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Age and season of pig slaughter at Late Neolithic Durrington Walls (Wiltshire, UK) as detected through a new system for recording tooth wear

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ABSTRACT

The recording of tooth wear is essential for the investigation of age in zooarchaeological assemblages, but most tooth wear methodologies apply only to mandibular teeth, thereby neglecting potentially valuable maxillary data. The large sample of pig maxillary jaws and teeth recovered at Durrington Walls has provided the opportunity to design a new recording method for maxillary as well as mandibular jaws. Work on previously excavated animal bone material from Durrington Walls (Albarella and Payne, 2005) suggested the possibility of seasonal pig killing at the site, but the issue has not, until now, been explored in detail. This paper therefore has a dual purpose: to describe the new method for recording tooth wear on pig teeth; and to use the new information from both the mandibular and maxillary teeth to explore pig age at death and seasonality at Durrington Walls. The results provide evidence of differential deposition of pigs of different ages at Durrington Walls, with one midden context containing younger pigs brought to the site to provide meat for predominately winter-based feasting events, and other contexts containing remains of older pigs (mainly in their second year) deposited in both domestic and more public locales also predominantly in winter. The study highlights the usefulness of maxillary teeth for our understanding of past systems of pig exploitation as well as the desirability of recording their wear in animal bone assemblages.

1. Introduction

1.1. Methodological background

The recording of age at death is a key aspect of zooarchaeological analysis. Age can reveal a great deal about the ways that humans interacted with past animal populations, by providing information about hunting and husbandry strategies, patterns of seasonality and even the origins of domestication. Epiphysial fusion information from bones, and eruption and wear information from teeth have traditionally been used to determine age patterns in archaeological assemblages. Epiphysial fusion data are generally thought to be less precise than those from teeth, as bones are more subject to taphonomic bias, and can only provide upper and lower age limits (Bridault et al., 2000; Bull and Payne, 1982; Klein and Cruz-Uribe, 1984). Numerous methodologies have been developed to determine age at death from tooth wear (*e.g.* Benecke, 1988; Brown and Chapman, 1990; Bull and Payne, 1982; Grant, 1982; Müller, 1973; Payne, 1973), and various authors have also provided details of eruption ages (*e.g.* Boitani and Mattei, 1992; Matschke, 1967; Silver, 1969). To provide accurate ageing information, eruption and tooth wear need to be studied in combination, particularly when dealing with tooth rows. Most methods for recording tooth wear apply only to mandibular teeth and, while this may be appropriate for the study of many assemblages, the possibility of extending this type of analysis to maxillary teeth has been insufficiently explored (but see recent work by Lemoine et al. 2014). Yet this can be a valuable approach for increasing sample size, for verifying the mandibular evidence, and for analysing assemblages where maxillary teeth predominate.

For pig, the most commonly used tooth wear recording system is that of Grant (1982), although the methods suggested by Müller (1973) and Benecke (1988) are also widely used, particularly within the central European tradition. Grant's method lays out a number of stages based on the patterning of wear on the occlusal surfaces of premolars and molars. These patterns are formed as the enamel of

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the occlusal surface gradually wears away, revealing the darker coloured dentine below. Bull and Payne (1982) devised a different method applicable to both upper and lower pig teeth. This system splits the tooth into a number of parts (one, two or three, depending on the number of 'pillars' on a tooth) and records wear separately for each. It distinguishes between the initial stages of enamel wear ('j') and dentine exposure ('w'), but it lacks detail beyond the presence and absence of enamel and dentine wear, and has not been widely used. The methods set out by Müller (1973) and Benecke (1988) can also be applied to maxillary teeth but, again, lack the detail of Grant (1982) and introduce a degree of subjectivity during recording.

The common occurrence of *Sus* maxillary teeth in the animal bone assemblage previously studied from Durrington Walls was the catalyst for the development of a new system, partly based on Bull and Payne's method, which was applied to upper as well as lower teeth (Albarella and Payne, 2005: 594; Fig. 4). This modified system recorded eruption and wear in more detail than previous methods, but was never fully published.

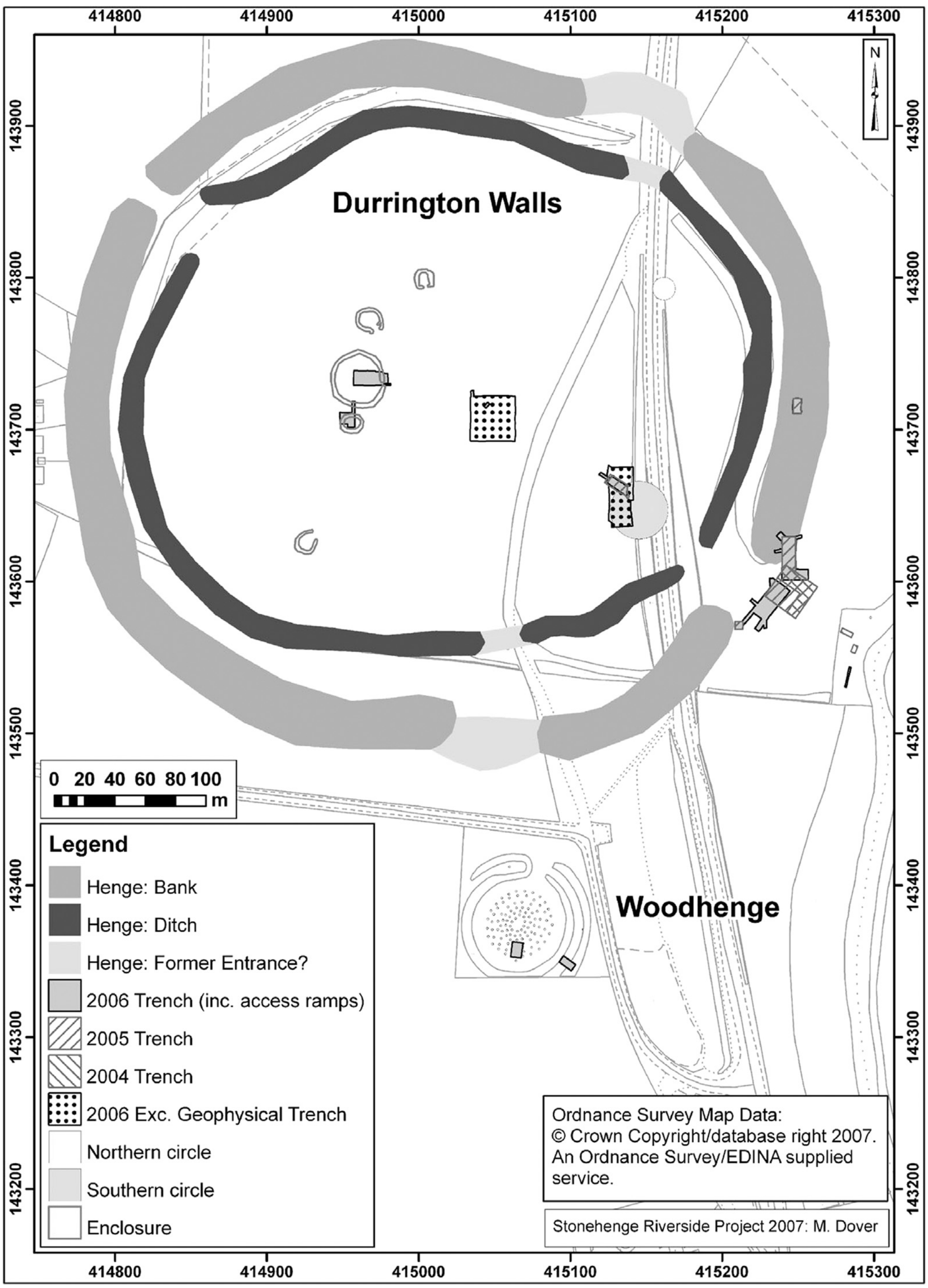


Fig. 1. Plan of Durrington Walls.

1.2. Durrington Walls research history

Durrington Walls is Britain's largest henge monument (Fig. 1). It is a nearly circular enclosure *c*.470–480 m across, surrounded by a ditch and external bank. Major excavations were carried out in 1966–1968 (Wainwright and Longworth, 1971). In 2004–2007 the Stonehenge Riverside Project carried out new excavations, revealing that the henge was built on top of a Late Neolithic settlement with a modelled date of 2515–2470 cal BC at 95% probability (Parker Pearson et al., 2011). The largest trench at the henge's east entrance revealed remains of seven houses astride a ceremonial avenue leading to the Southern Circle, one of two large timber circles (together with the Northern Circle) within the settlement's interior (Parker Pearson, 2007). Outside the houses were middens: the largest midden (context 593) was shared between five houses on the north side of the avenue, and the other midden (lower layer 886, upper layer 652) on the south side of the avenue was associated with an open-sided house positioned on the bank of the avenue. This south midden (contexts 886 and 652) is interpreted as being part of a large deposit of ash associated with more public activities taking place on and beside the avenue in front of the Southern Circle. Pits on both sides of the avenue ('special' pits) were dug and filled with special deposits of refuse, many of them at the abandonment of the houses into the floors of which they were dug (Parker Pearson, 2007: 140). The fills of these pits, along with the waste left on the floors of the abandoned houses, were most likely deposited later than the majority of the midden deposits. Amongst the copious evidence of domestic activity in the form of burnt and worked flint and animal bones, potsherds are of Late Neolithic Grooved Ware (Cleal and Mcsween, 1999). Other pit types are earlier in date. These include 'quarrying' pits, which are roughly dug out and backfilled with sparse and fragmentary finds, and 'avenue' pits, which appear to be more similar in nature to the 'special' pits, but they were found beneath the avenue and are therefore of an earlier chronology.

Faunal material from the 1966–68 excavations was initially analysed by Harcourt (1971), who identified around 8500 specimens mainly from domestic pig with smaller numbers of cattle. This assemblage composition is characteristic of Late Neolithic sites in southern Britain (Edwards and Horne, 1997; Grigson, 1982, 1999; Levitan and Serjeantson, 1999).

The bones from the 1966–68 excavations have been re-examined several times (Albarella and Payne, 2005; Albarella and Serjeantson, 2002; Richards and Thomas, 1984). The animal bone assemblage from the 2004–07 excavations has been recorded and analysed most recently by Sarah Viner-Daniels (SV-D) and Umberto Albarella (UA) as part of the AHRC-funded Feeding Stonehenge Project. The new method for recording pig tooth wear, outlined in this paper, was developed as part of Elizabeth Wright's (EW) Masters' dissertation project. This most recent analysis of the assemblage has confirmed the high proportion of maxillary teeth and has identified certain contexts in which maxillae outnumber mandibles.

Previous work at Durrington Walls (Albarella and Payne, 2005; Albarella and Serjeantson, 2002) highlighted a predominance of immature pigs (that died towards the end of their first year) from mandibular tooth wear data, whereas the data from maxillae showed a higher proportion of subadults (that died in their second year). On the basis of tooth wear, and on the assumption that most pig births would have taken place during the spring, a prevalence of mid-winter killings was suggested (Albarella and Payne, 2005), though the issue of seasonality was not investigated in detail. In addition, the relatively frequent occurrence of butchery and burning marks on bones, and their mode of deposition, was used as evidence for large-scale feasting at the site (Albarella and Serjeantson, 2002). These conclusions were based on the study of the initial animal bone assemblage excavated in 1966–1968 (Wainwright and Longworth, 1971) and needed to be compared and verified through study of the newly excavated assemblage, which provides much tighter stratigraphic and contextual information as well as forming a much larger sample.

The earlier study revealed inconsistencies in the age information obtained from mandibular and maxillary teeth, highlighting the need for both categories of data to be investigated in detail while studying the more recent assemblage.

The aims of this new research were:

- to provide a new and flexible system for recording wear on pig teeth, that could be used either in conjunction with or in place of Grant's (1982) system.
- to investigate in greater detail the issue of seasonality of pig slaughtering at Durrington Walls, to contribute to our understanding of the nature and purpose of the site (*cf* Parker Pearson et al., 2006).

Table 1
Definitions of codes used for each pillar of the dP4, M1, M2 and M3 and codes used to describe the connection between pillars on a tooth.

w1	No dentine exposure – enamel wear only
w2	Dentine exposed as one or more small unconnected area(s) on the occlusal surface
w3	Dentine exposed as a single area occupying most of the occlusal surface
w4	Enamel on part or all of the pillar edge has worn away
/	Signifies that tooth pillars are separated by an enamel bridge
-	Signifies that tooth pillars are joined by dentine exposure

Table 2
Definitions of codes used for the mandibular and maxillary P4.

Mandibular P4	
w1	No dentine exposure – enamel wear only
w2	Dentine exposed but broken by enamel into more than one area
w3	Dentine exposed and unbroken by enamel, creating one larger area of exposure
Maxillary P4	
w1	No dentine exposure – enamel wear only
w2	Dentine exposed on buccal side of tooth only
w3	Dentine exposed on both buccal and lingual sides of tooth

2. Materials and methods

2.1. Materials

The material discussed in this study derives from the most recent excavations (2004–2007) at Durrington Walls (Parker Pearson et al. 2006, 2007). All material was sieved through a 10 mm mesh, and subsequently mixed with the hand-picked finds (this was in contrast to the 1966–1968 excavations when sieving did not take place). In addition, many bulk samples were taken and were sieved separately on a stack of 10 mm, 5 mm and 1 mm sieve meshes. The recovery of a large number of loose teeth, including

Table 3
Eruption codes and definitions according to Ewbank et al. (1964).

Eruption codes according to Ewbank et al. (1964)	Description
C	Crypt
V	Tooth visible in crypt, but below bone
E	Tooth erupting through bone
H	Tooth half erupted
U	Tooth fully erupted but unworn

Table 4
List of possibilities of wear stages using the new system.

dP4 (mandibular)	P4	M1/2 and maxillary dP4	M3
E/E/E	E	E/E	E/E/E
U/E/E	U	U/E	U/E/E
U/U/E	w1	U/U	U/U/E
U/U/U	w2	w1/U	U/U/U
w1/U/U	w3	w1/w1	w1/U/U
w1/w1/U		w1/w2	w1/w1/U
w1/w1/w1		w2/w2	w1/w1/w1
w2/w1/w1		w3/w2	w2/w1/w1
w2/w2/w1		w3/w3	w2/w2/w1
w2/w2/w2		w3-w3	w2/w2/w2
w3/w2/w1		w3/w4	w3/w2/w1
w3/w2/w2		w4-w3	w3/w2/w2
w3/w3/w2		w4/w4	w3/w3/w2
w3-w3/w2		w4-w4	w3-w3/w2
w3/w3/w3			w3/w3/w3
w3-w3/w3			w3/w3-w3
w3-w3-w3			w3-w3/w3
w4-w3/w2			w3-w3-w3
w4-w3/w3			w4-w3/w2
w4-w3-w3			w4-w3/w3
w4-w4-w3			w4-w3-w3
w4-w4-w4			w4-w4-w3
			w4-w4-w4

deciduous premolars and incisors, reflects the efficiency of this retrieval method and suggests that very little material was lost during excavation.

2.2. Recording methods

Faunal material was recorded using a protocol established by UA (University of Sheffield). Mandibular tooth wear was initially recorded by UA and SV-D on part of the assemblage between 2004 and 2009 using the system set out by Grant (1982). Maxillary tooth wear was recorded on the same material by EW in 2009. The remainder of the faunal material, including both mandibular and maxillary wear, was recorded by SV-D as part the Feeding Stonehenge Project between 2010 and 2013.

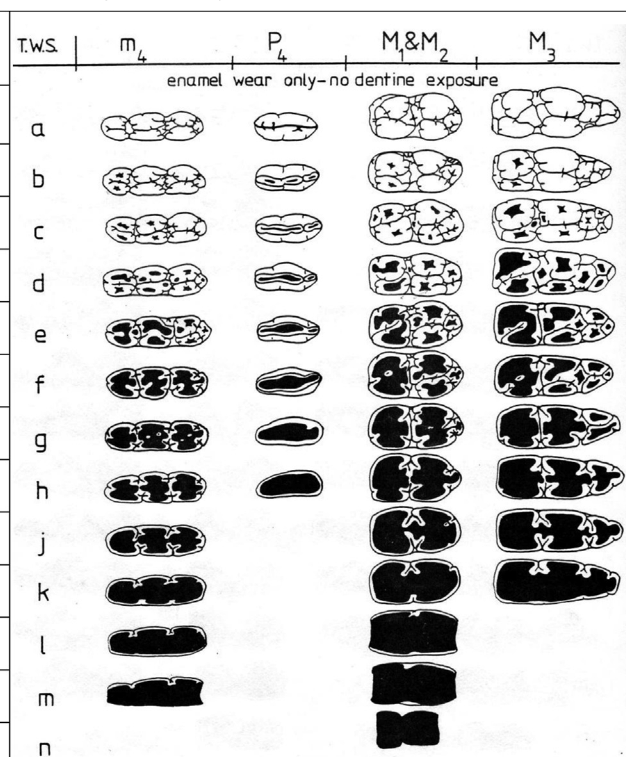
2.2.1. Description of the new system

The new pig tooth ageing system represents a substantially modified and extended version of the method employed by UA to record tooth wear during the 1990s (mentioned briefly by Albarella and Payne, 2005), and which had been previously designed by Sebastian Payne as a development of the system originally published in 1982 (Bull and Payne, 1982). The new method is applied to the maxillary and mandibular deciduous fourth premolar (dP4), permanent fourth premolar (P4), first permanent molar (M1), second permanent molar (M2) and third permanent molar (M3), the same teeth used by Grant (1982). The method separates each tooth into one, two or three 'pillars' (*sensu* Bull and Payne, 1982; Grant, 1982) depending on the tooth. Each pillar of a tooth, and the connection between pillars, is given a code depending on its state of wear, resulting in a detailed record of the level of wear on each particular tooth. The system does not rely on a visual illustration of the occlusal surface of the tooth (in the way Grant's (1982) system does) but rather on a description of the details of the wear stage (in a similar fashion to Payne's system [1973; 1987] for sheep/goat).

In mandibular teeth the P_4 has one pillar, the M_1 and M_2 have two pillars each, and the dP_4 and M_3 both have three pillars. In maxillary teeth, the P^4 has one pillar, the dP^4, M^1 and M^2 have two pillars each, and the M^3 has three pillars. Depending on the level of wear and the dentine exposure that is observed, each pillar is given

Table 5
Direct equivalents for Grant's (1982) stage and images showing the Grant stages (taken from Grant, 1982). The 'm4' is Grant's terminology is the same as the 'dP4' as defined in this paper., but note that not all Grant's stages have a separate wear code according to the new system, as this is not based on a match with an illustration.

dP4	P4	M1/2	M3
w1/w1/w1	w1	w1/w1	w1/w1/w1
w2/w1/w1	w2	w2/w1	w2/w1/w1
w2/w2/w1	w2	w2/w2	w2/w2/w2
w2/w2/w2	w2	w2/w2	w2/w2/w2
w3/w2/w2	w2	w3/w2	w3/w2/w2
w3/w3/w3	w3	w3/w2	w3/w2/w2
w3/w3/w3	w3	w3/w3	w3/w3/w2
w3/w3/w3	w3	w3/w3	w3/w3-w3
w3-w3-w3		w3-w3	w3-w3-w3
w3-w3-w3		w3-w3	w3-w3-w3
w3-w3-w4		w4-w4	
w4-w4-w4		w4-w4	
		w4-w4	



a code from the lowest level of wear (w1), to the most advanced wear (w4). Table 1 contains details of the codes used. Due to the differing morphology of the upper and lower fourth premolars, the codes used have different definitions depending on whether the tooth is from the upper or lower jaw (as set out in Table 2).

The connection between the different pillars of a tooth is coded by either '/' (separation of the pillars by an enamel bridge), or '-' (the pillars are joined by dentine; see Table 1). Pillars that cannot be assigned to a wear stage due to damage of the tooth are marked as 'X'. Eruption stages set out by Ewbank et al. (1964) (Table 3) can be used in conjunction with these wear stages only if part of a tooth is fully erupted, *e.g.* w1/w1/U. This is most applicable to the eruption stages 'U' and 'E' and applies most commonly to the third molar.

Wear is normally most advanced on the anterior pillar since this part of the tooth erupts first (Grant, 1982: 95), and the list of possible wear stage combinations (shown in Table 4) assumes this pattern. However, the system can be adjusted to account for heavier wear seen on the posterior pillar (*e.g.* 'w2/w3'), as is encountered occasionally. In this way the system can take into account anomalies in tooth wear in a way that the Grant (1982) system cannot. Direct equivalents to Grant's (1982) stages are presented in Table 5. Jaws with two or more recordable teeth in the dP4/P4-M3 range were used. Jaws containing one tooth were only used when the tooth present was the furthest back erupted in the jaw (*i.e.* if it was possible to directly assign the jaw to an age group using the method of O'Connor (1988)): that is, if it was a third molar, or a younger animal with a second or first molar where the other molars had not yet erupted.

It is important to note that, as for Grant's (1982) method, the intervals that occur between each of the wear stages outlined here do not represent equal intervals in time. Some stages last for a short period of time, but some last for much longer, for example wear stage w2/w2 is relatively long-lasting.

2.3. Application of the new system to pig teeth from Durrington Walls

The method described above was applied to all jaws from Durrington Walls, as well as to all relevant loose teeth (i.e. dP4/P4 – M3) encountered within the assemblage. The resulting data underwent a process of data analysis comprised of two stages: age at death and seasonality.

2.3.1. Age at death

When possible, both mandibular and maxillary jaws were directly assigned to an age stage according to O'Connor (1988, 2003) (see Table 6). For this to be possible, the tooth furthest back in the jaw had to be present. This would be the third molar in a fully developed dentition, or any other tooth depending on the developmental stage of the jaw (in a foetal jaw even the dP4 may represent the most posterior tooth). No loose teeth were used in this analysis.

In order to utilize as many jaws as possible, a method was devised to assign ages to specimens that could not be attributed to an age stage under O'Connor's system. Wear stages from the directly aged jaws were put into four charts (one each for dP4, P4, M1, M2; the M3 is not included as any jaw with an M3 could be assigned to a stage anyway) showing their wear stages according to Grant's system and their age stage following O'Connor's system. Charts were produced for both mandibular (Tables 7–8) and maxillary (Tables 9–10) teeth. Mandibular charts show Grant's (1982) wear stages and their equivalents according to the new system in the left hand column. Maxillary charts show new system stages only. These charts were then used to assign the jaws that could not be directly attributed to O'Connor's (1988) age categories by matching the tooth wear stages with the corresponding age category (*cf* the method used by Payne, 1973 to assign ages to sheep/goat jaws) and selecting the overlapping age stages. For instance a mandible with an M1 at Grant's stage 'g' (subadult/adult) and an M2 at Grant's stage 'f' (adult) would be assigned to the age stage of 'adult', as this is the overlapping age category. Only jaws that had two teeth with recordable eruption or wear were selected for such estimates. Overall 385 mandibles and 447 maxillae could be attributed to one of O'Connor's age categories. Raw data are provided in Supplementary material 2.

Table 6
Age categories for pig jaws, as set out by O'Connor (1988, 2003).

Age category	Description
Neonatal	DP4 unerupted, or just in the process of eruption
Juvenile	DP4 in wear, M1 not in wear
Immature	M1 in wear, M2 not in wear
Sub-adult	M2 in wear, M3 not in wear
Adult	M3 in wear
Elderly	Dentine exposure to or beyond stage j (*sensu* Grant, 1982)

2.3.2. Seasonality

2.3.2.1. Evidence for seasonality using Grant's (1982) Mandibular Wear Stages. Mandibular Wear Stages (MWS) (Grant, 1982) may highlight seasonal peaks in the slaughter of domestic animals (Ervynck, 1997, 2005). The MWS system is therefore a useful starting point for investigating seasonality at Durrington Walls. Mandibular jaws were assigned an MWS using Grant's system (1982). Those jaws that did not contain the full set of teeth required to assign an MWS directly were given an estimated MWS using the list of directly assigned jaws from this and previous studies (*e.g.* Albarella and Payne, 2005); jaws were arranged by order of age, and

Table 7
Deciduous and permanent fourth premolars molars at different stages of wear, from directly assignable mandibular jaws of different age groups according to O'Connor (1988).

	Juvenile	Immature	Subadult	Adult
dP4				
a (w1/w1/w1)				
b (w2/w1/w1)				
c (w2/w2/w1)	*			
d (w2/w2/w2)		****		
e (w3/w2/w2)		********************		
f (w3/w3/w3)		************	*	
g (w3/w3/w3)		******	*	
h (w3/w3/w3)		*		
j (w3-w3-w3)		***		
k (w3-w3-w3)				
l (w3-w3-w4)		*****		
m (w4-w4-w4)		*		
n				
P4				
a (w1)			***	*
b (w2)			**********	*******
c (w2)				********
d (w2)				****
e (w2)			*	**
f (w3)				*
g (w3)				*****
h (w3)				
j				
k				
l				
m				
n				

Table 8
First and second molars at different stages of wear, from directly assignable mandibular jaws of different age groups according to O'Connor (1988).

	Juvenile	Immature	Subadult	Adult
M1				
a (w1/w1)		*****		
b (w2/w1)		************************		
c (w2/w2)		**********************************	******	
d (w2/w2)		*****************	**************	***
e (w3/w2)		****	********	***********
f (w3/w2)			****	****
g (w3/w3)			*****	*******
h (w3/w3)			*	***
j (w3-w3)			***	****
k (w3-w3)				****
l (w4-w4)				****
m (w4-w4)				****
n (w4-w4)				*
M2				
a (w1/w1)			***********************	
b (w2/w1)			*******	*
c (w2/w2)			****************	********
d (w2/w2)			**	**************************
e (w3/w2)			*	**************
f (w3/w2)				*********
g (w3/w3)				***
h (w3/w3)				
j (w3-w3)				***
k (w3-w3)				
l (w4-w4)				*
m (w4-w4)				*
n (w4-w4)				

mandibles were assigned according to where they fell in the sequence.

Peaks in MWS data were interpreted by comparison with data from Ervynck (1997, 2005), who had identified peaks in the sequence, which he attributed to seasonal events. This method has previously been criticised due to potential biases that may arise from the unequal lengths of different MWSs (*e.g.* O'Connor, 2003; but see Ervynck, 2005 for a more detailed discussion). However, since the MWS is made up of the sum of wear stages from more than one tooth (the higher the MWS the more teeth involved) a number of different tooth combinations can result in the same MWS. This should have a dampening effect on any biases that arise (Ervynck, 2005). In addition, a previous study that measured crown height, in an attempt to link time lengths with tooth wear stages, has shown that there is no major variation in individual TWS length (Tams, 2002). Consequently, it seems unlikely that MWS results have been greatly biased by variable duration of the tooth wear stages (TWS).

Table 9
Deciduous and permanent premolars, and first and second molars, at different stages of wear from directly assignable maxillary jaws of different age groups according to O'Connor (1988).

	Juvenile	Immature	Subadult	Adult	Elderly
dP4					
w1/w1					
w2/w1	**	***			
w2/w2	*	***************************			
w3/w2		***			
w3/w3		**			
w3-w3		*****	*		
w4/w3					
w4-w3					
w4-w4					
P4					
w1			****	*	
w2			********	******************	
w3			***	*	*

The season of death was determined by referring to known eruption ages of pigs. There are a number of different studies that have provided eruption ages for pig teeth (*e.g.* Higham, 1967; Magnell and Carter, 2007; Matschke, 1967; Silver, 1969; see Legge, 2013 for a discussion and critique of these). Most of these studies have dealt with modern domestic animals. In the study of pigs from medieval Vilvoorde, Ervynck used tooth eruption ages for wild boar taken from Matschke (1967) on the assumption that primitive medieval pig breeds were likely to have tooth eruption timing more comparable with wild boar than domestic pigs. This is also an assumption that can be made for the Late Neolithic pig population from Durrington Walls. In fact, Legge's (2013) review of pig tooth eruption studies has shown that there is no consistent shift in tooth eruption timings between groups of domestic, feral, captive wild and free wild animals, and so perhaps this selection is not necessary. That said, tooth eruption stages from Matschke (1967) (see Table 11), have also been used in this study as these are considered to be the most reliable (Legge, 2013). Raw data are provided in Supplementary material 3.

2.3.2.2. Evidence of seasonal killing by comparison with modern specimens. Maxillary tooth wear data cannot be used to determine MWS and, therefore, a further study was made of modern specimens with known age at death. One of the major issues when interpreting MWS is the difficulty of relating wear stages to the real age of an animal (Ervynck, 1997, 2005). In this part of the study, wear patterns from archaeological specimens were compared to modern specimens of known age. A number of studies (*e.g.* Halstead, 2005; Rowley-Conwy, 1993, 2001; Rowley-Conwy and Stora, 1997) have determined season of death according to the dental developmental stages described by Higham (1967). The descriptions of the wear stages provided by Higham refer to 'primary', 'secondary' and 'tertiary' eruption and wear, but neither

Table 10
First and second molars, at different stages of wear from directly assignable maxillary jaws of different age groups according to O'Connor (1988).

	Juvenile	Immature	Subadult	Adult	Elderly
M1					
w1/w1		*******			
w2/w1		*************	*		
w2/w2		********************	**********************************	***********	
w3/w2			*	***	
w3/w3			**	******	
w3-w3			*	******	
w4/w3					
w4-w3					
w4-w4				*****	*
M2					
w1/w1			*****		
w2/w1			********	****	
w2/w2			*************	**	
w3/w2				******	
w3/w3				****	
w3-w3				***	
w4/w3				**	
w4-w3					
w4-w4					*

Higham nor the paper he uses as a source (Silver, 1963) provide clear definitions of these terms. Because of this problem, it was decided to use ages from an assemblage of pig mandibles of known age that were assigned to Grant's wear stages.

A combination of wild and unimproved modern specimens from a collection at the Museum for the Study of Domestic Animals in Halle, Germany, was used for this comparison (data collected by UA). In addition, aged pig jaws from skeletons held by the English Heritage Vertebrate Skeleton Reference collection (http://www.english-heritage.org.uk/publications/vertebrate-skeleton-reference-collection/), and recorded by Sylvia Warman from the Hakel collection (at the Erbeswalde Forestry Institute, Germany) were also included (Warman, 2000: digital appendix C) (see Supplementary material 1). Because tooth wear becomes more varied in older animals (Matschke, 1967), those over 24 months of age were omitted. The modern jaws were arranged by age and, by comparison with these specimens, the Durrington Walls mandibles were assigned ages depending on where they fell in the sequence. So that maxillary wear data could be used, the original wear stages (using the Grant system) were converted into the new system of codes.

Previous research has indicated that dental attrition of the mandibular and maxillary first molars may vary by up to two wear stages (Rolett and Chiu, 1994), but this was based on data from just one pig, so it is unclear whether these differences would be present across a whole population. Other studies, analysing larger samples, have found little difference in the eruption times of teeth in the upper and lower jaw (*e.g.* Lemoine et al. 2014 Matschke, 1967). Given this evidence it can be assumed that, although the eruption and wear of mandibular and maxillary teeth might vary to a small degree, there is no reason to assume any great difference in eruption, and therefore wear, of upper and lower pig teeth.

Each jaw was assigned a season according to its predicted age: winter = December–February, spring = March–May, summer = June–August, and autumn = September–November. Raw data are provided in Supplementary material 4.

Table 11
Tooth eruption ages according to Matschke (1967).

Tooth	Eruption age (months)
M1	5–6 (6)
M2	12–14 (13)
M_3	23–26 (25)

2.3.2.2.1. The issue of multiple farrowing. In temperate Europe, wild boar litters are most commonly born in March and April (*e.g.* Brownlow, 1994: 199; Lauwerier, 1983; Magnell, 2006: 76; Nowak, 1999: 1057) with the exception of occasional and unusual situations. Even in the Mediterranean area, where seasonal constraints can be different, spring births are reported as the most common (Bull and Payne, 1982, 57; Fernández-Llario and Carranza, 2000, 337; Toschi, 1965, 433). Thus, for the purpose of this research, birthing in British Neolithic pigs is nominally assumed to have taken place on the first of April.

Multiple farrowing is dependent on a number of conditions, including abundance of food supply, and would require technological knowledge of methods of herd improvement to encourage it in domestic animals (Albarella et al. 2007, 2011; Lauwerier, 1983). It is more likely within domestic rather than wild populations but is highly dependent upon the type of management regime adopted for the pigs. Historical sources provide evidence that, by the Roman period, these conditions had indeed occurred, but that multiple farrowing did not take place everywhere (White, 1970). Even in recent times, unimproved pig breeds would only farrow once a year if no abundant food supply was available (Albarella et al. 2011). During the Late Neolithic pigs are generally thought to have been herded in forest environments, probably in a 'free-range' way (Benecke, 1994) and isotopic analysis of diet has provided evidence that Early Neolithic pigs relied on woodland resources (Hamilton et al. 2009). Rearing pigs intensively, or at a household level, is not likely during the Neolithic period. At Durrington Walls the lack of pigs that died at a very young age, as revealed by current work on the assemblage, suggests that pigs were not giving birth on site, and supports the idea that these pigs were subject to free-range herding offsite. Ethnographic studies show that herded pigs are much less likely to have farrowed more than once per year than pigs kept at a household level (*e.g.* Halstead and Isaakidou, 2011) and early medieval Belgian sites where free-range pig herding is likely to have been in place provide evidence that is consistent with single farrowing in any one year (Ervynck et al. 2007). Overall, the evidence suggests that British Neolithic pigs would have had a reproductive cycle more comparable to wild boar than improved, artificially-fed domestic pigs. Single farrowing in spring therefore represents the most likely scenario for the Durrington Walls population.

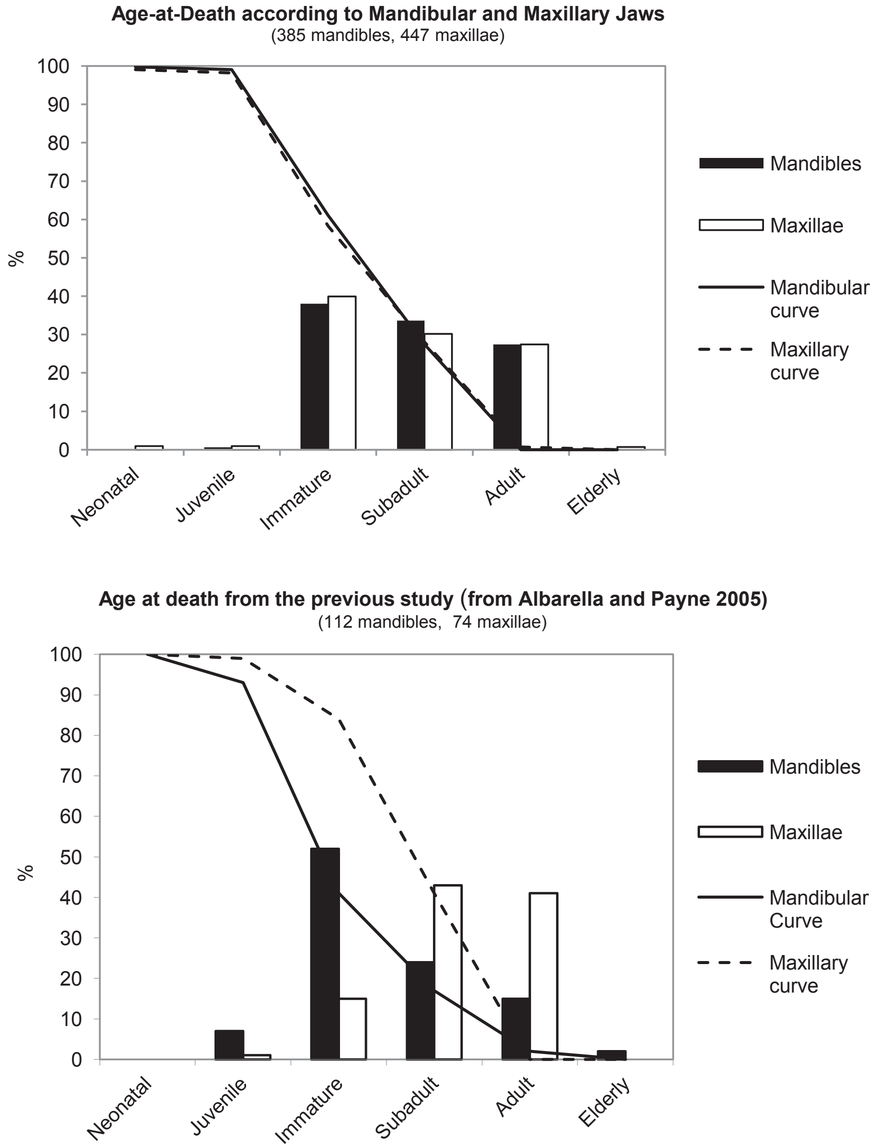


Fig. 2. Age at death of pigs from Durrington Walls from the 2004–07 excavations (top) and the 1966–68 excavations (bottom) using age categories after O'Connor (1988).

3. Results

3.1. Age at death

The large sample size provided by the most recent Durrington Walls assemblage, along with the use of a new recording system, provides more consistent results from pig mandibles and maxillae compared to the 2005 study (Fig. 2). Generally, the pattern from pig mandibles is similar between the two studies (with a tendency towards younger animals in the earlier study), but the evidence from the maxillae provides results that are substantially different, thereby demonstrating the benefit of working on a larger and more thoroughly collected animal bone assemblage. Due to greater sample size and more thorough recovery, the more recent investigation can be considered the more reliable. This also resolves the intriguing difference in age between upper and lower jaws that was identified within the earlier assemblage; this can now be considered as either the likely consequence of selective curation or the effect of recovery bias, or a combination of both.

Both upper and lower jaws indicate the killing of large numbers of immature pigs, followed by slightly smaller numbers of subadult and adult animals. Neonatal, juvenile and elderly stages are scarcely represented.

When material from midden deposits is examined, the pattern from the overall assemblage is maintained, with immature animals dominating, followed by subadult and adult animals (Fig. 3). Fig. 4 demonstrates the impact that midden context 593 has on both the overall midden pattern and the overall site pattern, with mandibles and maxillae from this context far outnumbering those from other middens. In fact, 593 makes up about 40% of the pig jaw assemblage from the whole site. Contexts 652 and 886 (both from the only other midden context with sample sizes large enough to provide useful results) come from a midden south of the avenue and show very different patterns to context 593, the midden located north of the avenue. Both of these contexts from the south midden contain a larger proportion of subadult and adult animals, and context 886 (a layer below 652) contains an especially low proportion of immature animals. Both these contexts show a greater disparity between mandibular and maxillary results than context 593, but sample sizes here are relatively small, which may affect the results.

Pit contexts (most of which contain Grooved Ware pottery) display an older kill-off pattern than midden 593, with more

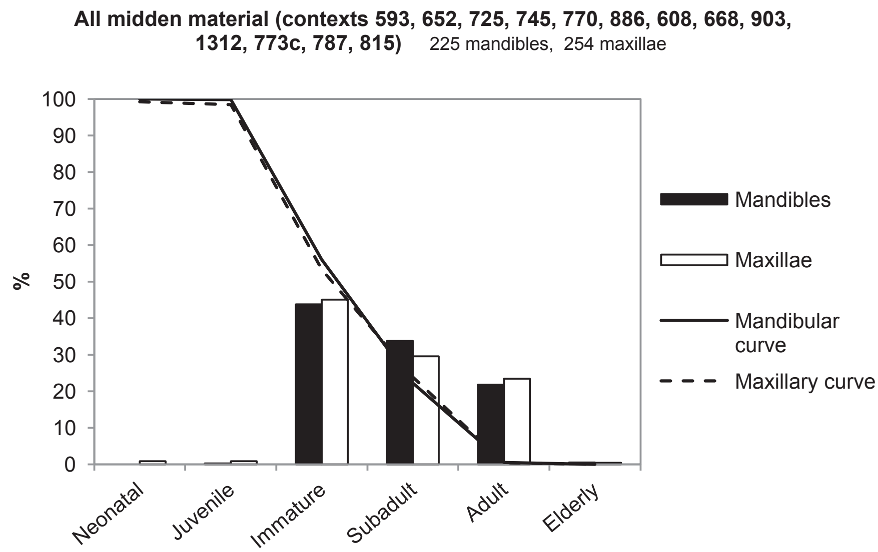


Fig. 3. Age at death of pigs from all midden contexts at Durrington Walls.

subadult and adult than immature pigs (Fig. 5). Most pig jaws derive from so called ‘special’ pits (>70%), with smaller numbers from ‘quarry’ and ‘avenue’ pits. The pattern displayed by the pit contexts is more similar to that seen in midden context 886, but the sample from the pits is larger and therefore more reliable. Results from all of the different pits types have been combined in this paper, because splitting them reduces the sample size considerably, making the evidence insufficiently reliable.

House floors contained relatively few jaws compared to the midden or pit contexts (Fig. 6), and there were few mandibles. The larger maxillary sample displays a pattern similar to that seen in the overall assemblage, and in midden context 593, although the proportion of subadult animals here is similar to that of immature animals. The disparity in the number of mandibles and maxillae here demonstrates the importance of the ability to use information from maxillary jaws – a sample size of 26 maxillae is enough to display a similar pattern of killing to that observed in the midden contexts.

The difference between midden and pit patterns was tested statistically using a Pearson's Chi-Squared test. The comparison between the north midden (context 593) and the south midden (652 and 886) was not statistically significant for either mandibles or maxillae. However, when 593 was compared with pit contexts, this did produce a significant result for both upper and lower jaws (see Table 12).

The overall predominance of immature animals is indicative of their selected slaughtering for food and is consistent with expectations for a site mainly characterised by consumption. The almost complete lack of neonatal and juvenile remains – despite extensive sieving – is consistent with off-site breeding. Midden context 593 contributes considerably to the overall site pattern, and contrasts with assemblages from pits that are, instead, dominated by animals killed at an older age. It is expected that meat yield would be most efficiently balanced against the amount of food required by an animal in the subadult group. Modern domestic pigs reach their full weight at about 1 ½ years (*c.* 18 months) (Lawrence and Fowler, 2002), but this is after a long period of stock improvement aimed at accelerating maturity. Neolithic domestic pigs, it can be assumed, matured more slowly. The immature age category is considered to represent animals of around a year old, or just over (O'Connor, 2003: 161). Therefore animals deposited in pit contexts were more likely to have been allowed to reach their highest meat yield, more so than those from the north midden (context 593). This has interesting implications for the interpretation of different types of deposition contexts at Durrington Walls.

3.2. Seasonality

Mandibular wear stages (after Grant, 1982) have been used elsewhere to provide evidence of seasonality in archaeological pig assemblages (Ervynck, 1997, 2005). Only mandibles can be used by this method, but it does provide the first step in our study of seasonality. MWS stages were assigned for both full (directly attributable) and incomplete (estimated) sets of teeth. The inclusion of estimated MWS both provides a larger sample size and avoids the risk of bias against those cases of mandibular wear that may be more difficult to attribute directly to a particular stage. Results from the previous analysis of animal bones from Durrington Walls (Albarella and Payne, 2005) have been included for comparison (Fig. 7).

The MWS pattern from the 2004–2007 excavations shows three peaks, the first at an MWS value of 9, the second at 17 and the third at 25. This pattern is found in both the directly attributed and estimated mandibles, though it is better defined in the latter. This suggests three killing events at three different age stages. The tailing off of this pattern is likely to reflect the increased variation in tooth wear among older animals. In the sample from the 1966–1968 excavations (Fig. 2: from Albarella and Payne, 2005) the first peak is in a similar position (although perhaps very slightly later) to that seen in the more recent, larger sample, but other peaks are not visible. This could result not only from the smaller sample size but also from potential biases in taphonomy, recovery and curation of the 1966–1968 assemblage that are difficult to evaluate (*cf* Albarella and Serjeantson, 2002).

The peaks in MWS displayed by the overall Durrington Walls dataset fall in almost exactly the same places as those at Medieval Vilvoorde, (from Ervynck, 1997). Ervynck attributes the three peaks at Vilvoorde to first, second and third winter killings, an interpretation that may also be applicable to Durrington Walls.

Differences between midden and pit contexts can clearly be seen in the MWS graphs (Figs. 8 and 9). The first winter peak is predominant in context 593 and the second winter peak is most pronounced in the pit contexts. The first peak represents those animals from the immature age group and the second peak, those

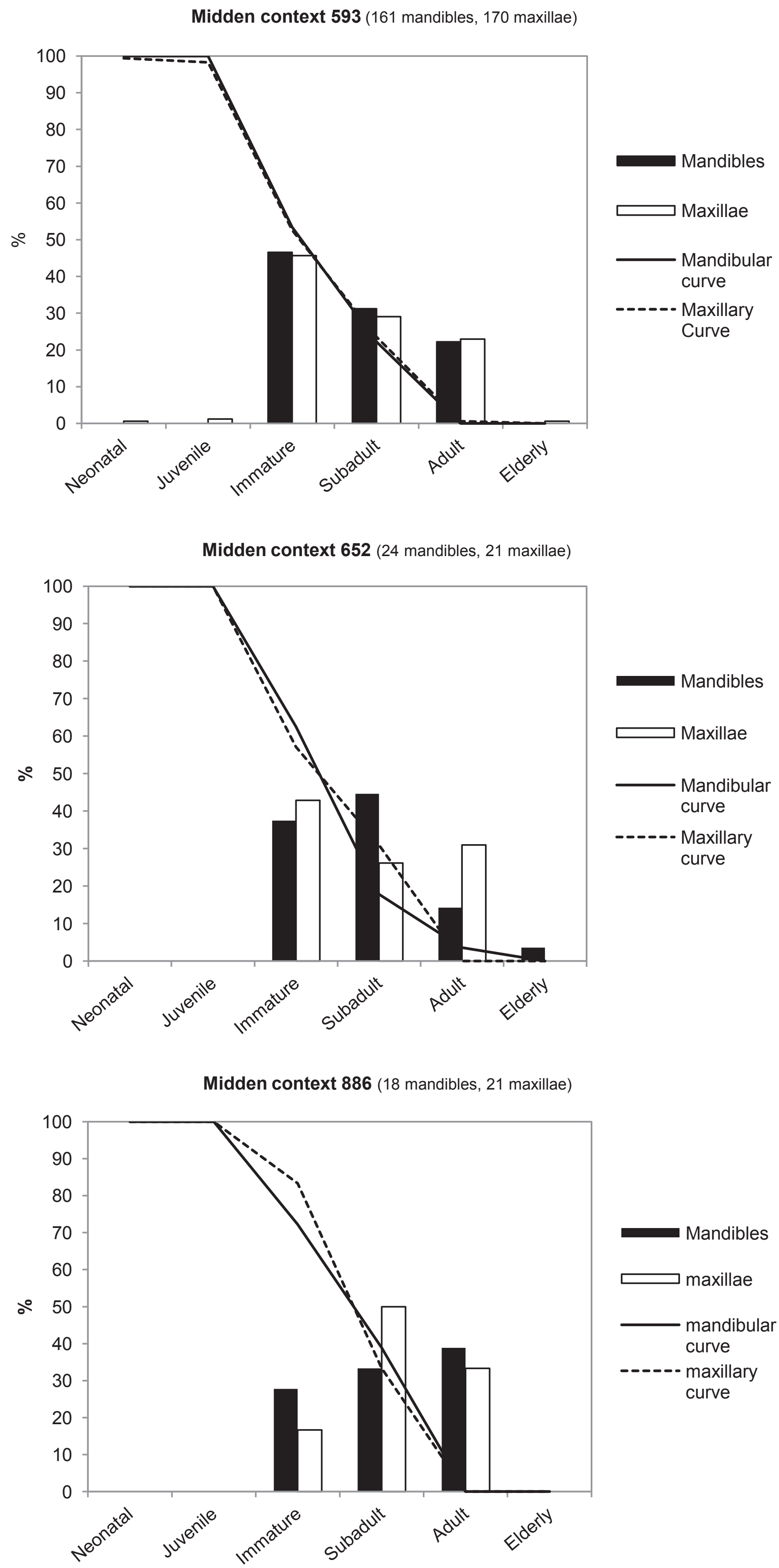


Fig. 4. Age at death of pigs from individual middens at Durrington Walls.

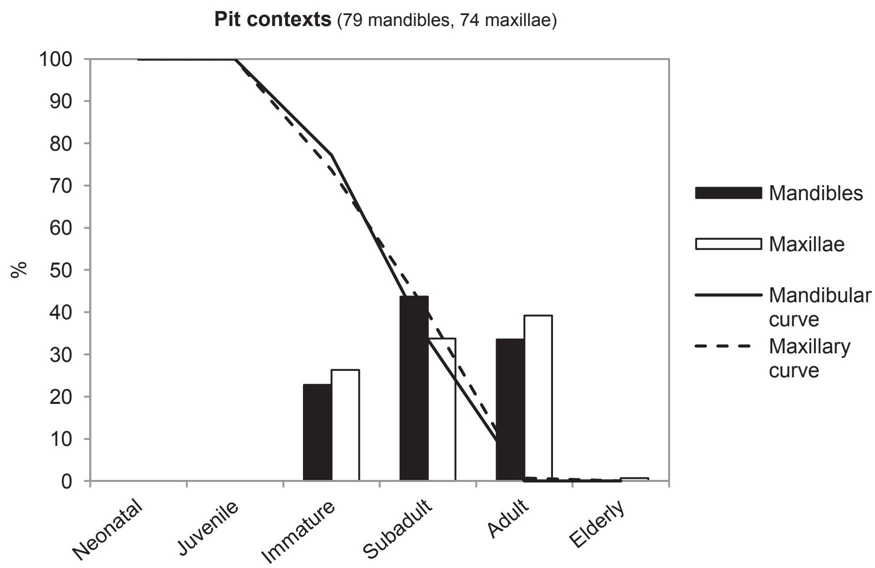


Fig. 5. Age at death of pigs from pit contexts at Durrington Walls.

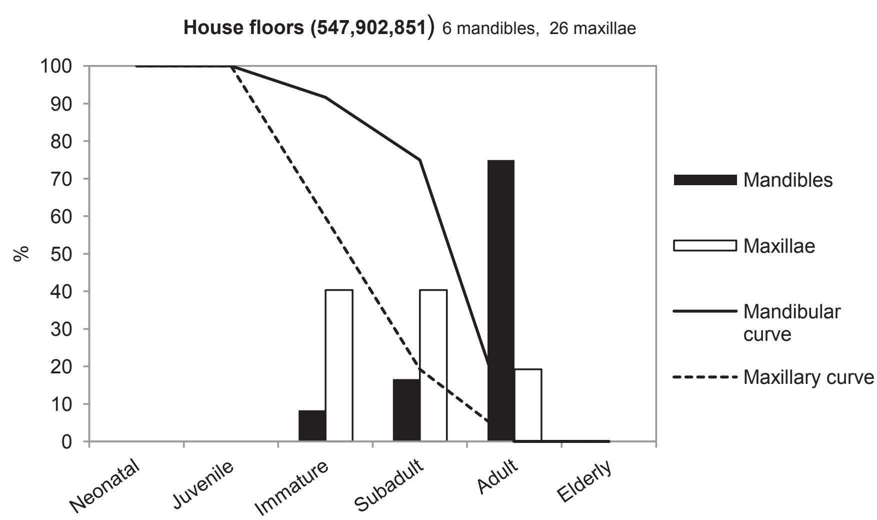


Fig. 6. Age at death of pigs from house floor contexts at Durrington Walls.

animals from the subadult group. This pattern therefore fits well with the results of age at death. There is nothing in the MWS results to suggest that multiple farrowing ever occurred among the pig population at Durrington Walls: the peaks are clear and unaffected by variation that would be expected if multiple farrowing was taking place (Ervynck, 1997, 2005).

Fig. 10 plots the season of death for both mandibles and maxillae, as estimated from reference material of known age. There is a killing peak during the first autumn and winter, followed by steadier killing between seasons during the second year. First-winter slaughter would account very well for the evidence that has been presented for both age at death and MWS. However, there is no sign of a peak in slaughter during the second winter, in contrast to the MWS results.

Again, the north midden (context 593) displays a pattern similar to that found at the site overall (Fig. 11). The only difference is that 593 has slightly lower proportions of killing during the second year, which are consistently under 10% for all seasons. The pattern from context 652 (upper layer of the south midden) broadly follows that of 593, whereas that of 886 (lower layer of south midden) displays a much more even pattern across the whole time period; however, their sample sizes are small and must therefore be treated with caution.

Pit contexts display a different pattern to all other contexts shown here (with the possible exception of 886); the proportion of killing in the second year is considerably higher, (Fig. 12). During

Table 12
Results of Pearson's Chi Squared test comparing midden and pit contexts. Significant results are indicated using an asterisk ('*').

	Value	Significance
Mandibles		
593 *vs* 652 & 886	2.299	0.317
593 *vs* Pits	13.127	0.001*
Maxillae		
593 *vs* 652 & 886	3.857	0.145
593 *vs* Pits	9.572	0.008*

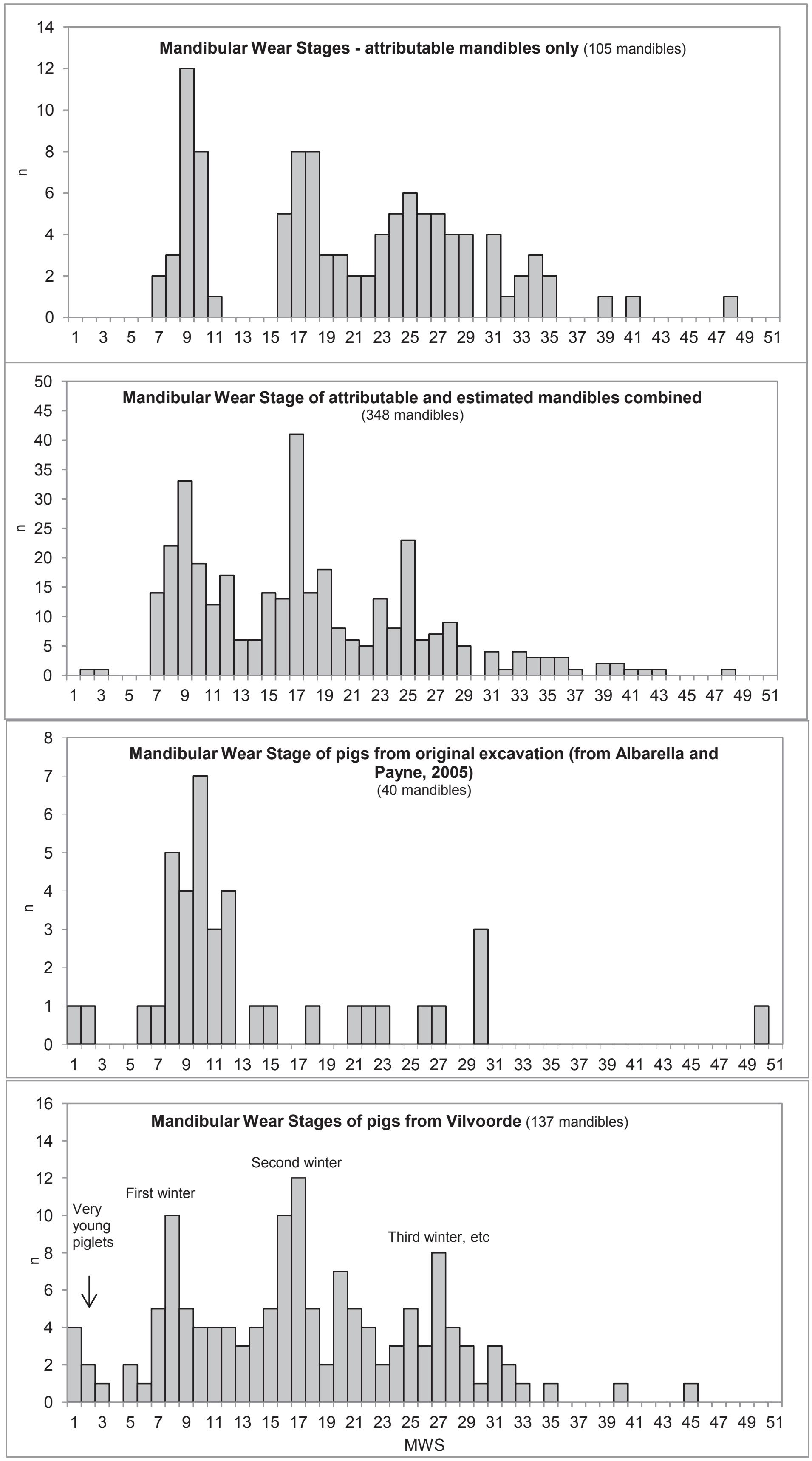


Fig. 7. Mandibular wear stages from directly attributable and estimated jaws from the most recent excavations at Durrington Walls (top two diagrams), from the original Durrington Walls study (third diagram) and from Medieval Vilvoorde (bottom diagram – reproduced from Ervynck 1997 – note that this diagram displays raw MWS counts, rather than the running mean, as displyed in the 1997 paper).

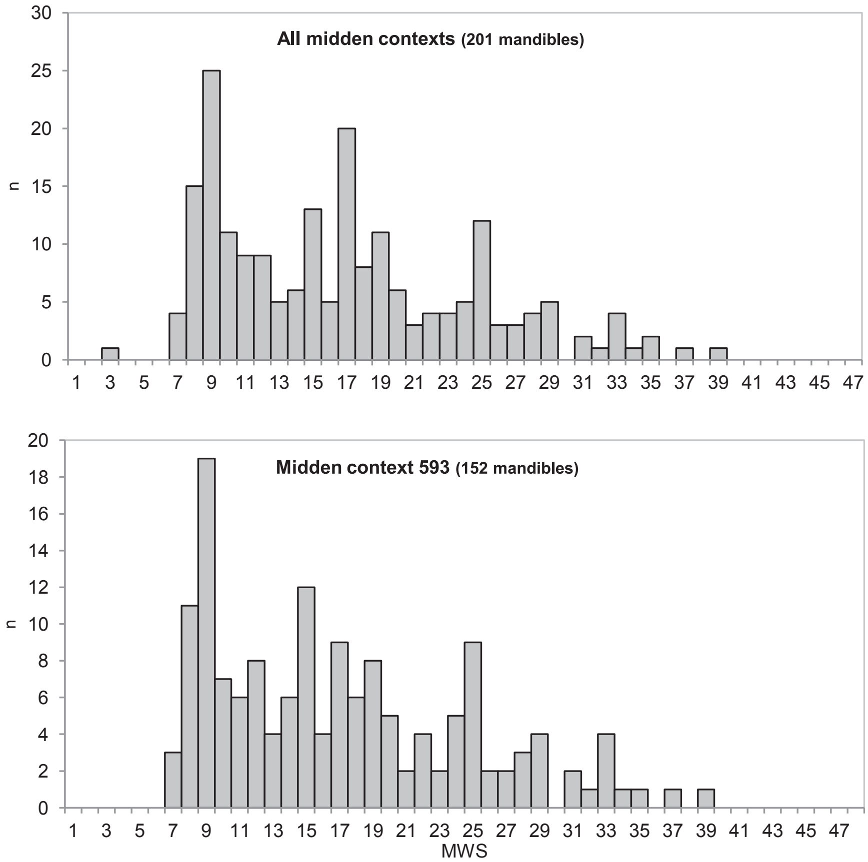


Fig. 8. Mandibular wear stages from both directly attributable and estimated jaws from midden contexts at Durrington Walls.

the first year the killing peak is in the winter, which is a similar to the pattern seen in midden 593, but in the second year the killing is spread out across a longer period and there is a less clear peak. The second year peak is not as clear as might be expected, given its clear signal in the MWS results, but this is likely to be related to increased variation in tooth wear in the second year compared to that of the first year.

Pit contexts show a consistently different pattern to middens (and particularly context 593) in all stages of this analysis. Midden contexts, the sizes of which greatly affect the overall assemblage pattern, indicate a predominance of immature animals killed in the first autumn and winter of their life, before the animals would have produced their highest meat yield. In contrast, pit contexts show a predominance of subadult animals in their second year, consistently older pigs than those deposited in midden context 593.

Mandibular and maxillary jaws display very similar patterns, except where there are large differences in sample size, but the presence of larger samples of maxillae (*e.g.* in the house floor contexts) demonstrates the value of including information from these jaws as well as from the mandibles. In addition, they provide a useful counterpoint for the pattern obtained from mandibles alone, especially because mandibles and maxillae could have been

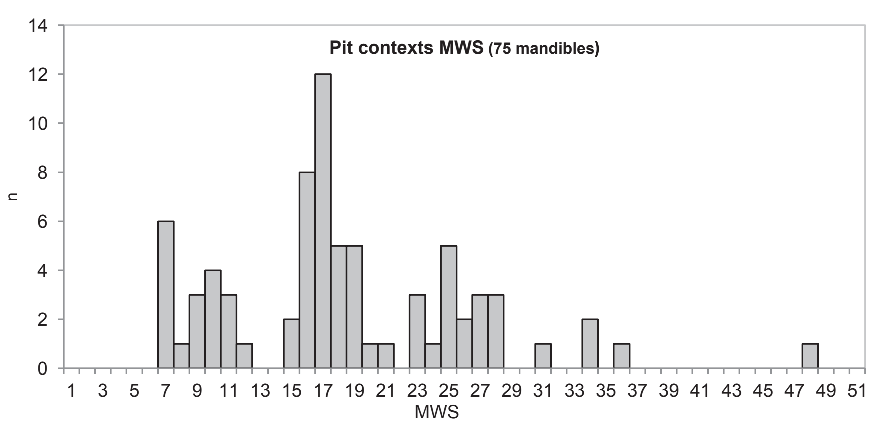


Fig. 9. Mandibular wear stages from both directly attributable and estimated jaws from pit contexts at Durrington Walls.

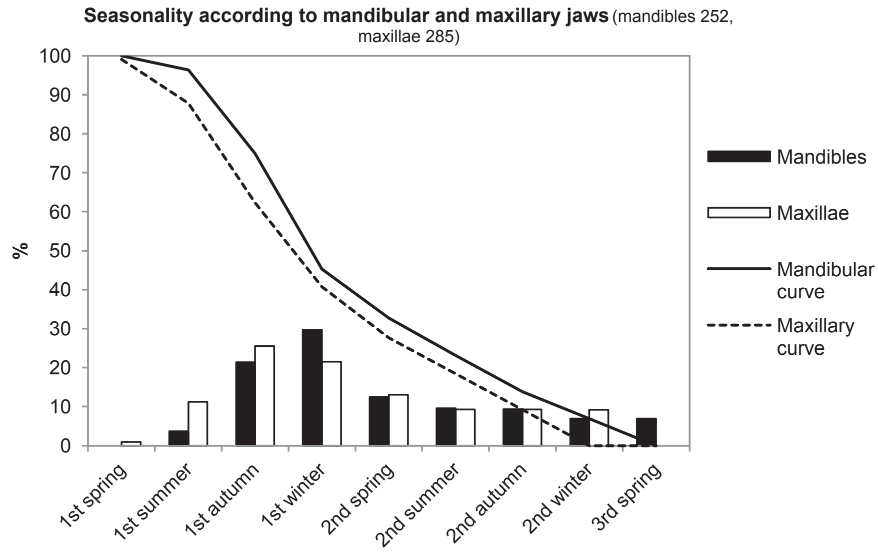


Fig. 10. Season of death of pigs based on mandibular and maxillary tooth wear during the first two years of life (seasons from each year are shown separately, and all Durrington Walls contexts are included).

subjected to different taphonomic processes. The similarity between mandibular and maxillary patterns demonstrates that the new recording method is compatible with that of Grant (1982).

4. Discussion

4.1. Age at death and seasonality at Durrington Walls

This study indicates that a large proportion of the Durrington Walls pigs were slaughtered during their first winter before reaching their optimal meat yield size, a pattern that is particularly clear among the jaws deriving from middens, and especially from the north midden (context 593). Pit contexts provide a consistently different pattern to middens; although their pig remains still emphasise winter killing, they derive predominantly from animals that died in their second year when they would have reached their peak.

There are a number of economic benefits to killing pigs in the winter. European historical sources from the Middle Ages (c.AD 1000–1500) reveal that pigs were killed mainly during the winter after being fattened on rich autumn food, and before any loss of body mass during the winter (Albarella, 2006; Ervynck, 2005). Ethnographic work in Sardinia and Corsica has indicated that pig breeders prefer to slaughter in the winter before food shortages begin (Albarella et al. 2007, 2011). These economic benefits are worth bearing in mind, and could have played some role in the overall kill-off pattern, but they do not explain the differentiation of the deposition areas of pigs killed at different ages. Archaeologically, the evidence is less clear-cut but, although on a small sample size, winter pig slaughtering has been suggested for Late Neolithic Rudston Wold, Yorkshire (Rowley-Conwy and Owen, 2011), in addition to the medieval cases discussed by Ervynck (1997) mentioned above.

An alternative – or perhaps additional – interpretation is related to the ceremonial function of Durrington Walls (*e.g.* Albarella and Serjeantson, 2002; Parker Pearson et al., 2011). Evidence of regular patterns of butchery and burning, rapid burial of bones and the differential treatment of certain remains has led to the interpretation of the assemblage as the remains of feasting activity (Albarella and Serjeantson, 2002). The predominance of younger pigs deposited in a particular area fits well with this hypothesis, and provides evidence that the north midden (context 593) may represent an area of the site that was particularly associated with feasting activities. The south midden had higher proportions of subadult and adult pigs among these two admittedly small samples (contexts 652 and 886), though this has been interpreted as the product of more public events than context 593. The evidence from Rudston Wold (Rowley-Conwy and Owen, 2011) has also been taken to indicate winter feasting.

In contrast, the pig remains deposited in pits and on house floors may be more representative of domestic, as opposed to public, feasting towards the end of the settlement's use, when food remains were left un-cleared from house floors, and pits were dug into and around houses in the course of rituals of abandonment. The pits also provide evidence of a lower level of killing throughout the year, not just in the winter, suggesting that these rituals of house ‘closure’ may not have been tied to calendrical events. In such situations they were more often killed in their second year so that the highest meat yield could be gained from each animal. Analysis of ceramic residues also highlights a difference between the midden and pit features at Durrington Walls. Samples from the north midden were variable and produced evidence of mostly ruminant fat (most likely beef) and dairy fat. In contrast, most ceramic sherds (11 of 16 sampled) from pit contexts produced evidence of pork fat and only one was consistent with dairy (Craig et al., forthcoming). This confirms the likelihood of different activity patterns reflected by different depositional contexts.

The different patterns of age at death and seasonality evident from the north and south midden and from the pits could be interpreted as differential deposition of refuse from synchronous but varied activities, reflecting degrees of domestic and public, or ritual and day-to-day activities. However, it is most likely that these three sets of contexts formed at different times, with the north midden accumulating largely or entirely before the houses were abandoned and the pits dug.

Ethnographic studies have shown that pigs are central to economic, social and religious life for many Pacific cultures such as the Tsembaga (Rappaport, 1968), the Yali (Studer and Pillonel, 2007) and the Wola (Sillitoe, 2007). In these cultures pork is a particularly valued source of protein, but also has important ritual connotations related to festivals where large numbers of animals are slaughtered simultaneously. Pig ownership and differential carcass preparation may also reflect gender or status in these societies. The pig is the quintessential animal kept for meat production and is also very prolific, making it possible for large numbers of young animals to be slaughtered without jeopardising the survival of the herd. With this in mind, it is not unsurprising that British Neolithic society may have considered pigs as an important animal in many respects, and that it may have been chosen as the main component of feasting activities.

The predominance of animals killed at the end of their first year, confirms the pattern found in previous work, and fits with the interpretation of midwinter feasting activity (Albarella and Serjeantson, 2002). Midwinter feasting may have been important

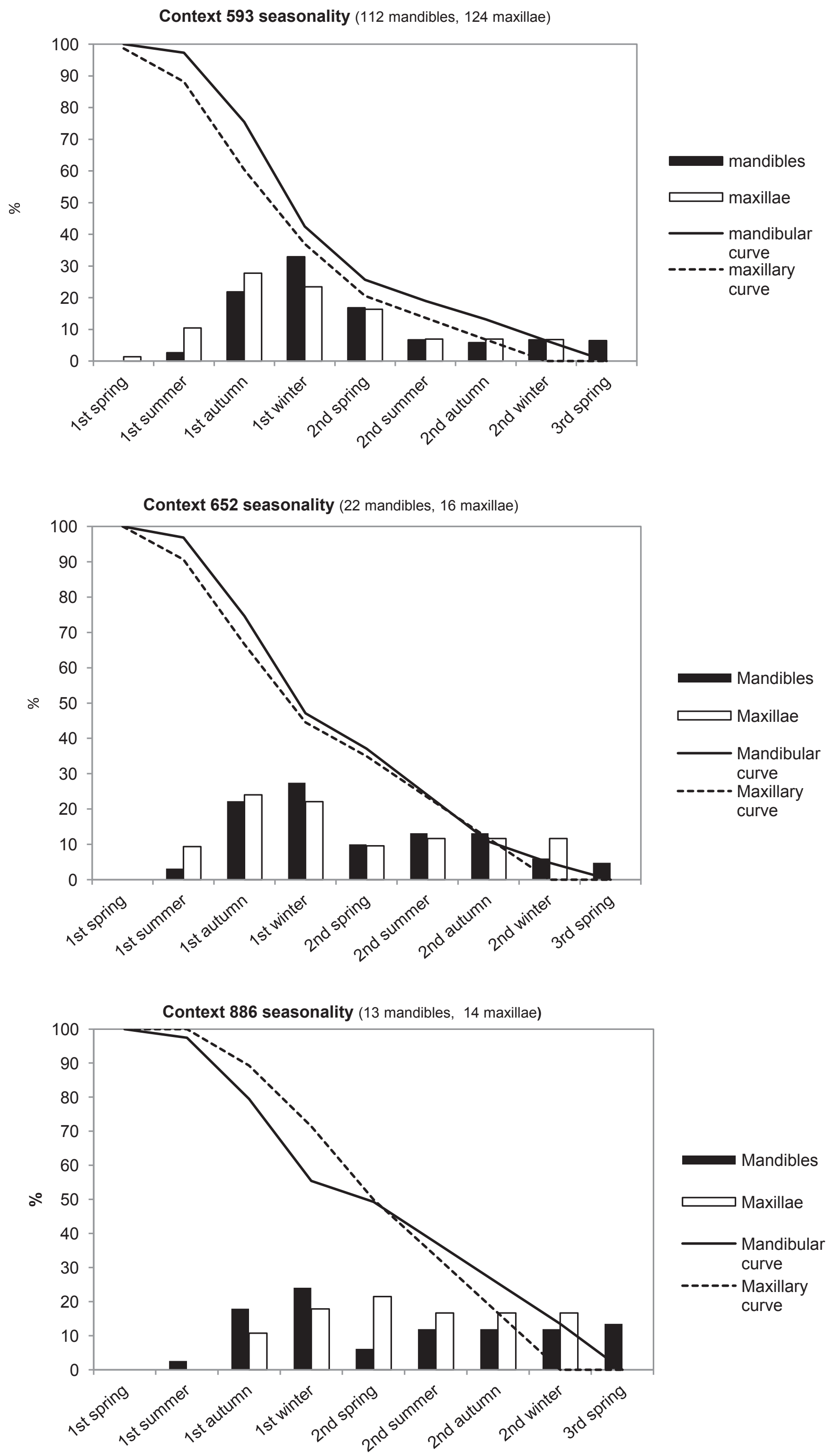


Fig. 11. Season of death of pigs from individual midden contexts.

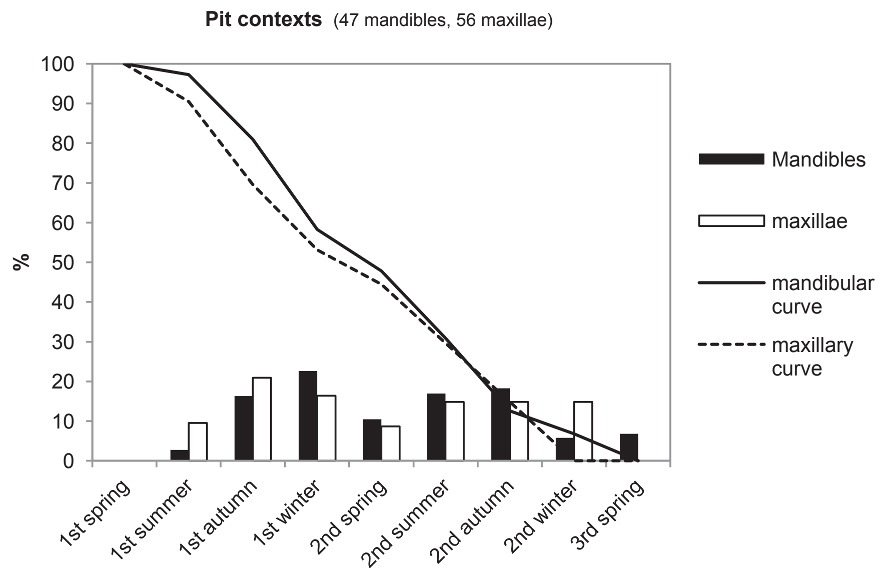


Fig. 12. Season of death of pigs from pit contexts.

in terms of the site's relationship with Stonehenge. The Durrington Walls avenue is oriented towards the midsummer sunset, whilst the Southern and Northern Circles are oriented to the midwinter sunrise (Parker Pearson et al., 2006). This provides a complementary arrangement to the orientation of Stonehenge where the avenue and stone circle look towards midwinter sunset in one direction and midsummer sunrise in the other (Parker Pearson et al., 2006, 2007). Furthermore, study of laser-scanned images of Stonehenge has revealed that its stones were dressed so as to emphasise the approach to Stonehenge facing towards the midwinter solstice sunset (Abbott and Anderson-Whymark 2012: 51).

For many years archaeologists have emphasised the midsummer solstice at Stonehenge but, with the evidence from the recent laser-scanning of Stonehenge as well as the clear importance of winter feasting at Durrington Walls, it now appears that midwinter was more important than midsummer, and that the ritual, social and economic realms of the two sites were entwined year round.

4.2. Reflections on the new ageing method

The recording of tooth wear using the new method has allowed us to incorporate upper jaws in the analysis of pig ageing at Durrington Walls and to provide more solid support for our interpretation of the kill-off pattern. Similarities between mandibular and maxillary tooth wear imply that the new recording system is comparable to Grant's (1982) method and can be used as an alternative, or as an addition to it. Although additional use may be preferable, considering the widespread use of Grant's system, Tables 6 and 7 allow conversion from one system to the other. The presence of larger samples of maxillae in some contexts at Durrington Walls, and the useful information gained from these (*e.g.* the house floors) demonstrates the value of including these jaws alongside the mandibles, in order to discover different patterns of discard in upper and lower jaws (see also Lemoine et al. 2014).

The new system is able to take into account anomalies in tooth wear that Grant's (1982) system cannot. This information may be instrumental in highlighting unusual tooth wear patterns in populations that may be due to pathology or to particular feeding practices. It is also less subjective as it is based on the definition of a wear stage — more like Payne's (1973) system for caprines — rather than on matching between the tooth and a pre-defined set of illustrated wear stages.

The similarities between upper and lower tooth wear also suggest that teeth from these jaws come into wear at a similar time, and that upper and lower teeth wear at a similar rate. However, the analysis of these results would be more accurate if maxillary wear from pigs of known age could have been used in order to age maxillary jaws for the seasonality study. These data are not currently available, but the recording of this kind of information from a collection such as that at Halle would be extremely beneficial for future work on maxillary tooth wear, as well increasing the sample of recorded jaws of known age.

5. Conclusions

This study has highlighted the importance of maxillary teeth and jaws for the study of pig ageing and seasonality through detailed analysis and careful recording of pig tooth ageing data. The method outlined here has been successfully applied to the Late Neolithic site of Durrington Walls, with the result that new light has been shed on the activities of the community occupying the site, including feasting, seasonal patterns of use and depositional practices. In sum, pigs were brought to Durrington Walls to be slaughtered at a young age (short of a year) to provide meat for predominately winter-based feasting events. In addition, older pigs (mainly in their second year) were eaten and deposited in pits associated with the ritual closure of houses as they became abandoned. These older pigs may have been slaughtered throughout the year, though still preferentially in winter, suggesting that such closing rituals at the household level were not necessarily linked to the calendrical festivities of the wider community.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2014.09.009.

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