Hungate.

4.2: Is goose eggshell an indicator of high status?

Significant differences were observed in the prevalence of goose and duck eggshell at the two sites. It is possible that this results from the difference in status between the sites. Although direct data for the Anglo-Scandinavian period are unavailable, it has been estimated that chickens in England were producing 70-100 eggs per year by the late medieval period (late 13th – early 14th century), and that members of every social stratum would have had access to these (Slavin, 2009). In comparison, medieval domestic geese seem to have been, as now, seasonal layers, producing of the order of 40 eggs per year, predominantly in the spring (Serjeantson 2002). It seems reasonable to propose that hens' eggs may have been an everyday food item during the Anglo-Scandinavian period, whilst goose eggs would have been only seasonally available. Albarella (2005) shows that goose husbandry was well established in England during Anglo-Saxon times, so it is likely that this husbandry persisted in the Danelaw regions. Comparing eggshell results with bird bones from the two York sites, only Coppergate has a fully quantified analysis (O'Connor 1989). From all Anglo-Scandinavian deposits, 363 specimens could be attributed to *Anser anser*, compared to 1267 specimens of domestic fowl, a ratio of about 3.5 hens per goose. Although the contemporary material from Hungate has yet to be quantified fully, first impressions are that the proportion of goose bones is appreciably lower than at Coppergate. At Coppergate, the goose bones were predominantly of adult birds. Although immature bird bones are obviously more vulnerable to taphonomic loss than those of adults, taphonomic attrition of the Coppergate assemblage was minimal and even immature goose bones are relatively large and recoverable. It is a fair inference, therefore, that the geese at Coppergate were kept as much for feathers and eggs as for meat, and the eggshell results would seem to confirm that interpretation.

The results of this study might begin to suggest that the eggs of ducks and geese were higher status or more expensive items in Anglo-Scandinavian society. Direct evidence to support the notion that

goose eggs were a higher status food during the Anglo-Scandinavian period in England is lacking other than by interpretation of associated structural and artefact assemblages. However, some support may be found in roughly contemporaneous accounts from Ireland. The probably twelfth century Irish tale 'Fled Dúin na nGéd' suggests that goose eggs were considered higher status fare than chicken eggs (Mac Con Iomaire & Cully, 2007). Direct comparison between Anglo-Scandinavian northern England and Ireland is historically valid: major cultural links between the Vikings and Ireland were well established by this stage (e.g. Ó Corráin, 2001). Indeed, it has been argued that the Viking parties which dominated Dublin and York may have had a common origin in Scotland (e.g. Ó Corráin, 1998). It seems reasonable to expect a degree of cultural overlap between these regions during the Anglo-Scandinavian period. In Ireland, the perception of goose eggs as a luxury food seems to have persisted into the Modern era (Mac Con Iomaire & Cully, 2007).

4.3: Wild vs. domestic resource use in Anglo-Scandinavian York

There is a complete lack of demonstrably wild species in the eggshell assemblages (Figure 3, Table 2). Although the technique described above cannot presently distinguish between different species of duck and goose, or between domestic and wild types, these are known to have been kept domestically in the city during the Anglo-Scandinavian period (O'Connor, 1989, 2000). It is therefore parsimonious to cautiously propose that the duck and goose eggshell represents domestic species, while acknowledging that this cannot be stated conclusively. This is in contrast with the bird bone assemblages from the two sites, which exhibit a wide range of wild species, including water-fowl and seabirds (O'Connor, 1989, 2000).

It has been suggested that egg production was probably the main focus of chicken farming in Anglo-Scandinavian York (O' Connor, 2000), consistent with the predominance of adult birds in bone

assemblages. Given the extensive nature of the surrounding agricultural economy, it would not be surprising if the inhabitants of Anglo-Scandinavian York were able to obtain all of their eggs from domestic species. It would perhaps be more surprising if there were no preference for certain types of wild egg. For example, razorbill eggs were highly prized for their taste among diverse British communities from the 17th century until the mid-20th century (Baldwin, 2009; Kightly 1984). While it is pure speculation to extrapolate this back to the Anglo-Scandinavian period, it is interesting that no evidence of preference for any wild eggs has been forthcoming from either site, particularly in the higher status Coppergate assemblage. Razorbill (*Alca torda*) and guillemot (*Uria aalge*) bones are found at Coppergate (O'Connor, 1989), showing that transport of goods from coastal regions was occurring.

The lack of demonstrably wild species in the eggshell assemblage is consistent with the idea that wild species may have been a focus of exploitation outside of their breeding season, probably during winter (O'Connor, 2000). Wild-fowling may have provided additional food and/or income during the period when the time demands of normal economic activity may have been relaxed; according to this interpretation, during the fairly narrow window when wild eggs were available, people would have been occupied with normal economic activities (O'Connor, 2000). The eggshell results from Hungate and Coppergate begin to suggest that domestic species were the only source of eggs exploited in the city during this period. Although this is a preliminary interpretation, based upon analysis of only two sites, it is based on a large number of samples representing an occupation period of at least two centuries. The Coppergate contexts analysed here are confidently assigned to the Anglo-Scandinavian period; the Hungate contexts provisionally so, pending completion of post-excavation analysis. Future research will aim to further develop understanding of the use of bird eggs in Anglo-Scandinavian York, and beyond. Current research is analysing eggshell assemblages

from contemporaneous coastal sites, which are expected to contain a higher proportion of wild bird eggshell.

5: Conclusions

For a long time, eggshell has presented a conundrum for archaeologists; it is a common archaeological resource, but the volume and/or value of information which can be gained by studying it have often been limited. This case study on egg shell fragments from Anglo-Scandinavian York has highlighted the archaeological potential of eggshell by demonstrating that taxonomic identification can be made on sufficient material to give useful results, and that contrasts between contemporary neighbourhoods within one town can be clearly seen, raising the possibility that the eggs of different species were of different cultural value during this period, and may therefore become useful as indicators of status. Expanding the evidence base for egg use in Anglo-Scandinavian Britain (and beyond) is the subject of on-going research; this will facilitate new interpretations of egg use in the past.

6: Acknowledgements

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7: Supporting Information

Appendix S1 (example of Chicken Hawk output) and Table S1 (list of peptide markers) are available online as supplementary information.

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Marker ID	**Peptide *m/z***
Galliformes	1018.5
Galliformes	1024.5
Galliformes	1042.6
Galliformes	1047.5
Chicken	1150.6
Anseriformes	1290.6
Galliformes/Corvidae/Charadriiformes	1309.7
Chicken/Grouse/Magpie	1345.7
Chicken/Duck	1348.8

Duck	1366.6
Duck/Swan	1382.6
Chicken	1688.7
Duck/*L. fuscus*	1723.7
Chicken	1734.9
Duck/Swan	1739.8
Chicken	1774.8
Galliformes	1808.9
Chicken	1859.8
Anseriformes	2051.8
Duck	2362.2

Table 1: Sample of peptide markers identified from the reference database. These represent a sample from Coppergate (context 34726) which contained both chicken and duck eggshell. Note that markers are capable of variable levels of taxonomic resolution, and also the examples of convergent peptide masses. The full list of peptide markers (n = 491) is given as supplementary information (Table S1).

Hungate				**Coppergate**				
Context	**Fragments**	**Chicken**	**Goose**	**Context**	**Fragments**	**Chicken**	**Goose**	**Duck**
48310	*2*	*X*		1118	4	X		
48314	*12*	*X*		2562	2	X		
48709	5	X		3054	12	X		
48716	2	X		6437	3	X		
48780	7	N/A	N/A	6531	1	X		
49087	1	X		6536	1	X		
49223	2	X		6879	8	X		
49478	60-70	X		7696	2	X		
49480	2	X		7863	8	X		
49487	40-50		X	13577	10	X		
49494	4	X	X	14297	109	X	X	
49509	2	X		15311	23	X	X	
49599	>1000	X		16605	26	X		
49645	3	X		16877	43	X	X	
49646	50-60	X		18429	7	X	X	
49671	150	X		19271	8	X	X	
49720	4	X		21204	1		X	
49731	12	X		22154	72	X		
49810	6	X		22209	17	X		
49817	*1*	*X*		22452	18	X	X	
49827	2		X	22574	173	X	X	
49854	3	X		22746	69	X	X	
50551	10		X	22857	18	X		
50834	*6*	*N/A*	*N/A*	23437	61	X	X	
50839	2	X		24560	2	X		

51266	80	X		27017	8		X	
51435	1	X		28384	12	X		
52192	1	N/A	N/A	34290	22	X	X	
52300	13	N/A	N/A	34276	18	X		X
52438	60	X						
52444	60	X						
52852	70	X						
52960	50	X						
83328	*66*	*X*						
83350	*6*	*X*						
83460	*66*	*X*						
83461	*108*	*X*						
83471	*26*	*X*						
83548	*16*	*X*						

Table 2: Composition of Hungate and Coppergate eggshell assemblages by context. Results presented in italics represent contexts known to post-date the Anglo-Scandinavian period.