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Cetacean exploitation in Roman and medieval London: Reconstructing whaling activities by applying zooarchaeological, historical, and biomolecular analysis

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ABSTRACT

Cetacean (whale, dolphin, and porpoise) remains are occasionally encountered at Roman and medieval sites in London and are regularly the topic of medieval historical sources. These sources are often concerned with whale strandings and the subsequent claims on the carcass by the king, queen, or other members of the nobility or clergy with jurisdiction over the coastline that the whale stranded upon. The meat stripped from the carcasses was regularly transported to London and cetaceans have therefore been ascribed as a “high-status food source”. Besides, strandings, several historical sources also suggest that active whaling was undertaken, and that meat was sold at several London markets. Based on these historical sources it however remains unclear to what extent active whaling was undertaken, and which species were exploited.

Zooarchaeological studies address whales and their role in Roman and medieval society more directly through the study of animal bones. This study combines historical sources and the identification of zooarchaeological cetacean remains from the London sites of Bermondsey Abbey, Westminster Abbey (cellarium), Winchester Palace, Vintry, St Peter's Hill, and Trig Lane through Zooarchaeology by Mass Spectrometry (ZooMS) and morphological analysis. The historical and zooarchaeological evidence from London indicates that cetacean meat was indeed associated with a high-status diet, in particular the ecclesiastical diet, though some form of commercialization of cetacean meat also took place. On occasion, whale bone was used for the creation of bone artefacts or tools, primarily during the Middle Saxon period. Additionally, it is suggested that active whaling might occasionally have been undertaken, potentially already from the Middle Saxon period onwards. However, the majority of the remains were probably acquired through opportunistic scavenging of stranded individuals.

1. Introduction

Cetaceans have been understudied in the field of zooarchaeology for years. Even though several studies have attempted to fill a gap in our knowledge regarding the early exploitation of cetaceans by analysing zooarchaeological cetacean remains (Mulville, 2002; Speller et al., 2016; Rodrigues et al., 2018; van den Hurk, 2020), many zooarchaeological specimens remain unstudied. This is also the case for Roman and medieval London (see Table 1 for the periodization considered as part of this study), for which several cetacean remains have been uncovered from archaeological contexts. These provide an exceptional opportunity to reconstruct the early exploitation of cetaceans, cetacean

consumption, and whale bone working practices in a large urban context. Throughout this study the term “exploitation” will be used as a general term to encompass both the opportunistic scavenging of stranded cetaceans as well as the active hunting of cetaceans.

Additionally, throughout this study the term whale will be used as a general term for all cetaceans, unless specific references to whales as being distinct from dolphins and porpoises is made.

Recently it has been argued that the Romans might have practiced whaling in the western Mediterranean region (Rodrigues et al., 2018). While there is little evidence to support that whaling was already practiced in Great Britain during the Roman period, some zooarchaeological cetacean remains have been recovered from Roman contexts,

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Table 1

Periodization of London considered as part of this study.

Period	Dates (CE)
Roman	43–410
Early Saxon	410–660
Middle Saxon	660–900
Late Saxon	900–1066
High medieval period	1066–1272
Late medieval period	1272–1485

most likely indicating that stranded cetaceans were opportunistically exploited during that period (Speller et al., 2016).

Medieval historical sources for England discussing cetaceans are however more abundant. Gardiner (1997) suggested that during the high medieval period cetaceans were perceived as a high-status food source, often associated with the nobility and clergy. Additionally, with the spread of Christianity, cetaceans became an established food source for fasting periods (Hoffmann, 2005). The historical sources seem to indicate that the nobility and clergy restricted access to whale meat to themselves, which would have provided limited opportunities for people from different social strata to get access (Gardiner, 1997).

However, other sources from the same period indicate that merchants sold whale meat at local markets in London, suggesting that some form of commercialization also took place (Gardiner, 1997). This might have provided the more affluent members of the urban population of London with the opportunity to consume whale meat as well, in an attempt to copy the lifestyle and diet of the nobility (Ervynck, 2004).

From these historical sources it is however not clear which species were consumed. Furthermore it is also not clear whether active whaling was undertaken or whether people relied on opportunistic scavenging of stranded cetaceans along the shore. Cetacean remains are notoriously difficult to assign to species because of the well-known friability of their bones, with a thin external cortical layer and oil-filled cancellous bone. As a result, fragmentation of whale bones often occurs due to various taphonomic processes, here including butchery practices (Speller et al., 2016). Moreover, a lack of extensive osteological cetacean reference collections and the inexistence of a comprehensive osteological identification manual renders identification to species difficult. For these reasons, likewise for the sites in this study, the majority of cetacean remains from archaeological sites have not been identified to the species level and are only identified as “whale” or “large whale”. The specific identification of cetacean remains could play a vital role in clarifying our understanding of the species exploited and the associated social practices and dietary rules of Roman and medieval societies.

The meat and bones from individuals caught or stranded could have been transported to London, however, as whale bones are quite large, these might have been left at the foreshore, where they are often inaccessible to archaeologists. This has likely led to an underrepresentation of cetacean bones at archaeological sites (also for Roman and medieval London) and has resulted in cetaceans often being called “invisible” to archaeologists (Smith and Kinahan, 1984). Cetacean bone was probably only transported inland if value was placed on the bones themselves, for example for the creation of artefacts or tools (Mulville, 2002).

During the medieval period, antler had been the preferred raw resource for the creation of objects, but it appears that bone was also heavily exploited for such purposes during the Middle Saxon period. This has been called the “Middle Saxon Worked Bone Interlude” (Riddler and Trzaska-Nartowski, 2013). Bone is an inferior material to antler for the creation of tools such as combs, and it has been suggested that its use was expedient, at a time when antler supplies were insufficient to cope with demands imposed on craftsmen working with skeletal materials. The shortage of antler and a switch to bone for the creation of artefacts and tools has been observed for a range of other sites in England, particularly for Hamwic, Ipswich, and York, especially during the 8th century CE (Riddler and Trzaska-Nartowski, 2013). While cattle bones

were principally used for bone working, several sites have provided worked whale bone, potentially arguing that such bone found at Middle Saxon sites does not necessarily indicate the consumption of whale meat, but rather the usage of whale bone for bone working purposes.

This study aims to analyse zooarchaeological cetacean remains from Roman and medieval London in order to get a clear understanding of cetacean exploitation and the use of whale bone in London. Amongst these sites are Bermondsey Abbey (BYQ98); Westminster Abbey (cellarium) (WYA10); Winchester Palace (WP83); Vintry, 68–69 Upper Thames Street (VRY89); St Peter’s Hill (PET81); and Trig Lane (TL74). A selection of the zooarchaeological cetacean remains were subjected to Zooarchaeology by Mass Spectrometry (ZooMS) in order to identify these particular remains to family, genus, or species. The combination of historical sources and the zooarchaeological data allows for an evaluation of which species were exploited and whether active whaling might have been undertaken. Additionally, by analysing the whale bones for butchery marks and signs of working and/or burning, in combination with contextual information, it was then possible to suggest whether these bones were food or working waste and whether the exploitation of cetaceans was restricted to people from a specific social milieu or whether people from all social backgrounds had equal access to whale meat.

2. Historical Context: Cetaceans in London

Cetacean exploitation and ownership over caught and stranded cetaceans are recurring themes in various medieval sources. With the introduction and spread of Christianity, ‘fish’ (which includes marine mammals as they were perceived as fish during the medieval period) became commonly consumed during fasting periods such as Lent (Hoffmann, 2005). The apparent taste for cetacean meat observed in various historical sources further underlines a possible increase in cetacean exploitation during the high medieval period (Gardiner, 1997). Whale meat might have been transported to London as well and there is evidence that imported whale meat was relatively expensive (Wilson, 1973). Notably, the harbour porpoise (*Phocoena phocoena*) appears to have been a popular fasting food (Gardiner, 1997).

In addition to their nutritional value, oil could also be extracted from cetacean carcasses (blubber and bone). Cetacean oil was valued as it could be used for illumination purposes. In *A Life of the Abbot Philibert* written by Ermantarius in the 9th century CE, it was recorded that the abbot of Jumièges in France had prayed for oil for lamps. Soon after this prayer, one of the monks came and announced that a dead “fish” had been washed up on the shore. From its carcass the monks extracted oil for oil-lamps (Musset, 1964).

Cetaceans washing up on the shores of England were treated in a similar way as shipwrecks; as recorded in the *Leges Henrici Primi* (dating between 1116 and 1118 CE). Material considered the “wreck of the sea and things cast up by the sea” were the right of the king (Gardiner, 1997). This included cetaceans, which were known as “Royal Fish” during the medieval period. During the 12th, 13th, and 14th centuries, the king occasionally granted religious houses or members of the nobility the rights to these “wrecks” (Gardiner, 1997). Henry I, King of England from 1100 to 1135 CE, granted to St Paul’s Cathedral in London all cetaceans stranded on their land, with the exception of their tongue (Peckham, 1946). He granted similar rights to Chichester Cathedral and Battle Abbey (Peckham, 1946; Johnson and Cronne, 1956). There are numerous examples of claims by 12th–14th century members of the nobility and clergy with coastal estates of ownership over cetaceans that stranded upon their land (Gardiner, 1997). Although for France these rights to take wrecks and whales predate the Norman Conquest, this is not the case for England, suggesting that royal claims to items cast up on the foreshore may have been asserted only decades after the Norman Conquest (Gardiner, 1997).

However, this law was occasionally broken. A section in the *Calendar of Patent Rolls* dating to December 10th 1336 records the stranding of a

whale on the riverbank of the Thames somewhere between Greenwich and Northfleet, County Kent. Instead of it being claimed by the king, several people were reported as “touching and carrying away of a whale”. As a result, the oath men of the counties Essex and Kent were ordered to undertake an inquisition (Boynton, 2016). Numerous records from the *Calendar of Patent Rolls* are concerned with cases like this in which people were punished or fined for exploiting stranded cetaceans (“wrecks”) to which they had no claim (Gardiner, 1997).

As London is not located on the coast, historical sources agree that cetaceans were primarily obtained elsewhere (either the exploitation of stranded individuals or those actively caught) and were subsequently transported to London, though they might have been caught in the Thames as well. Cetaceans stranding on the riverbank of the Thames were treated in a similar fashion as shipwrecks and therefore belonged to the king. From historical sources, as well as modern cases, it appears that a wide range of cetacean species entered the river Thames.

One of the earliest references to cetaceans in London dates to 1240 CE, when a whale was chased and butchered at Mortlake (Velten, 2013). Similarly, other sources record that in 1392 a dolphin was spotted at London Bridge and in 1457 another source mentions that two whales, a narwhal (*Monodon monoceros*), and a walrus (*Odobenus rosmarus*) were caught in the Thames (Gardiner, 1997; Velten, 2013). In post-medieval London, cetaceans were also reported entering the Thames such as a North Atlantic right whale in 1658, a killer whale (*Orcinus orca*) in 1793 and a common minke whale (*Balaenoptera acutorostrata*) in 1842 which was killed near Deptford Pier (Fig. 1) (Hoare, 2010; Velten, 2013).

Nowadays rescue attempts are undertaken whenever (large) cetaceans enter the Thames. Nevertheless, many cetaceans wandering into the Thames still frequently die of natural causes. In 1961 a minke whale, and in 2006 a northern bottlenose whale (*Hyperoodon ampullatus*) died in the Thames (Hoare, 2010). However, some do return to the sea, as shown for example by a pod of twenty long-finned pilot whales (*Globicephala melas*) first sighted swimming in the Thames off Woolwich Pier on November 11th 1965.

It is however unlikely that cetaceans were merely hunted in the Thames and historical sources indicate that cetacean meat was transported from elsewhere. It appears to have been a valuable commodity over which taxes had to be paid. In the law-code known as “IV

Æthelred”, that has been attributed to Æthelred II dating to the late 10th century CE, merchants from Rouen, France were taxed in order to sell *craspois* or ‘fat fish’ (i.e. whale meat) in London, indicating that cetaceans were also commercially interesting products (Middleton, 2005).

However, a recent re-evaluation of the law code indicated that the portion concerned with the *craspois* most likely dates to the immediate aftermath of the Norman Conquest (Naismith, 2019). Rouen was part of Normandy, for which active whaling activities in the English Channel have been recorded from at least the mid-9th century CE up until the 12th century CE (Musset, 1964). With the Norman Conquest during the late 11th century CE, interest in cetacean exploitation and consumption might have become more popular in London and the rest of England as well.

Moreover, another source that has been used to argue that whaling was already practiced during the 10th century is Ælfric’s *Colloquy*. This document, written by the abbot Ælfric of Eynsham (955–1010 CE), was used to teach Latin vocabulary and grammar to pupils, but provides valuable information regarding medieval practices as well. One of the sections is about a fisherman who has a dialogue with a master about his work. When asked whether he would ever be considering catching whales, the fisherman argues that “...it is a risky business catching whales. It’s safer for me to go on the river with my boat, than to go hunting whales with many boats.....I prefer to catch a fish that I can kill, rather than a fish that can sink or kill not only me but also my companions with a single blow.” He however continues saying that many do catch whales and make great profit by it (Swanton, 1975, 110–111).

Ælfric might have referred to the merchants from Rouen, though whaling might have been undertaken in England as well. Two North Atlantic right whale (*Eubalaena glacialis*) carcasses dating to somewhere between the late ninth century to early eleventh century CE, with clear butchery signs, have been unearthed during archaeological excavations at the site of Dengemarsh, in south-eastern England, about 100 km away from London (Gardiner et al., 1998). It is unclear whether these individuals naturally stranded or were potentially caught by the whalers Ælfric mentioned.

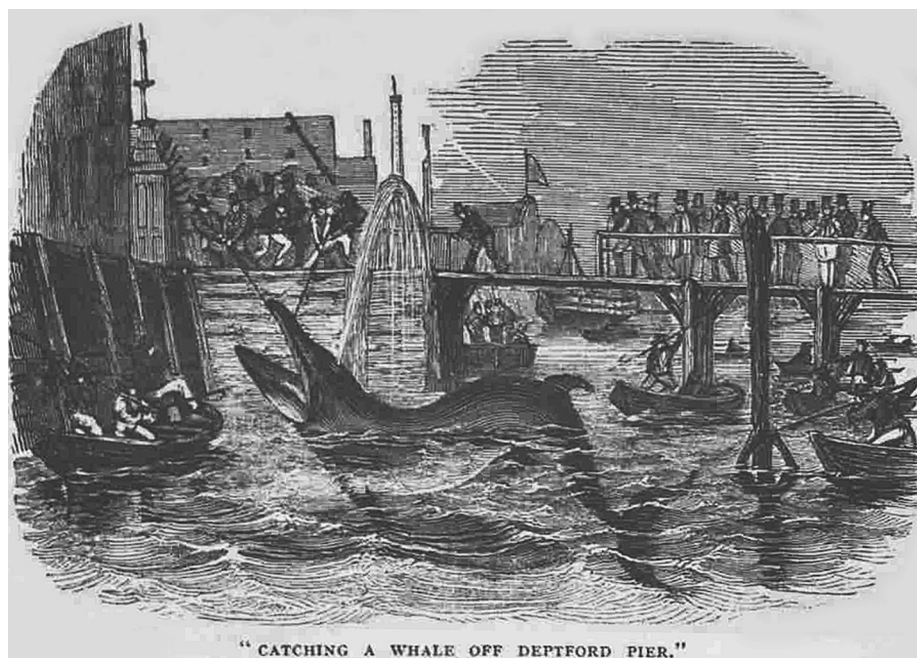


Fig. 1. “One Hundred Years Ago: Catching a Whale off Deptford Pier, London” From the Illustrated London News – Saturday 31 October 1942. © Illustrated London News/Mary Evans Picture Library.

3. Material and methods

As part of this study, zooarchaeological cetacean remains from medieval contexts were synthesised in order to get a clear overview of the location and contexts of the various specimens, as well as which species were represented in the archaeological record, with each specimen also examined for signs of butchery, burning and other taphonomic traces. These cetacean remains included sixteen specimens from Bermondsey Abbey (BYQ98); three from Westminster Abbey (Cellarium; WYA10); one from Winchester Palace (WP83); one from Vintry, 68–69 Upper Thames Street (VRY89); one from St Peter's Hill (PET81); and one from Trig Lane (TL74). All specimens showed high degrees of fragmentation and as a result ZooMS was undertaken on twelve of the specimens from Bermondsey Abbey and one from Westminster Abbey, removing a small sample of 0.03 g using a Dremel at University College London. The other two specimens from Westminster Abbey showed signs of burning and therefore were not included in the ZooMS analysis as the method requires unburned specimens, while those from Winchester Palace, Vintry, St Peter's Hill, and Trig Lane were not available for destructive analysis.

ZooMS is an increasingly established biomolecular method that can be used to identify zooarchaeological remains to the family, subfamily, genus or sometimes species level (depending on taxa under investigation; Buckley et al., 2009) based on the analysis of bone collagen. It has already been shown that variation in the collagen peptide amino acid sequences preserved in bone can be used to differentiate between related cetacean genera (Buckley et al., 2014; Speller et al., 2016; Evans et al., 2016; Rodrigues et al., 2018; Hufthammer et al., 2018). However, in general an evolutionary divergence of at least 5–6 million years between species is needed to allow for effective ZooMS identification (Buckley, 2018). ZooMS is for example, not able to separate the North Atlantic right whale (*Eubalaena glacialis*) from the bowhead whale (*Balaena mysticetus*; Buckley et al., 2014).

ZooMS was undertaken at the University of Manchester following the protocol established in van der Sluis et al. (2014). This involved the addition of 1 mL 0.6 M hydrochloric acid (HCl) to ~ 25–50 mg bone powder overnight at room temperature. The next day, the samples were centrifuged at 12,400 rpm for 1 min and the supernatant removed for ultrafiltration into 50 mM ammonium bicarbonate (ABC); 1 mL 50 mM ABC was centrifuged through the 10 kDa molecular weight cut off ultrafilters, and 100 µL of the retentate collected for digestion with 0.4 µg sequencing grade trypsin (Promega, UK). The samples were then ziptipped following manufacturer's protocols (OMIX, UK) and after resuspension with 10 µL 0.1% trifluoroacetic acid, one tenth was co-crystallised onto a stainless-steel Matrix Assisted Laser Desorption Ionization (MALDI) target plate with an equal volume of alpha hydroxycinnamic acid matrix (10 mg/mL in 50% acetonitrile/0.1% TFA). Dried sample spots were analysed using a Bruker MALDI instrument (Autoflex II Smartbeam) with the *m/z* range 700–3700. Resultant spectra were then compared with those of reference spectra for a range of marine mammals (Buckley et al., 2014).

However, ZooMS collagen peptide mass fingerprinting was for most cases not able to identify remains to species level, but instead to sub-family or family level only. Therefore, in order to identify the zooarchaeological remains to species, the zooarchaeological specimens that were not too fragmented and still contained some diagnostic features, were also morphologically compared to specimens held at the Natural History Museum in London (UK) and the Smithsonian Institution in Washington DC (USA). This allowed for more precise identifications to be made.

4. Results: ZooMS and morphological analysis

ZooMS was undertaken on twelve specimens (out of sixteen) from Bermondsey Abbey and on one specimen (out of three) from Westminster Abbey (cellarium). ZooMS analysis provided results for twelve of the thirteen samples tested and only failed for one of the specimens

from Bermondsey Abbey (Table 2; Fig. 2; Supplementary figure 1 and 2). Morphological analysis was able to optimize species identification for those specimens in some cases, as well as for some of the specimens not analysed through ZooMS.

4.1. Winchester Palace

At Winchester Palace (WP83), from a dark earth deposit (context 316), a rib of a medium sized cetacean dating to 800–1200 CE was unearthed. No ZooMS was performed on this specimen.

4.2. Vintry, 68–69 Upper Thames Street

A fragment of the proximal end of the mandible of a large baleen whale was found at Vintry (VRY89) taken from context 872. The specimen dates to 0 CE – 1600 CE. The exterior cortical layer of the bone surface was well preserved allowing it to be identified as a mandible fragment. Several chop- and cutmarks have been identified, suggesting it was used as a cutting surface (Gibbs, 2013). No ZooMS was performed on this specimen.

4.3. St Peter's Hill

A rib of a large cetacean was found at St Peter's Hill (PET81), from context 640, dating to 1200–1500 CE. No ZooMS was performed on this specimen.

4.4. Trig Lane

At Trig Lane (TL74) from context 368, the rostrum of a baleen whale dating to 1200–1500 CE was identified. It has been sawn through at the posterior end. No ZooMS was performed on this specimens but morphological analysis indicated that it belonged to a common minke whale.

4.5. Westminster Abbey (Cellarium)

Three cetacean specimens derive from the Westminster Abbey (cellarium) site and all date to 1150–1350 CE. A skull fragment, displaying seven cutmarks, was identified as a common minke whale through ZooMS. The two other specimens were partially burned and ZooMS was not performed on these specimens. These specimens were morphologically identified as harbour porpoise; the first specimen resembles a vertebral body of a caudal vertebra and the second a spinous process of a caudal vertebra (Fig. 3). These two specimens displayed signs of burning as well as chop- and cutmarks. This might potentially be the result of cooking practices, suggesting the meat of the harbour porpoise was consumed at the site. The signs of burning might also be the result of use as a supplementary fuel source or the specimens might have been included in refuse fires. Unfortunately signs of burning were not reported on for the other zooarchaeological remains in the site report, rendering comparison with those remains impossible (Rielly, 2003).

4.6. Bermondsey Abbey (BYQ98)

Sixteen cetacean specimens were identified at Bermondsey Abbey (BYQ98). Four of the bones displayed cutmarks, indicating butchery practices and suggesting the meat was stripped from the carcass and consumed. Additionally, one vertebral specimen bore signs of burning, which might also indicate cooking practices, though it might also imply that the oil from within the vertebra was used for illumination practices, used as a supplementary fuel source or included in refuse fires. Unfortunately, the site report for Bermondsey Abbey was not published just yet, rendering comparison with the state of burning of other zooarchaeological specimens from the site impossible.

Thirteen specimens were analysed using ZooMS, and only failed for

Table 2

ZooMS and morphological analysis results of the specimens. * For these specimens (3221 (a and b) and 7465; all vertebral fragments) no ZooMS analysis was undertaken, but as they were located in the same contexts as material that was identified as long-finned pilot whale/false killer whale/Risso's dolphin and as they are of a similar size and displayed a similar osteological morphology, they are likely also from the same species.

Site	Context/ Specimen no.	Description	Butchery/Burned	Dates (CE)	ZooMS identification	Morphological identification	Final identification
BYQ98	3878	Indeterminate	–	43–100	Fin whale	Cetacean	Fin whale
	8202	Vertebra	2 Chopmarks	300–400	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	3221(a)	Vertebra	–	400–1066	Not tested	Medium cetacean	Cf. Long-finned pilot whale *
	3221(b)	Vertebra	1 Chopmark	400–1066	Not tested	Medium cetacean	Cf. Long-finned pilot whale *
	3221(c)	Vertebra	1 Chopmark	400–1066	Long-finned pilot whale/False killer whale/Risso's dolphin	Long-finned pilot whale	Long-finned pilot whale
	3221(d)	Skull fragment	–	400–1066	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	7374	Vertebra	Partially burned	400–1066	Long-finned pilot whale/False killer whale/Risso's dolphin	Long-finned pilot whale	Long-finned pilot whale
	7465	Vertebra	1 Cutmark	400–1066	Not tested	Medium cetacean	Cf. Long-finned pilot whale*
	9056	Vertebra	1 Cutmark	900–1066	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	7460	Vertebra	–	900–1066	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	7379(a)	Indeterminate	–	1050–1150	Not tested	Cetacean	Unknown cetacean
	7379(b)	Indeterminate	–	1050–1150	ZooMS Failed	Cetacean	Unknown cetacean
	7388	Skull fragment	–	1050–1150	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	7447	Indeterminate	–	1050–1150	Long-finned pilot whale/False killer whale/Risso's dolphin	Medium cetacean	Cf. Long-finned pilot whale
	9183	Scapula	1 Chopmark	1050–1150	Balaenidae	Large cetacean	Cf. North Atlantic right whale
	4577	Vertebra	1 Cutmark	1680–1750	Long-finned pilot whale/False killer whale/Risso's dolphin	Long-finned pilot whale	Long-finned pilot whale
WYA10	262	Skull fragment	7 Cutmarks	1150–1350	Minke whale	Large cetacean	Common minke whale
	785	Spinous process (vert.)	Burned	1150–1350	Not tested	Harbour porpoise	Harbour porpoise
	910	Vertebra	2 Chopmarks; burned	1150–1350	Not tested	Harbour porpoise	Harbour porpoise
WP83	316	Rib	–	800–1200	Not tested	Medium cetacean	Medium cetacean
VRV89	872	Proximal end mandible	Several chop- and cutmarks	0–1600	Not tested	Large baleen whale	Large baleen whale
PET81	640	Rib	–	1200–1500	Not tested	Large cetacean	Large cetacean
TL74	368	Rostrum	1 Sawmark	1200–1500	Not tested	Common minke whale	Common minke whale

specimen 7379(b). One fin whale (*Balaenoptera physalus*) bone dating to the second half of the 1st century CE was identified. Additionally, a scapula fragment of a North Atlantic right whale or bowhead whale dating to 1050–1150 CE was identified. Based on the geographic location this is probably a right whale, as the bowhead normally only occurs in more northern waters, though this cannot be stated with absolute certainty and aDNA analysis would be needed to confirm this.

Moreover, nine of the samples were identified as Risso's dolphin (*Grampus griseus*), false killer whale (*Pseudorca crassidens*), or long-finned pilot whale (*Globicephala melas*). These three species are part of the Globicephalinae subfamily. ZooMS collagen fingerprinting struggles to differentiate between these three species, which is unsurprising given their relatively recent evolutionary divergence within the last 5–6 million years (Vilstrup et al., 2011), which is unfortunately just the limit of divergence of taxonomic resolution required to allow ZooMS identification for large mammals (Buckley, 2018).

Five other species also belong to the Globicephalinae subfamily and these five species also diverged from each other within the past 5–6 million years (Vilstrup et al., 2011), indicating that they potentially have similar ZooMS identification markers. However, for these species, ZooMS reference spectra have not been created and as a result nothing can be said regarding these species considering the ZooMS results. These five species do not or only very rarely occur in British waters (Shirihai and Jarrett, 2011), though this might have been different in the past.

Morphological comparison was undertaken to enhance the ZooMS identifications. Unfortunately, this could only be undertaken for three of the specimens, as the other nine fragments were too fragmented or weathered. These three specimens were vertebral remains. All three vertebrae were cranially and caudally unfused. It is not known at what age stage the vertebral epiphyses fuse to the vertebral body for the three Globicephalinae species considered (in fact this is poorly understood for many cetacean species), therefore it is not possible to determine whether the vertebrae derive from adult or juvenile individuals merely based on the unfused status of the vertebrae (Galatius and Kinze, 2003).

The size of the three specimens could provide some information regarding the species, as the Globicephalinae species display differences in size (Fig. 4). Based on the size of the vertebrae, the specimens were identified as belonging to a large species, either a pilot whale species or a false killer whale. Furthermore, the dimensions of the vertebral bodies of the entire vertebral column of the Globicephalinae species were compared with zooarchaeological specimens. For the false killer whale, the length of vertebral body for the second half of the thoracic vertebrae, the lumbar vertebrae and the first couple of the caudal vertebrae exceeds the height and the breadth of the vertebral body (Buchholtz and Schur, 2004). This was not observed for the three vertebral specimens from Bermondsey Abbey, indicating the specimens derived from the long-finned pilot whale. Morphological comparison to the long-finned pilot whale specimens held at the Smithsonian Institution, confirmed the

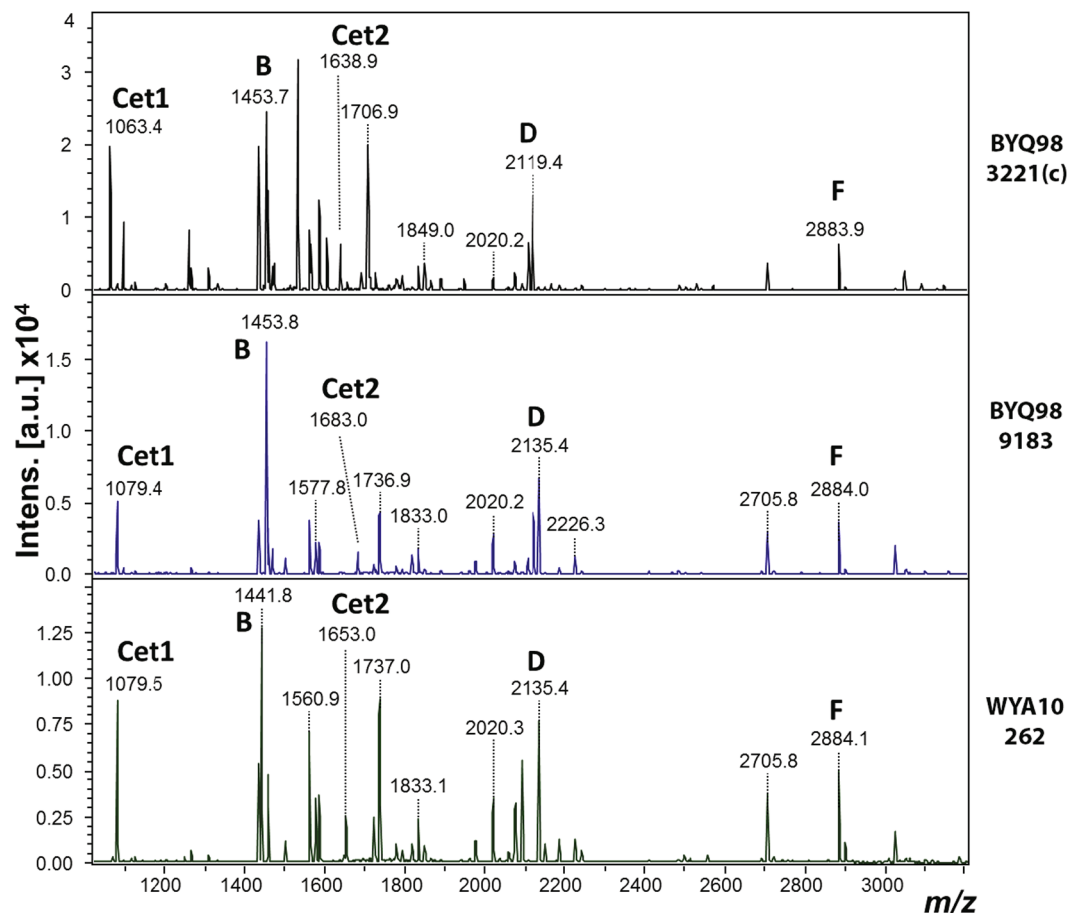


Fig. 2. ZooMS Spectra for three of the identified specimens. BYQ98 3221(C) identified as a long-finned pilot whale, false killer whale, or Risso's dolphin. BYQ98 9183 identified as a North Atlantic right whale or bowhead whale. WYA10 262 identified as a common minke whale.

identification of the three zooarchaeological specimens as long-finned pilot whales (a 5th thoracic vertebra, a 1st lumbar vertebra, and a 12th lumbar vertebra). These identifications are based on the position and orientation of the pedicles, laminae, and transverse processes (Fig. 5).

Concerning the other Globicephalinae specimens from Bermondsey, for which no morphological analysis was possible, it is highly likely that these derive from long-finned pilot whales as well, as those fragments are of a comparable size and some of these also derive from the same contexts. As the remains were recovered from contexts dating centuries apart it is possible that pilot whales were regularly consumed at Bermondsey. Another possibility is that, as the analysed vertebrae are all of a comparable size and are all unfused, they (and the other Globicephalinae specimens) might derive from just one individual (Minimum Number of Individuals (MNI): 1) brought to Bermondsey Abbey and post-depositionally ending up in various levels of the archaeological sequence. Indeed the specimens dating to Saxon period derive from plough soil contexts which are likely disturbed. Considering the various dates and contexts, the individual was most likely caught during the 11th century CE.

Nineteen fin whale specimens from the Scottish site of The Cairns identified through ZooMS, were later analysed using aDNA analysis which indicated all specimens derived from just one individual (ArchaeologyOrkney, 2020). This might therefore have been the case for the Bermondsey specimens as well, though aDNA analysis is required to assess whether the specimens from Bermondsey also derived from just one individual.

5. Results: Other zooarchaeological cetacean remains from London

Besides the remains from Bermondsey Abbey, Westminster Abbey (Cellarium), Winchester Palace, Vintry, St Peter's Hill and Trig Lane, which were analysed as part of this study, archaeological cetacean remains have been found at 23 other Roman and medieval sites in Greater London (Table S1). This brings the total number of identified specimens (NISIP) to 55 (Fig. 6).

All these sites have been temporally plotted by assessing the number of identified specimens and dividing those by the length of the date range of that site to give an estimate of frequency density across that range. This provided an estimated frequency distribution in a similar manner to that shown by Orton et al. (2014) who analysed cod remains from London. In opposition to this method, the sites were divided into the categories "ecclesiastical" and "non-ecclesiastical". This categorization was based on the contexts of the sites and the archaeological and other zooarchaeological findings made (see Supplementary Table 1 for site descriptions). Five-year intervals for the period of 0 CE–1600 CE were used to produce an overall distribution (Fig. 7). Contexts with date ranges over 500 years were excluded. Even though the sample size for the cetacean remains dealt with in this study is considerably smaller than the sample size for the cod remains in Orton et al. (2014), this method allows the incorporation of specific dating information for each relevant archaeological context without lumping data into coarse-grained and arbitrary chronological groups (e.g. century blocks in which archaeological data is often displayed).

From this graph a clear pattern arises. During the Roman period only a handful of cetacean remains have been recovered, after which



Fig. 3. Fragment of spinous process (left) and vertebral body (right) of a harbour porpoise from Westminster Abbey (Cellarium) in comparison to the 7th caudal vertebra (top) of harbour porpoise specimen 572,612 of the Smithsonian Institution – Cranial view.

numbers of remains increased rapidly during the Middle Saxon period. At the end of the 9th century with the abandonment of Lundenwic (Saxon London, centred on the modern day Covent Garden), the number of cetacean remains decreased again. With the re-settling of London (within the confines of the Roman city walls) shortly after, numbers increased again with cetacean remains most frequently found at ecclesiastical sites. From the late 12th century however, cetacean remains appear more and more frequently at non-ecclesiastical sites, with

relatively few cetacean remains from the late 14th century onwards. The data indicates clear trends in cetacean exploitation that will be discussed in the discussion section.

In addition to the species identified in this study, several other species have been identified from medieval contexts in London (Fig. 8). Due to the high number of long-finned pilot whale remains from Bermondsey Abbey, this species is the best represented overall. Apart from the bones from Bermondsey Abbey, long-finned pilot whale remains have also been found at three other sites, including one vertebra from Middle Saxon Drury Lane (Cowie et al., 2012), one caudal vertebra from late 11th century Queenhithe – Bull Wharf (Rielly and Pipe, 1998), and one vertebra from Middle Saxon Royal Opera House (Rielly, 2003). However, these specimens have been tentatively identified based on their size. ZooMS or aDNA will be necessary in order to confirm these identifications. However, if the identifications are accurate, this goes some way to confirm the apparent prevalence of this species.

The harbour porpoise is the second-best represented species and remains of this small cetacean species have been recovered from seven different sites (Table S1). Historical sources frequently mention harbour porpoise exploitation and suggest that they were imported to London (Gardiner, 1997). They are the most frequently encountered cetacean species in European medieval contexts, suggesting that it was occasionally exploited (van den Hurk, 2020). This species is known to wander into the Thames, therefore, the exploitation of harbour porpoises might well have occurred in the Thames itself. Interestingly, harbour porpoise remains are most frequently found at ecclesiastical sites (at five out of the seven ecclesiastical sites incorporated in this study). The species, other than harbour porpoise, recovered from ecclesiastical sites, tend to be represented by one or two specimens and often limited to one site. This might indicate that these other species were merely opportunistically exploited when naturally stranded. However, the sample size, though substantial for an urban context, is still low and more cetacean findings in the future might be able to shed light on cetacean exploitation more thoroughly.

6. Discussion

Few cetacean remains derive from Roman London, perhaps suggesting little interest in cetaceans. It has been argued by Rodrigues et al. (2018) that whaling might have been undertaken by the Romans in the western Mediterranean. This study has unearthed no proof that this might have been the case for London as well. This might have been different for more coastal regions of Britain, but more research is needed to assess this.

The same can be suggested for the Early Saxon period, which also provided very few cetacean remains. This situation changed however in the Middle Saxon period, especially during the 8th and early 9th

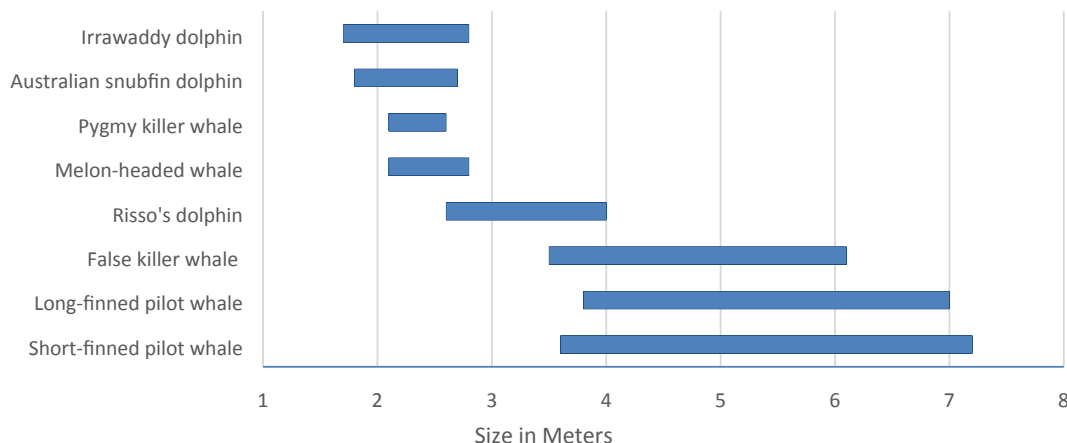


Fig. 4. Size of adult *Globicephalinae* sp. in meters based on data by Shirihai and Jarrett (2011).

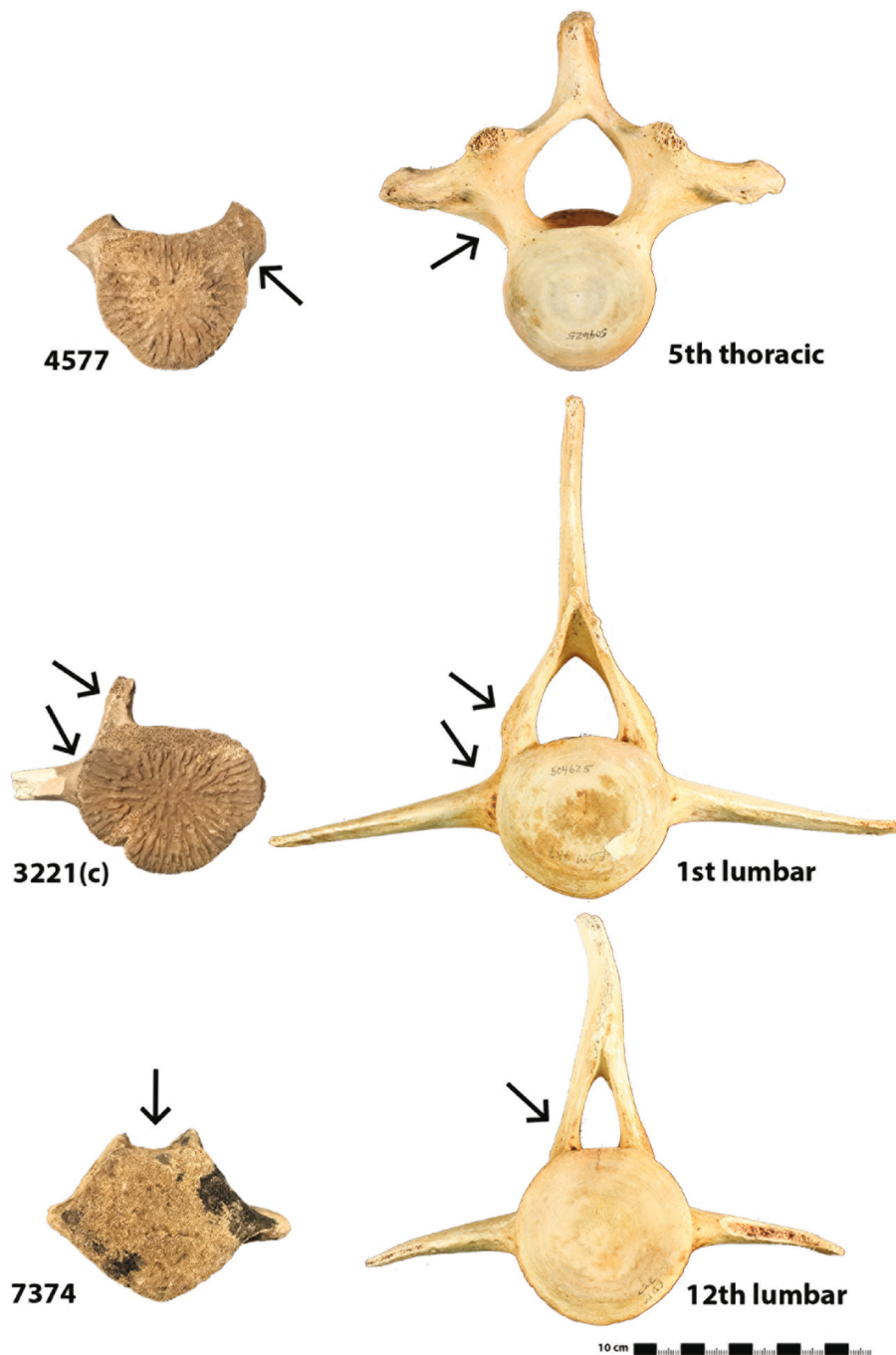


Fig. 5. Zooarchaeological specimens compared with osteological specimens at the Smithsonian Institution (specimen 504625). 4577 identified by comparison to the pedicle (5th thoracic vertebra; cranial view), 3221(C) identified by comparison to the position and orientation of the lamina and transverse process (1st lumbar; caudal view), and 7374 identified by comparison to the position and orientation of the lamina (12th lumbar; caudal view). The arrows point at the position and orientation of the laminae and the pedicles of the zooarchaeological specimens and how those compare to the reference specimens.

centuries CE. A large number of these specimens from this period also show signs of working. The Middle Saxon period (660–899 CE) saw a general rise in bone being used as a raw material for the creation of artefacts and tools. This has been called the “Middle Saxon Worked Bone Interlude” (Riddler and Trzaska-Nartowski, 2013). The shortage of antler and a switch to bone for the creation of artefacts and tools has been observed for a range of other sites in England, particularly at Hamwic, Ipswich, and York, as well as Dorestad in the Netherlands and Münster in Germany, especially during the 8th century CE (Riddler and Trzaska-Nartowski, 2013).

Bone and antler working for Middle Saxon London has been considered by Keily (2012) and Keily and Rielly (2012). Large quantities of antler pieces have been reported, suggesting antler was commonly used in the area, primarily for the creation of combs. Keily (2012)

reported on at least 169 antler comb blanks and tooth plates as well as shavings and tine trimmings from several Middle Saxon sites in London. However, this clearly coincided with a notable use of bone for the creation of objects (Keily, 2012). This was particularly notable at Middle Saxon Bedford Street, where worked bone pieces outnumber those made from antler. For this site, cattle metapodia were extensively used, primarily for the production of combs. One of the comb tooth plates from Bedford Street was however identified as whale bone. This is the only example of whale bone from these Middle Saxon sites from which 419 worked bone and antler pieces have been identified (Riddler and Trzaska-Nartowski, 2013).

As part of this study several other whale bone pieces from Middle Saxon London have been identified, suggesting that whale bone was occasionally used as a substitute for antler working. However, antler or



Fig. 6. Location of medieval sites in Greater London that have provided cetacean remains.

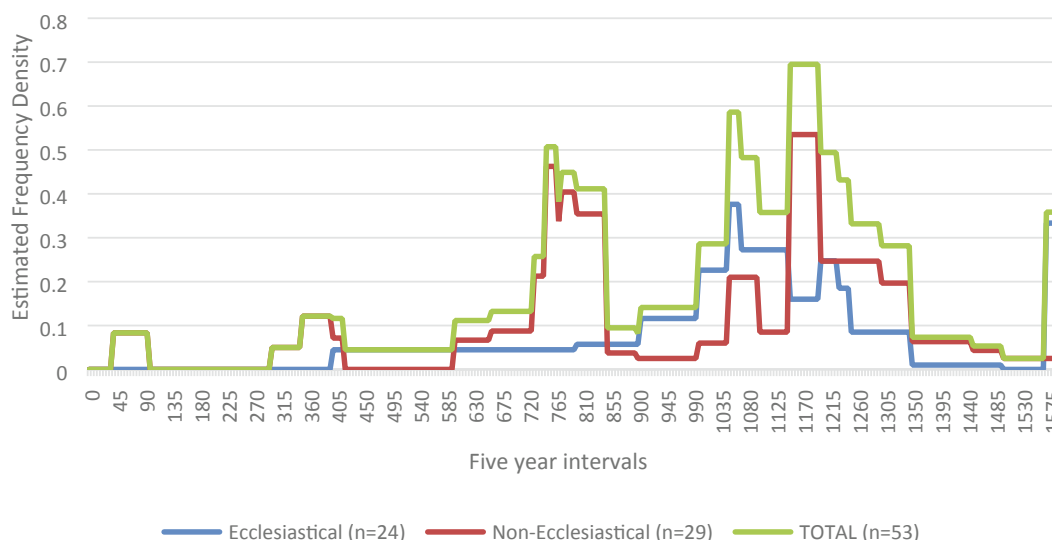


Fig. 7. Estimated frequency density distribution by site type and polynomial regression for London cetacean remains.

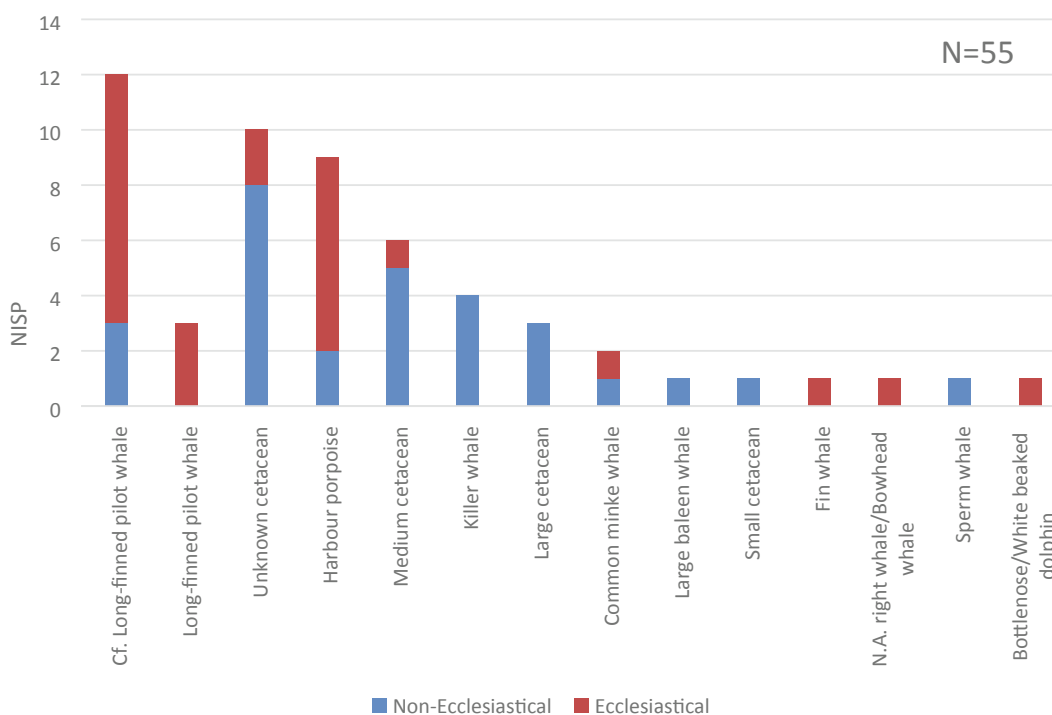


Fig. 8. NISP of the cetacean species identified at all the Roman and medieval sites of London, including those identified as part of this study.

bone of other animals is far more frequently identified. Examples of this are the sites of 67–68 Long Acre; Bruce House, 1 Kemble Street; and 26–27 Southampton Street, for which virtually all non-antler bone waste comprises cattle long-bone fragments (Keily and Rielly, 2012).

This suggests that while whale bone was occasionally used, it did not have the same importance as the contemporary coastal site of Hamwic where much larger quantities of worked whale bone has been identified. The large quantity of whale bone at Saxon Hamwic, might suggest whaling was already undertaken there and might actually represent the whaling described by Ælfric (Riddler and Trzaska-Nartowski, 2014). Notably, fragments of large cetaceans have been found at Hamwic, potentially derived from locally caught (or stranded) North Atlantic right whales, though ZooMS or aDNA is needed in order to test this.

Furthermore, at the site of Flixborough, North Lincolnshire, high

numbers of common bottlenose dolphin (*Tursiops truncatus*) remains have been found (Dobney et al., 2007), as well as occasional specimens of killer whale and common minke whale. Mostly dating to the Middle Saxon era, there is some continuity into the Late Saxon period, all suggestive of active whaling at this site across several centuries (Dobney et al., 2007).

The specimens from Hamwic and Flixborough indicate active whaling was undertaken in Middle Saxon England. Moreover, it raises the possibility that two distinct methods were used, as the specimens from Hamwic represent large cetacean species, while those from Flixborough primarily represent dolphins. This demonstrates the people in England during the Middle Saxon period were innovative and had the skills and means to hunt a variety of cetacean species. This suggests that some of the specimens from Middle Saxon London might have been

acquired through active whaling as well.

The quantity of whale bone from London dating to the Middle Saxon period, or any other period, is low, suggesting only occasional use of whale bone. However, antler and whale bone are hard to distinguish, especially when worked (Margaris, 2014). This might have resulted in the misidentification of whale bone as antler, and potentially larger numbers of whale bone are present in London. A re-evaluation of worked bone and antler objects might identify more whale bone pieces. ZooMS would especially be suitable to distinguish between the two.

Following the Middle Saxon period, during the 10th and 11th centuries, Christian dietary practices spread all over England (Hoffmann, 2005). As Gardiner (1997) suggested based on historical sources, the ecclesiastical order attempted to get access to cetacean meat more frequently from the onset of the 10th century and this is confirmed by the zooarchaeological data, with many cetacean remains deriving from ecclesiastical contexts.

Following the Norman Conquest, even more cetacean remains are recovered from London (Fig. 7). Normans are known to have performed whaling in Normandy (Musset, 1964), and their influence on London might have resulted in an increase in cetacean consumption. This increase can potentially also be explained by the spreading of the Christian dietary rules and improvements made in preservation techniques, such as salting, drying and brining, allowing for marine resources to be preserved longer and allowing for transportation to regions farther inland, such as London (Hoffmann, 2005). Interestingly, it is from this period that the majority of the harbour porpoise remains derive and most of these come from ecclesiastical contexts. As recorded in *A Life of the Abbot Philibert* and various other sources, cetaceans are often associated with ecclesiastical houses. The porpoise findings from London agree with these historical sources. However, porpoise remains have also been recovered from Anglo-Norman urban contexts in Canterbury and Dover (Sabin et al., 1999), either suggesting porpoise meat was available to people from other social backgrounds as well, or that they illegally undermined elite control over harbour porpoise consumption. Canterbury and Dover are additionally located closer to the shore making access to any stranded or caught cetaceans considerably easier.

For London, when considering all cetacean specimens, over half of the sites are not of an “ecclesiastical” type, suggesting that cetacean meat was not restricted to the social elite *per se* and was available to people from various social strata, either catching them themselves, illegally taking advantage of stranded cases and in this way undermining elite control, or purchasing whale meat from merchants. Another possibility is that those specimens deriving from non-ecclesiastical sites, primarily represent whale bone working and do not actually indicate cetacean meat consumption. Indeed large numbers of worked whale bone derive from non-ecclesiastical contexts, while no worked whale bone specimens derive from ecclesiastical contexts. This suggests that while consumption of cetaceans (primarily the harbour porpoises) was the main reason for cetacean exploitation for the ecclesiastical order, the main reason for cetacean exploitation of the non-ecclesiastical citizens of London was whale bone working and the creation of artefacts and tools.

From the end of the mid-14th century onwards, cetacean exploitation appears have gradually declined again, suggesting cetacean meat was no longer perceived a prestigious food source and infrequently used for bone working. During this period, known whaling cultures such as the Normans and the Flemish, ceased their whaling activities, probably due to the collapse of the North Atlantic right whale population in the eastern North Atlantic, while the Basques ventured in search of unharvested whale populations in western North Atlantic waters (van den Hurk, 2020).

Though whale bone has been recovered from a variety of archaeological sites, based on zooarchaeological remains alone it is almost impossible to prove that active whaling was undertaken as stranded specimens may likewise have caused whale bones to occur in archaeological assemblages. A large portion of the bones bore butchery marks,

but it is not possible to differentiate between those that were inflicted during a potential hunt or post-mortem dismembering (Mulville, 2002).

Some of the species identified in this study are species that are known from historical whaling activities. Pilot whale drive hunting (also known as the *Grind*) was already practiced by at least 1588 CE in the Faroe Islands (Szabo, 2008). Drive-hunting has previously been suggested to have taken place at the Californian Channel Islands and another site in the Cape Region of Baja California dating to 6440 cal BC to 1400 cal CE (Porcasi and Fujita, 2000), Japan during the Jomon Period (Hiraguchi, 1993), and in Ra's al-Hadd during the Bronze Age period (Mosseri-Marlio, 2002). No historical records suggest drive hunting being undertaken in the London area, but it is possible the practice could have been undertaken in the Thames estuary and the caught dolphins could have been transported up to London. However, a more likely explanation is the opportunistic exploitation of stranded pilot whales.

Harbour porpoises could have been hunted in the waters of Britain, even in the river Thames itself. The fact that these animals are smaller, would have allowed the transportation of whole carcasses up to London. This may have led to an overrepresentation of this species in comparison to the larger cetaceans, where it can be assumed that the bones would have been left on the foreshore unless of course specific value was placed on the bone itself (e.g. for the production of bone artefacts or tools).

Another known actively hunted species is the North Atlantic right whale, which was frequently targeted in other areas of medieval Europe such as Normandy (Musset, 1964; Szabo, 2008). This species may have been hunted during the Anglo-Saxon Period with parts of carcasses transported to London. Though historical evidence is less strong in comparison to Normandy on the other side of the English Channel (Riddler, 1998), the large quantity of whale bone from large cetaceans deriving from excavations at Hamwic suggest such whales might indeed have been hunted off this part of the south English coast.

Fin, minke, sperm (*Physeter macrocephalus*), and killer whales were probably not hunted during the Medieval period in England because these animals are fast swimmers, were too big and aggressive, or sink after being killed, making them a poor target for medieval whalers.

Besides meat, it is possible that oil was extracted from the bones found at the medieval sites in London. One of the bones displayed signs of burning and though this can potentially be the result of cooking practices, a study by Hambrecht and Gibbons (2018) on over 3000 burned cetacean remains from Gröf, Iceland indicated that burning signs were probably associated with the usage of the bone material as a fuel source. The streets of London, as well as Birmingham and Hull, were illuminated thanks to whale oil by the mid-18th century CE (Fichter, 2019). It is possible that medieval London houses may have been lit using a similar resource, although alternatively whale bones may have been used as a supplementary fuel source or were included in refuse fires.

7. Conclusions

Zooarchaeological cetacean remains have largely remained unstudied until recently. While ZooMS has resulted in an increase in interest in cetaceans, the technique still faces problems in that it is not as precise as aDNA analysis, frequently not leading to a species level identification. This study has shown that a combination of ZooMS with osteological morphological analysis can lead to more precise identifications. In this case it has shown that a large portion of the cetacean material from Bermondsey Abbey probably stemmed from the long-finned pilot whale, potentially from just one individual.

The zooarchaeological data from London indicates that a wide variety of species were exploited. Historical sources suggest that some sort of active whaling already existed during the medieval period, however the observed species variety amongst the archaeological collections suggest that the largest part of the material probably derived from stranded individuals that were opportunistically exploited and transported to London. Reasons for cetacean exploitation might have varied

as well with the ecclesiastical order having an interest in the consumption of cetacean meat, especially that of the harbour porpoise, while specimens from non-ecclesiastical contexts frequently display signs of working, indicating that whale bone was also frequently used for the creation of artefacts and tools, such as combs and gaming pieces.

This study has indicated the wealth of information that can be extracted from the study of zooarchaeological cetacean material. Many medieval cetacean remains from the UK, as well as the rest of Europe, remain unstudied and provide a great opportunity to study medieval foodways, dietary practices, as well as to reconstruct past whaling activities. Future research should focus on the in-depth analysis of cetacean remains in order to optimize our understanding of these poorly understood animals.

CRediT authorship contribution statement

Youri van den Hurk: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft. **Kevin Rielly:** Data curation, Formal analysis, Investigation, Resources, Validation, Writing - review & editing. **Mike Buckley:** Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2021.102795>.

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