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Zwammerdam on the Rhine: The contribution of archaeozoological research to the current knowledge of Roman *Nigrum Pullum*

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ABSTRACT

The Dutch Roman frontier is known for providing a great deal of archaeozoological research, but the real potential has not been reached yet as there are data from many excavated sites that have still not been analysed in detail or are buried as grey literature. The research project *Romeinse vicus aan de Rijn* aims at filling this gap through the study and publication of Roman military *vici* along the Dutch part of the Rhine to better understand the development and significance of these key locations. Within this frame, archaeozoological remains from various sites are being re-analysed in order to reinforce the knowledge of economic and cultural patterns, to better understand supply networks and to study how these activities shaped the surrounding environment and impacted the landscape.

One of the studied sites is the Roman fort and *vicus* of Zwammerdam-*Nigrum Pullum*, located on the Rhine in the West Netherlands. Archaeozoological remains were collected during excavations in 1968–1971 and in 2003–2004, but some of the material was not studied, and a thorough synthesis was still missing. Because of this, certain aspects within this Roman settlement remain poorly analysed.

With a thorough analysis of the archaeozoological remains from both excavations at Zwammerdam, integrated with contextual and chronological data, this study brings forward new archaeozoological information for this Roman settlement. The new data not only make it possible to compare animal exploitation in the *vicus* with that of the fort, but it also provides an opportunity to analyse these patterns throughout time both locally and regionally. While limited to a small area in the Roman Empire, the data from Zwammerdam can provide a further step for new, broader archaeozoological research towards the role of animals in the Roman culture and economy.

1. Introduction

Since the start of the 21st century, a large number of archaeozoological studies on the Dutch Roman frontier have come forward studying different aspects of animals including biometric and morphological studies (Filean, 2008; Lauwerier, 2015), husbandry practices (Groot, 2009, 2008a, 2008b; Groot et al., 2009; Groot and Kooistra, 2009; Lauwerier, 1988; Van Dijk and Groot, 2013), supply systems (Cavallo et al., 2008; Kooistra et al., 2013) or ritual practices (Groot, 2008b). Still, the picture of the Dutch *limes* is highly dotted, with many sites excavated in the mid-20th century poorly documenting some materials or not even publishing them at all, as is the case with a great deal of faunal reports (Cavallo et al., 2008). To study lesser known aspects of Roman *vici* -civil settlements adjacent to the forts-, a research and citizen science project was initiated in 2016. The *Romeinse vicus aan de Rijn* project aims at investigating the development, activity and significance of Roman *vici* along the Dutch part of the Rhine, by studying and combining multiple types of archaeological evidence, including written excavation reports, archaeological objects and archaeozoological remains (Chorus et al., 2019). Within the project, data from older excavations are re-analysed, re-examined and compared with current knowledge and new data collected during recent archaeological excavations. In addition, archaeological finds that were not previously published are now studied and evaluated under a more current perspective in order to gain insight into the yet unknown aspects of the Dutch *vici* and its associated fort (Chorus et al., 2019). To contribute to this end, we present the recent archaeozoological analysis from one of these re-analysed settlements, Zwammerdam-*Nigrum Pullum* (Alphen

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aan den Rijn, the Netherlands; Fig. 1), and frame the results chronologically and regionally.[1]

Archaeozoological remains were collected during the first excavations at Zwammerdam, carried out by the *A. E. van Giffen Instituut voor Prae- en Protohistorie* (IPP) from 1968 to 1974, and during recent excavations by the *Archeologisch Diensten Centrum* (ADC) in 2003 and 2004. Both publications of these excavations (Haalebos, 1977; Ploegaert, 2006) give little more than a general mention that archaeozoological remains were found. A couple of (published) reports exists, but these are similarly limited in terms of discussion (Van Mensch, 1974a; Van Mensch and IJzereef, 1977; van Wijngaarden-Bakker, 1970). While interesting publications, they are limited to specific taxa from the IPP excavations and none presents an overview of all archaeozoological evidence collected during the complete IPP campaign.

By analysing and comparing a large selection of archaeozoological remains from the 1968–1971 IPP excavations and the complete set of archaeozoological remains from the 2003–2004 ADC excavations, the aim is to contribute to a better understanding of the exploitation of the main mammal taxa and human activities in the Roman settlement of Zwammerdam-*Nigrum Pullum* and to frame it in its regional context.

2. The fort and vicus of Zwammerdam

The first excavations at Zwammerdam were carried out by the IPP from 1968 to 1971. Previous (non-invasive) archaeological survey on the site brought forward that the remains of the Roman fort of *Nigrum Pullum* were to be found at this location. This fort was known from the *Tabula Peutingeriana* and was located between the forts of *Albaniana* and *Laurium*, which have been recovered at Alphen aan den Rijn and at Woerden (De Weerd, 1975; Haalebos, 1977; Van der Kley, 1968). A first small-scale study of the property and its archaeological structures was therefore initiated in 1968, with the excavation of a few trenches. This was soon extended into large-scale excavations when several Roman structures were discovered. Excavations continued from 1968 to 1971, bringing forward the complete outline of the Roman fort (Fig. 2). Apart from the rampart and stone wall of the fort, the *principia* and other (timber) internal buildings, parts of the associated *vicus* and a section of the Roman bank of the Rhine with quay structures were excavated. After the find of a wooden dug-out canoe from the Roman period in 1971, excavations were continued for three more years (De Weerd, 1988, 1975; Haalebos, 1977).

The excavations allowed to differentiate between three chronological periods of fort development. In the first period, from *ca.* 47 to 69–70 CE, the fort area consisted of a small, unfortified military settlement, as Haalebos interprets (Haalebos, 1977). Reassessment of the documentation has revealed traces that indicate a fort (Chorus, in press). This settlement was most likely destroyed during the Batavian revolt in 69/70 CE. In the second period, starting around or slightly after 70 CE and lasting until *ca.* 175 CE, the fort consisted of a timber rampart with three gateways and two defence ditches. These defences were replaced by a stone fortification wall in the third period, which lasted from c. 175 to 260 CE. While it is not known why the fort was abandoned, burned residue and charcoal may indicate an abrupt end (Franzen et al., 2000; Haalebos, 1977; Haalebos and Franzen, 2000).

In addition to the fort, parts of the associated *vicus* were excavated to the west of the Roman fort. The excavations revealed part of a Roman road and several house plans, mostly indicated by the ditches that divided the house properties. Similarities in archaeological finds between the fort and the *vicus* made it possible to place the occupation of the *vicus* in the second period of the fort, between 70 and 175 CE. Unfortunately, due to the disruption of the *vicus* structures by later features, it is hard to determine if the *vicus* was also occupied in the last period of the fort or later. Similarly, due to modern developments, amongst which the construction of the nearby railroad, it was difficult to study the size of the *vicus* (Haalebos, 1977; Ploegaert, 2006).

An opportunity to study more of the Roman *vicus* presented itself in 2000, when construction works were planned in an area that had previously not been excavated, to the northwest of the Roman fort. Archaeological research, executed by the University of Nijmegen and ADC, took place between 2000S and 2004. The campaign in 2000 only yielded few results, but during the excavations in 2003 and 2004 clear remains of the Roman *vicus* were uncovered (Fig. 2). These remains consisted of ditches, pits and several postholes, of which some seemed to be related to a house plan. All structures that yielded dating material could be dated to the end of the first century CE and/or the second century CE. No evidence for occupation in the third century CE was

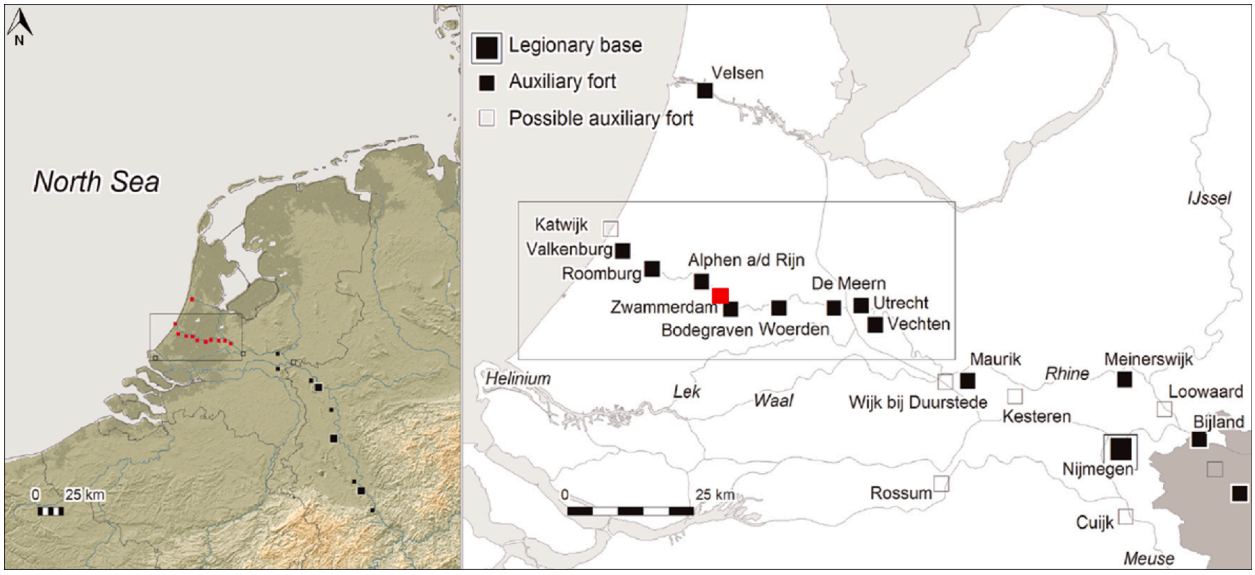

Fig. 1. Location of Roman fortifications along the Rhine frontier, with focus on the auxiliary forts situated in the Western Rhine delta, as indicated by the rectangular outline (after Kooistra et al. 2013, 6).

[1] This article is based on data collected as part of the MSc thesis of the first author (Reynaert, 2020).

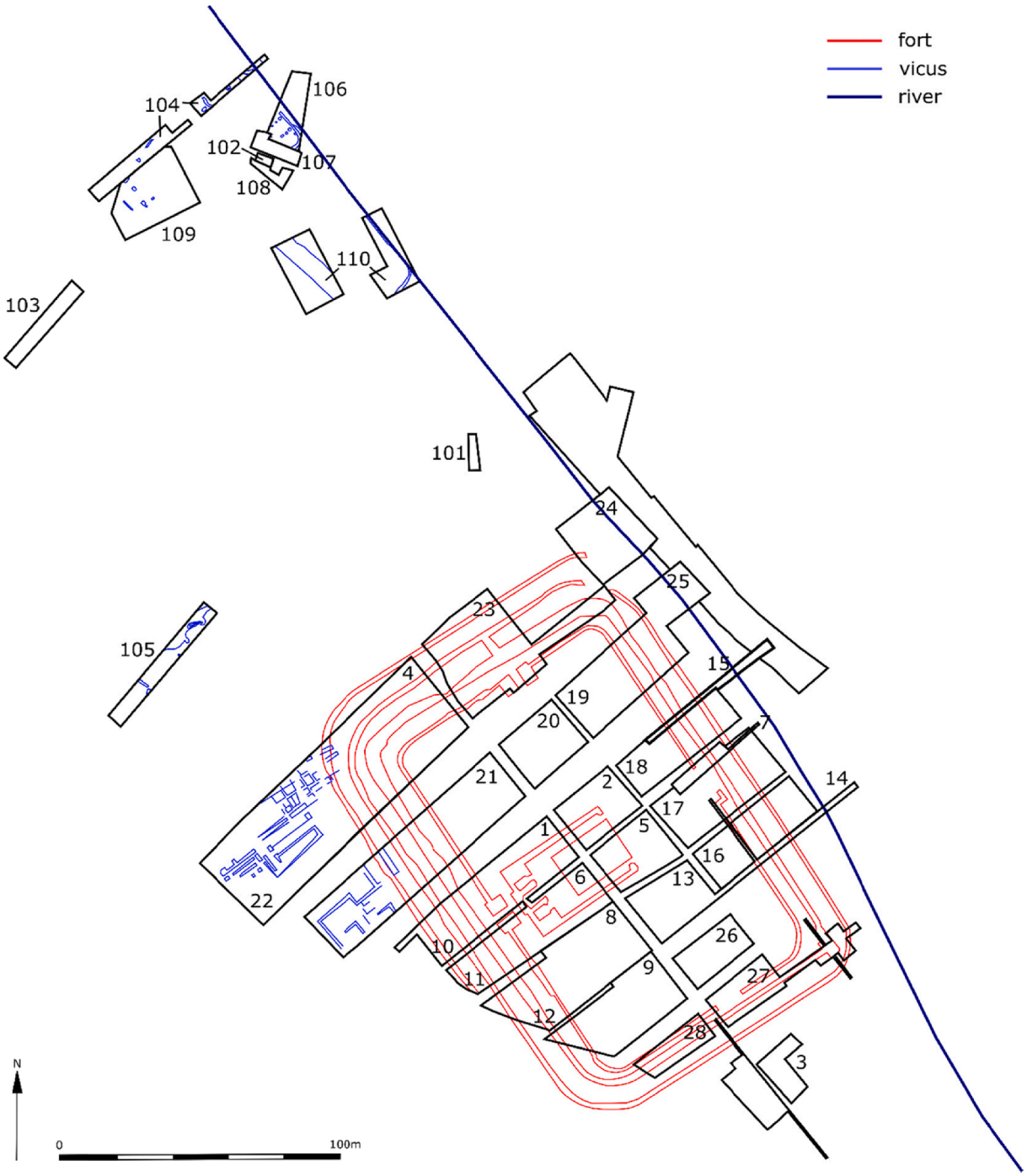

Fig. 2. Location of the excavation trenches of the IPP (1–28) and ADC (101–110) excavations with an indication of the excavated vicus remains, the location of the fort (based on the third period lay-out) and the course of the river Rhine in the Roman period (after Haalebos 1977, Beilage 1a-1b; Franzen et al. 2000, 7; Haalebos and Franzen 2000, 18-19; Ploegaert 2006).

found. This supplements the idea presented after the IPP excavations that the *vicus* should be related to the second development phase of the fort, between c. 75 and 175 CE (Franzen et al., 2000; Ploegaert, 2006).

3. Material and methods

Archaeozoological remains derive from the 1968–1971 IPP and the 2003–2004 ADC excavations. All archaeozoological remains were collected by hand during both excavations. For this study, a selection was made from the remains collected during the IPP excavations, focusing on material from the *vicus* and fort for which contextual and chronological information was available. In the case of the ADC excavation, all faunal remains were studied. In total, 97 and 25 contexts have been studied from the IPP and ADC excavations respectively.

Within the IPP contexts, 85 have been associated to the fort -the majority dating to the first two periods of the occupation- two to the *vicus* and ten to the bank of the river Rhine, dated between 70 and 260 CE (Appendix A). Within the fort, most of the contexts seemed to be related to a building structure, a defence ditch or the ground level in the Roman period (Chorus et al., in prep., based on Haalebos 1977 and field drawings). All the contexts from the ADC excavations are related to the *vicus* located to the northwest of the Roman fort. The contexts that could

be dated generally start around 70–75 CE or in the second century and continue into the second or third century (Ploegaert, 2006).

Archaeozoological remains were taxonomically and anatomically identified with the reference collection housed at the Laboratory for Archaeozoological Studies of the Faculty of Archaeology of the University of Leiden and recorded in the Access database BonBone developed by Eric Dullaart following the guidelines of the ROB-archaeozoological protocol (Lauwerier, 1997). Mammal elements that could not be identified taxonomically were categorized in size classes, medium-sized mammals (sheep, goat, pig) and large-sized mammals (cattle, horse). No remains of small-sized mammals or microfauna were present within the sample, probably due to the hand collecting. The remains of sheep and goat were grouped together, as the small, fragmented sample made it impossible to clearly and reliably make a distinction between these two taxa. The elements for which no skeletal element or species could be determined were labelled indeterminable.

For each element, the symmetry, degree of fragmentation and preservation was recorded following Lauwerier (1997) and used to quantify the Number of Identified Specimens (NISP) per context. In addition, all elements were weighed and measured whenever possible. Measurements were taken with a Powerfix digital caliper (estimated error ± 0.05 mm) following Von den Driesch (1976). The measured greatest length of long bones was used for the calculation of the withers height using Matolcsi (1970) and Von den Driesch and Boessneck (1974) with constant values for cattle and values from May (1985) for horse.

Ageing was estimated based on both epiphyseal fusion and tooth wear eruption and wear stages provided by general references for ageing archaeozoological remains alongside sex (Boessneck, 1969; Grant, 1982; Habermehl, 1975; Silver, 1969; Wilson et al., 1982) and, in the case of pig mandibles, from Bridault et al. (2000) and Genov et al. (1992). The presence of taphonomic marks were recorded following general guidelines from Lyman (1994), both through ocular inspection and with a Leica M30 stereo microscope (x10; x40). Within the butchery marks, cutting, chopping or sawing marks were differentiated. Other bone surface marks, such as burning and gnawing marks, and pathological changes of the bone were also recorded.

4. Results

A total of 1,053 archaeozoological remains from the excavations at Zwammerdam-*Nigrum Pullum* have been studied of which 36 % corresponded to the Roman fort and 55.5 % to the Roman *vicus* (Table 1). The remaining 8.5 % derived from the Roman river contexts. The determined sample size of these contexts with NISPs over 100 remains allow to a good proxie of how Zwammerdam inhabitants exploited the main taxa (Davis, 2002; Schmölcke, 2013). The archaeozoological remains were generally fairly well preserved (weathering stages 0 or 1; Behrensmeyer, 1978) but were quite fragmented (classes 2 to 4; Huisman et al., 2006) due mostly to human activity which explains the percentage of non-identified remains.

The assemblage is basically constituted by mammal remains (99 %) where cattle clearly is the most represented species with NISP contributions ranging between 52 and 99 % (Table 1). Other domestic ungulates, such as pig, sheep/goat and horse, presented lower and varying percentages in each context. Cat remains, when recorded, were always minimally present in the assemblages. One species of cervids was determined exclusively in the IPP excavations although their contribution is anecdotical (below 0.5 %). Non-mammal fauna include only a few remains of birds (chicken) and molluscs. Small and medium size taxa are probably underrepresented because of retrieval biases, which in the analysis of the main domestic ungulate ratio could have a slight decrease in the relative percentage of cattle/horse remains if more meticulous collection had been applied (Clason and Prummel, 1977). However, the overall proportion of domesticates at Zwammerdam seems to follow the pattern of the Dutch Roman settlements (Çakirlar et al., 2019; Groot, 2016; Lauwerier, 1988), and the difference would probably not be statistically significant for this discussion. Only a small fraction of the mammal remains (7.6 %) could not be identified taxonomically and were classified as either medium-sized or large-sized mammal remains.

Most of the remains were related to butchery or consumption refuse assemblages as evidenced by the presence of most body parts of the main ungulate domesticate (i.e. cattle) alongside the identification of fresh fractures and butchery marks (cutting, chopping and shaving marks) detected in most of the bones (c. 34 % NISP, mostly in cattle). One fragment of a red deer antler from the fort was sawn off at two sides, which might indicate antler working activities within the settlement.

A juvenile cat was identified within a context of the IPP *vicus* sample dated to the second period of occupation, between 70 and 175 CE (Table 1), corresponding with the period that the domesticated cat was introduced in the Netherlands, between 12 BCE to 70 CE or 70–270 CE (Çakirlar et al., 2019). This element most likely belonged to a pet, or an animal kept to catch rodents, and should not be interpreted as consumption refuse. One context (105–27) from the ADC *vicus* excavations contained partially articulated limbs of a single adult equid. These remains can either be interpreted as a burial, which was only partly retrieved, or as a special animal deposit of only leg elements, possibly in relation to the nearby house structure. The remains from the river contexts, except from an equid element and the presence of oyster shells (Table 1), do not stand out compared to the fort and *vicus* samples.

In terms of exploitation strategies, dental data from four remains indicate that pigs were slaughtered at their optimum weight peak between 1 and 3.5 years old and only one was over that threshold (Baron et al., 2019). The presence of butchery marks in two elements further supports the use of the animals for consumption.

Table 1
Number of Identified Specimens (NISP), percentage of the total identified species (%) and number of non-identifiable elements analysed from Zwammerdam.

	IPP fort		**IPP Rhine**		**IPP *vicus***		**ADC *vicus***	
	NISP	%	NISP	%	NISP	%	NISP	%
Cattle *(Bos taurus)*	214	74.3	25	44.6	155	99.4	81	70.4
Pig *(Sus domesticus)*	28	9.7	13	23.2			5	4.3
Sheep/Goat *(Ovis aries/Capra hircus)*	6	2.1	6	10.7			6	5.2
Equid *(Equus* sp.*)*			1	1.8			17	14.8
Cat *(Felix catus)*					1	0.6		
Red deer *(Cervus elaphus)*	1	0.3						
Medium Mammal	5	1.7					2	1.7
Large Mammal	30	10.4	8	14.3			4	3.5
Chicken *(Gallus gallus)*	3	1.0						
Mollusca	1	0.3	3	5.4				
Total identified remains	**288**	**100**	**56**	**100**	**156**	**100**	**115**	**100**
Non-identifiable remains	94		33		0		311	
Total number of remains	**382**		**89**		**156**		**426**	

Less detailed information is available for the sheep/goat remains. No butchery marks were found on sheep/goat and only limited age data were available. One element belonged to an animal younger than 12–28 months, which was most likely killed purely for consumption. The production of milk and wool cannot be discarded given the scarce number of caprines recorded.

As cattle remains were the most abundant within the total studied remains, more specific information could be presented for this species. Firstly, elements of the whole skeleton were recorded with teeth and bone-bearing teeth presenting higher NISP frequencies due to their more mineralised nature (Fig. 3). Other frequency differences seem to correspond to collecting biases.

The cattle mortality profile shows that adults between 2,5 and 8 years old were preferentially slaughtered, especially prime adults (Fig. 4). Subadult individuals were secondarily slaughtered (16 %), and only 2 % were juvenile individuals. This profile conforms a mixed exploitation strategy of meat, dairy products and ploughing activities.

In fact, the identification of pathologies in some of the cattle bones suggests the use of cattle for draught exploitation. Eburnation and pitting was identified on the proximal end of a femur fragment and on the inside of the acetabulum of a pelvis fragment and osteophyte formation (i.e., new bone formation) is also visible on the edge of the acetabulum. These pathological changes are most likely caused by osteoarthritis of the hip joint. Osteoarthritis is commonly caused by old age, but in the hip joint it can also be caused by using cattle as a draught animal, especially when cattle is used for traction in agricultural activities (Groot, 2010, 2005). Additional bone growth was also identified on the caudal sides of the two first phalanx elements and on a calcaneum element. Pathological change of the phalanges can also be caused by the use as a draught animal (De Cupere et al., 2000; Groot, 2010).

All three stages of butchery were detected in cattle, namely, primary butchery (cutmarks indicating the removal of inner organs/evisceration and skinning), secondary butchery aimed at division of the skeleton into separate portions (chopping marks), and tertiary butchery in which further division into manageable and consumable portions and preparation of meat for consumption takes place (chopping and cutting marks) (Lauwerier, 1988).

A specific pattern of butchery marks could be identified on cattle scapulae. A total of 84 scapula elements were identified of which 67 % (56 remains) had one or multiple butchery marks and on 25 elements a hole in the middle of the shoulder blade could be identified (Fig. 5). This hole is typically interpreted as a perforation related to the smoking of the shoulder blade and caused by a hook that was attached to the meat so that it could be hung during the smoking process (Çakirlar et al., 2019; Lauwerier, 1988; Van Mensch and IJzereef, 1977). While on some scapulae this hole was quite clear, other elements showed a crevice that might have been created by a hook. In addition, a specific pattern of butchery marks was identified beside the hole in the shoulder blade that can be related to the smoking process. These include chop marks on the Cavitas glenoidalis, tuber scapulae and the spinal acromion, related to the separation of the shoulder blade from the humerus, and shaving and cutting marks on the edges of the collum and on the medial side, related to the removal of the smoked meat from the bone and its consumption (Lauwerier, 1988; Van Mensch and IJzereef, 1977).

Altogether, it seems that cattle were exploited for their skin, horns, meat and other primary products while the abundance of adult individuals and the presence of pathologies suggest that these animals served a secondary purpose, probably for the production of milk and as a draught animal. That end is however difficult to prove in our assemblage, where the sample size in osteomorphological or osteometrical data does not allow for a conclusive interpretation of exploitation models, as is the case in other Dutch Roman sites (Groot, 2016). In addition, cattle may have been slaughtered at Zwammerdam but animals may have been brought from different places, potentially complicating the osteometrically sex determination with different populations involved.

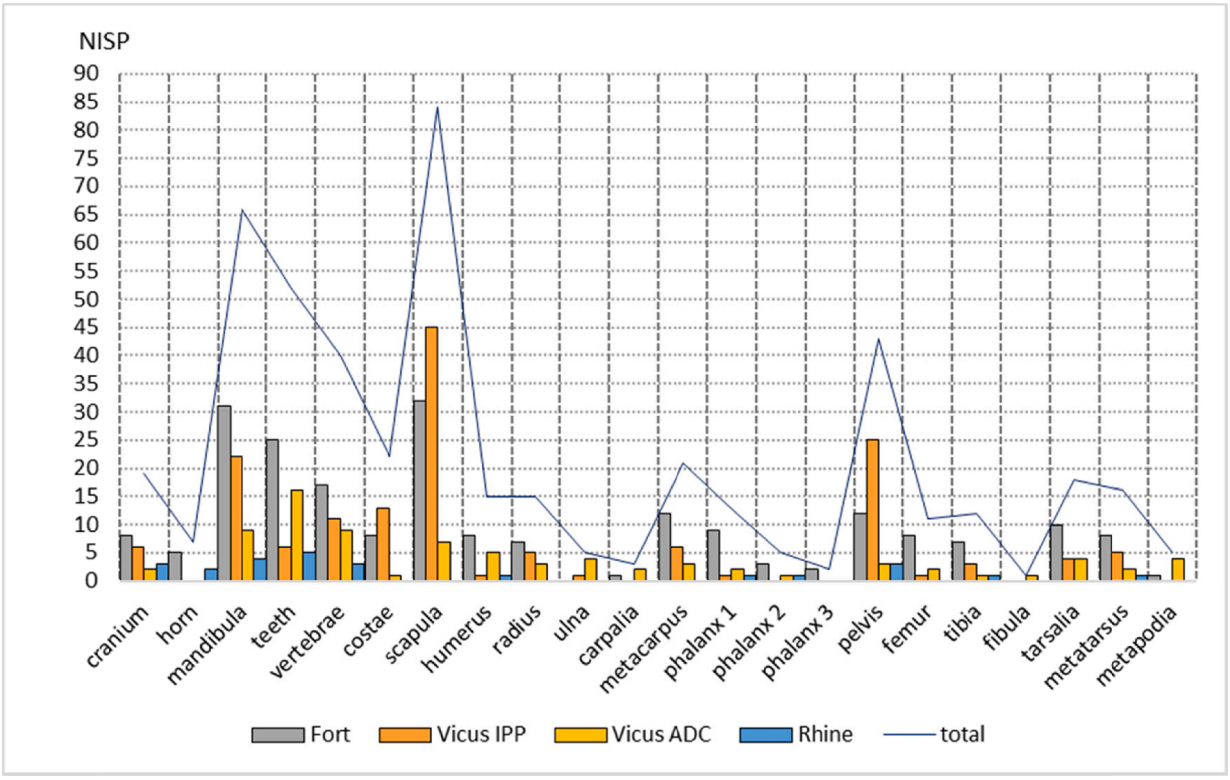

Fig. 3. Skeletal element distribution of cattle within the fort sample (n = 214), the IPP vicus sample (n = 155), the ADC vicus sample (n = 88) and the Rhine sample (n = 25).

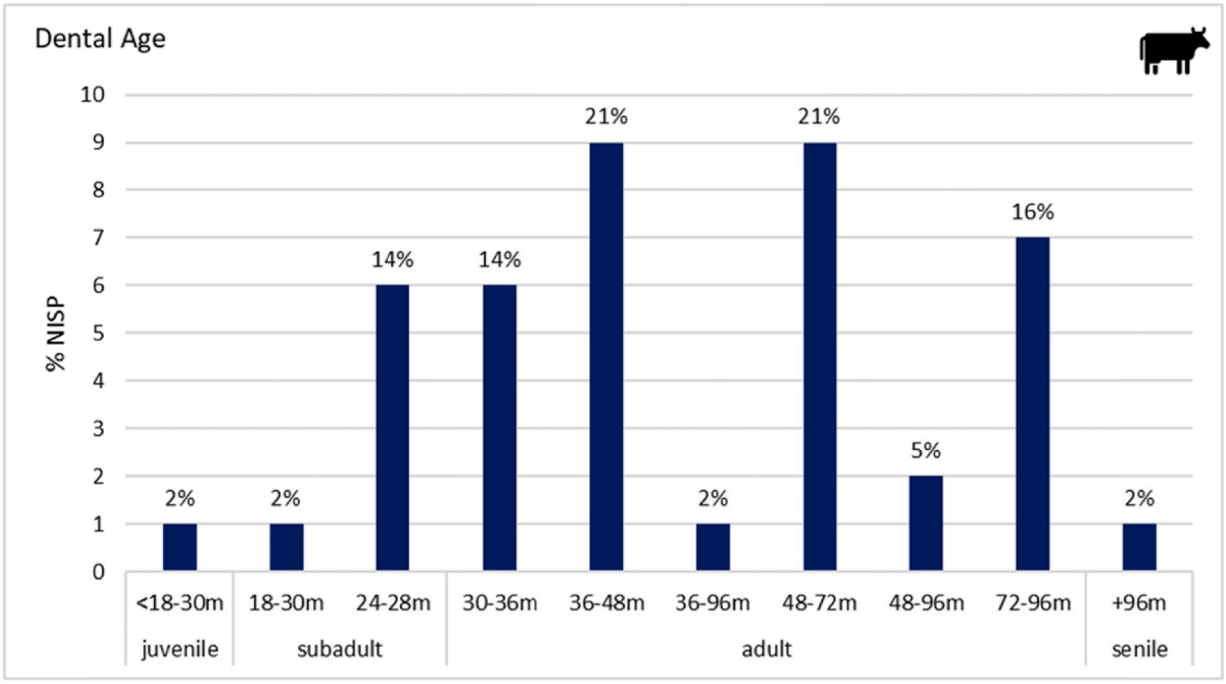

Fig. 4. Age distribution of cattle elements based on dental wear and tooth eruption data (n = 43).

Fig. 5. Butchery marks on cattle scapulae related to smoking: hole in the shoulder blade (1), chopped off tuber scapulae (2) and/or spinal acromion (3) and cutting marks on the edges (4) (Van Mensch and IJzereef, 1977, 145).

4.1. Animal use within the settlement

Cattle, alongside caprines and pig, constitute the main consumption source within the settlement of Zwammerdam-*Nigrum Pullum*. When the fort and the *vicus* assemblages are compared, cattle constitutes the most important species in both the fort and the *vicus* with contributions of 86 % and 95 % respectively. Small differences between the *vicus* and the fort derive from a slightly higher contribution of pig within the fort (Fig. 6). The presence of a *vicus* context with exclusively cattle elements (NISP = 155) might have increased the representation of cattle in the total *vicus* sample even more. Containing elements of all the skeleton, but scapulae with evidence of smoking activities (Fig. 3) being particularly abundant, one could be tempted to interpret the assemblage as a smoking-house located in the settlement. However, the bones would only be thrown away after consumption of the smoked meat, as indicated by the shaving and cutting marks caused by the removal of the meat (Van Mensch and IJzereef, 1977; Lauwerier 1988, 156), and could therefore also be imported from another settlement. This issue remains open until further archaeological evidence can confirm any of these hypothesis.

The re-analysis of the IPP material has made it possible to compare the species composition of cattle, sheep/goat and pig within the fort throughout the three different chronological periods, and to compare this with the data of the vicus (Fig. 7). Only the remains from the ADC *vicus* sample were added to this comparison, in order to avoid bias from a large context from the IPP excavations containing exclusively cattle elements (context 10–219.221, n = 155). The comparison shows that in the fort the percentage of sheep/goat decreases throughout time, while the percentage of pig increases. In the *vicus*, which was occupied during the second period of the fort, the ratio between sheep/goat and pig is roughly the same. The percentage of cattle stays over 82 % in all periods, but reaches the highest percentage in the second period, between 70 and 175 CE. It has to be taken in mind that the data in Fig. 6 is based on a selection of the total excavated remains from the IPP excavations. Most

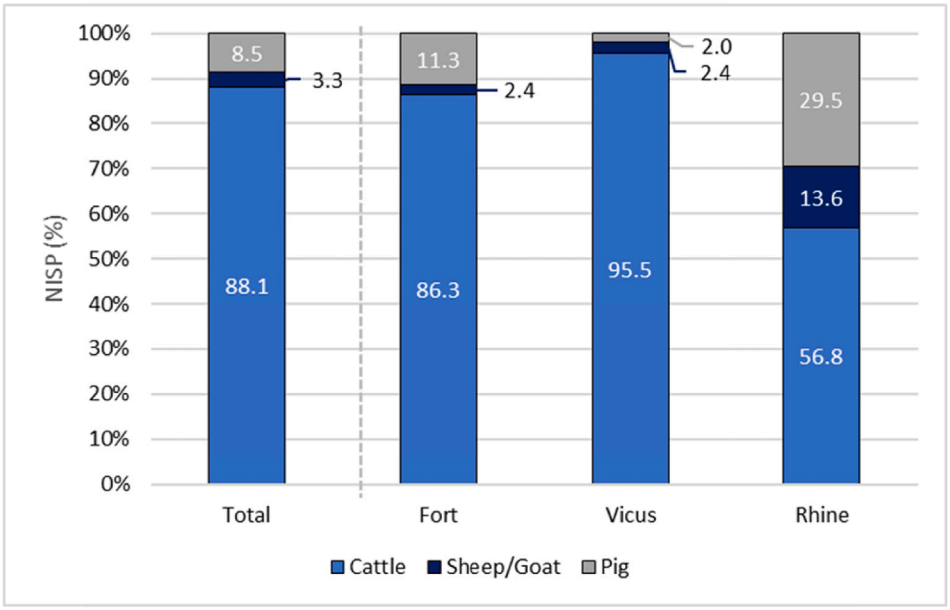

Fig. 6. Relative abundance of cattle, sheep/goat and pig in the total sample (NISP = 475) and divided over the fort (NISP = 214), the vicus (NISP = 236) and the river (NISP = 25). IPP and ADC data have been pooled.

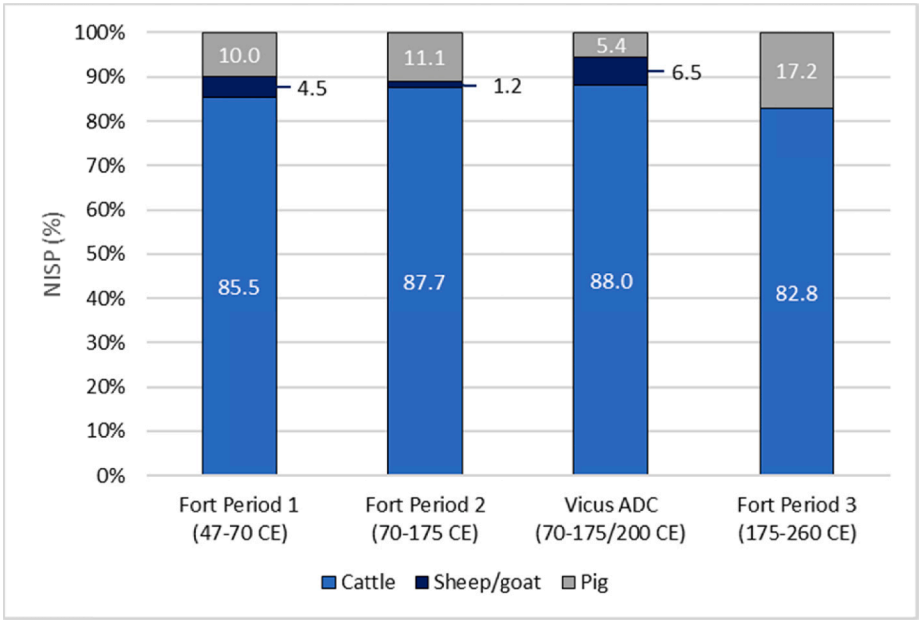

Fig. 7. Relative abundance of cattle, sheep/goat and pig within the fort for period 1 (NISP = 94), period 2 (NISP = 71) and period 3 (NISP = 24) and within the ADC sample of the vicus (NISP = 81). Remains from contexts that were broadly dated (e.g. period 1–2 or period 1–3) have been excluded.

of these remains could be dated to the first period of the fort, while only a small sample was available for the third period. There is therefore a possibility that the picture presented here will differ if more archaeozoological remains from the IPP excavations are included.

5. Discussion

Overall, there are no big differences in the species composition between the fort and the *vicus* at Zwammerdam. This is consistent with the idea that the inhabitants of a *vicus* had a close relation with the soldiers in the nearby fort and most likely had a similar diet. The *vicus* seems to conform a consumer settlement (see below), just like the fort, and would have obtained its food from producer settlements, for instance from nearby rural villages or farms (Kooistra et al., 2013).

The use of cattle, first as a working animal and maybe for dairy products, and later for consumption, corresponds with the general idea of cattle use in the Dutch river area in the Roman period (Çakirlar et al., 2019; Lauwerier, 1988). The distribution of the skeletal elements has shown that most parts of the skeleton were present on this site suggesting that cattle was most likely killed on the site (Groot, 2018, 2010). However, based on the kill-off pattern and the presence of pathologies as well as data from other sites, the animals were most likely used as a draught animal in another (rural) settlement and then transported to the fort and *vicus* where they would be used for consumption (Çakirlar et al., 2019; Groot, 2008a, 2008b; Groot and Deschler-Erb, 2017; Vossen and Groot, 2009). Something similar can be argued for the smoked

shoulders; although the scapulae could be smoked at the settlement, it is possible that the meat was transported from somewhere else.

The archaeozoological remains from the older IPP excavations that were studied by Van Mensch (1974b) have previously been used to support the idea that Roman military forts in the Dutch river area relied more on pig consumption before 70 CE (Cavallo et al., 2008). After 70 CE an increase in cattle remains is seen within the studied sites, while the percentage of pig decreases. According to these studies, pig was easier to transport and to keep within or closer to the settlement and, due to their fast reproduction, would be able to offer a good supply of meat. The new forts therefore had their own supply, without having to rely on nearby local settlements (Cavallo et al., 2008). Cavallo et al. (2008) used the low percentage of pigs at Zwammerdam (9 %), within contexts dated between 80 and 175 CE, as evidence for the decrease of pig after 70 CE (Cavallo et al., 2008). However, in our diachronic overview of the settlement it can be seen that rather than a decrease, the percentage of pig increases throughout time (Fig. 7). In addition, pig percentages in Zwammerdam remain low throughout all periods.

5.1. *Zwammerdam-Nigrum pilum in the wider context*

Located in the western part of the Lower Rhine delta, on the southern embankment of the river, the settlement of Zwammerdam-*Nigrum Pullum* is part of a series of three other forts located in a similar landscape – Alphen aan den Rijn, Bodegraven and Woerden (Kooistra et al., 2013, see Fig. 1). The archaeozoological data from these sites exhibited a fairly similar pattern to our compiled data from Zwammerdam where cattle dominates the samples, followed by either sheep/goat or pig. Frequencies of other domesticated species (such as horse, dog or cat), wild mammal species and non-mammal remains vary across the different samples (Table 2).

In a previous archaeozoological analysis from Woerden (Van Dijk, 2008), it was noted that the amount of sheep/goat and pig was slightly higher in the fort than in the *vicus*. According to Van Dijk, data from Alphen aan den Rijn and Bodegraven seemed to follow the same trend. This can be explained by either a chronological difference between the samples or by a difference in consumption between the fort and the *vicus* (Van Dijk, 2008). A higher percentage of sheep/goat and pig has previously been interpreted by multiple researchers as a typical military preference, while a lower percentage was interpreted as a native consumption pattern (Çakirlar et al., 2019; Groot and Deschler-Erb, 2017; Lauwerier et al., 2005; Van Dijk, 2008).

When data from Zwammerdam and additional data from Alphen aan den Rijn are analysed (Fig. 8), higher percentages of sheep/goat and pig are present within all fort samples except one from Bodegraven. While one of the samples from Bodegraven was previously interpreted as a *vicus* sample (AWN 2002, Van Dijk, 2008), it is now known that this should be interpreted as a waste dump, possibly related to the fort. Definite remains of a corresponding *vicus* have not (yet) been identified at Bodegraven, limiting a comparison of *vicus* and fort contexts at this site.

In Woerden, Zwammerdam and Alphen aan den Rijn, the higher percentages of caprines and pig correspond with the samples collected within the forts. In Bodegraven, the higher percentages correspond with only one of the fort samples (AWN 1996) dated to an earlier phase, 50–100 CE (Lauwerier et al., 2005). This difference might be explained by the fact that the material corresponds to an earlier period, in which sheep/goat and pig were consumed more than in a later period. There is, however, an overlap of 50 years between the samples, limiting a full chronological comparison.

Still, a chronological difference might also explain the differences in relative frequencies in Woerden. The sample from the fort, with a higher

Table 2
Identified species for Alphen aan den Rijn, Bodegraven, Woerden en Zwammerdam. For each species the Number of Identified Specimens is presented.

	Alphen aan den Rijn			**Bodegraven**			**Woerden**			**Zwammerdam**	
	Van Dijk, 2008		van der Kuijl, 2006	Lauwerier et al., 2005			Van Dijk 2008				
	Fisher P29 fort	Fisher P40 riverside	Synthegra 2004 *vicus*	AWN 1995	AWN 1996	AWN 2002	fort	other	*vicus*	fort (*P*1-3)	*vicus* (IPP&ADC)
	41–270	41–270	Roman	50–250 CE	50–100 CE	50–250 CE	41–70 CE	70–175 CE	70–175 CE	47–260 CE	70–260 CE
Mammal											
Cattle *(Bos taurus)*	228	201	208	93	261	295	275	425	405	214	236
Horse/Equid *(Equus caballus/ Equus* sp.*)*		2			9	16		6	2		17
Sheep/Goat *(Ovis aries/Capra hircus)*	39	2	8	7	66	9	38	18	18	6	6
Pig *(Sus domesticus)*	126	7	4	4	140	23	58	21	23	28	5
Cat *(Felis catus)*											1
Dog *(Canis familiaris)*					2	5	6	2	1		
Moose *(Alces alces)*					1	1					
Red deer *(Cervus elaphus)*	3				1		1	2		1	
Wild boar *(Sus scrofa)*							1				
Beaver *(Castor fiber)*				1	18	1					
Otter *(Lutra lutra)*					1						
Mustelids (Mustelidae)					2						
large mammal	196	7	124	86	168	61	176	152	204	30	4
medium mammal	53	5	13	23	160	13	46	15	26	5	2
small mammal	2				3						
Indet. mammal	30		43	98	98		33	100	41	94	311
Total mammal	**677**	**224**	**400**	**312**	**930**	**424**	**634**	**741**	**720**	**378**	**582**
Birds				1	28	4	2	5	2	3	
Fish					20	1	12				
Molluscs					76	2	12		7	1	
Total	**677**	**224**	**400**	**313**	**1054**	**431**	**660**	**746**	**729**	**382**	**582**

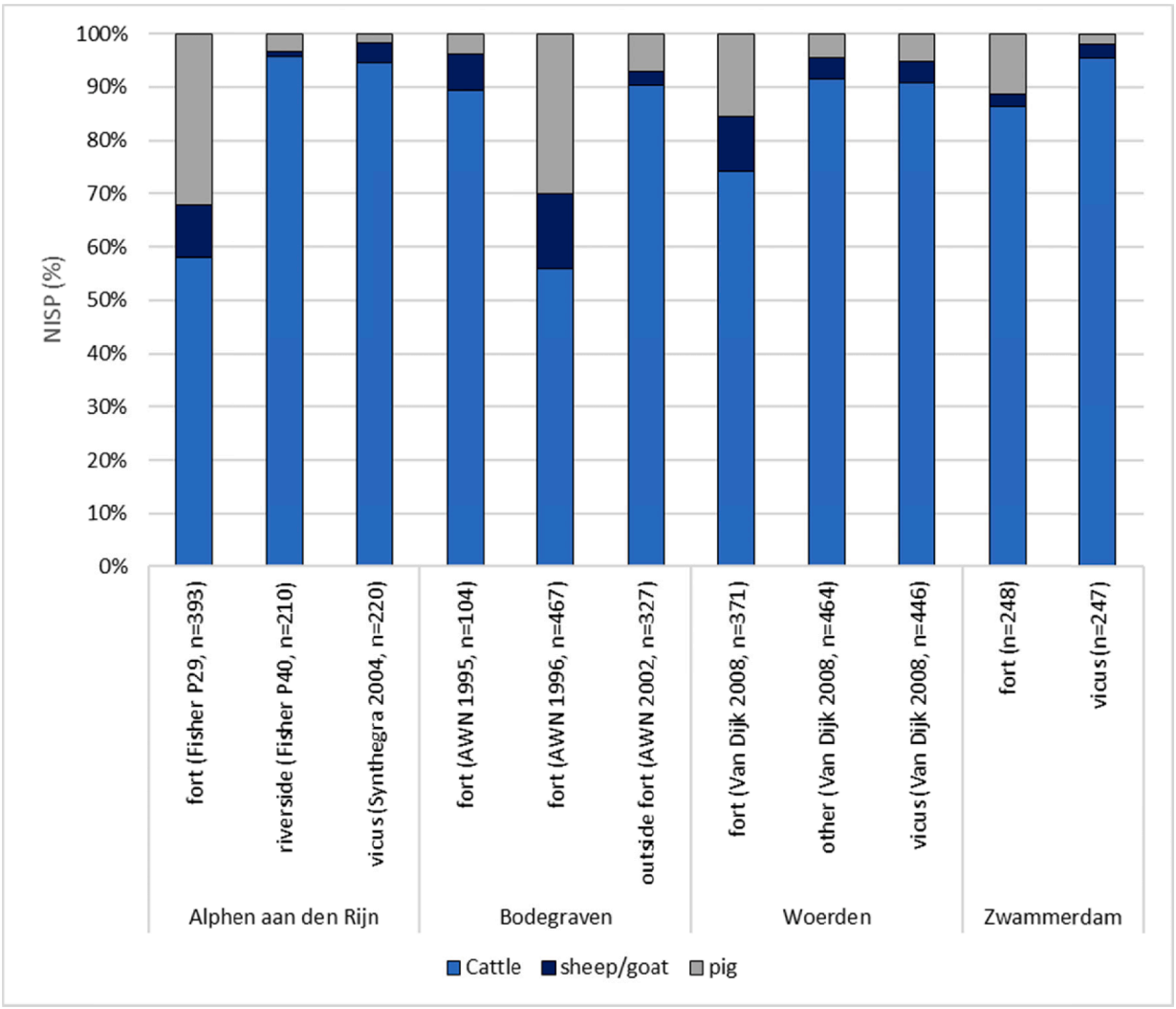

Fig. 8. Relative abundance of cattle, sheep/goat and pig for archaeozoological samples of Alphen aan den Rijn, Bodegraven, Woerden and Zwammerdam (after Van Dijk 2008, Van der Kuijl 2006, Lauwerier et al. 2005).

contribution of sheep/goat and pig, was dated before 70 CE, while the other samples are dated after 70 CE (Van Dijk, 2008). Unfortunately, no chronological information is available for the samples from Alphen aan den Rijn. In the case of Zwammerdam, results showed a decrease in sheep/goat and pig after 70 CE, but this decrease is less than 1 % and does not clearly signify a real change (Fig. 7). Additional research focusing on context and more precise dating (as planned in the *Romeinse vicus aan de Rijn* project), can highly contribute to better understanding these differences and uncertainties.

All in all, it seems that the percentages of sheep/goat and pig decline throughout time in the region studied, while the percentage of cattle increases, possibly related to a change in consumption preference. Such a change is consistent with the idea that the diet of the inhabitants of a fort and its associated *vicus* was quite similar (Kooistra et al., 2013). Both the *vici* at Woerden and Zwammerdam were established a few decades after the fort was first built. If a difference in diet, for instance a preference for cattle, could be observed after the *vici* came into being, then this might be related to an influence of the *vicus* inhabitants. While it is not known what ethnicity these inhabitants had (Groot, 2018; Thomas and Stallibrass, 2008), differences in diet might be related to different customs or ethnicity (Thomas and Stallibrass, 2008). With the establishment of the *vicus* and its inhabitants, the general consumption pattern of the settlement might have changed. An increase in cattle frequency can be related to a decrease of pigs, as suggested by Cavallo et al. (2008) but such increase might also be related to a local preference for cattle, which seemed to be the case in the late Iron Age and Early Roman Netherlands (Çakirlar et al., 2019; Van Dijk and Groot, 2013). Local inhabitants in rural areas seem to have set such husbandry strategies since the Bronze Age and might have influenced the dietary patterns of the Roman military with their own preferences (Çakirlar et al. 2019). The idea of a local 'native' and a military diet (as presented, amongst others, by Groot and Deschler-Erb, 2017; Lauwerier et al., 2005; Van Dijk, 2008), might still apply in this scenario, but a factor of time and especially changing and mixing preference over time, should also be taken into account.

More research is however needed to properly investigate this theory. The data available at the moment have too few samples dated to the same period and the theory presented above is based on only four settlements. Other factors might be of influence, and until more data and more settlements are included, these ideas will remain mere speculations.

6. Conclusion

About 50 years ago the first excavations of the Roman settlement of *Nigrum Pullum* at Zwammerdam were carried out. Both these and more recent excavations have yielded archaeozoological remains of the Roman occupation. It was the aim of this study to combine the older and

more recent data from Zwammerdam – *Nigrum Pullum* to get a more detailed synthesis of the archaeozoological data and gain more information about animal use within the Roman settlement.

Previous archaeozoological publications of Zwammerdam focus on some of the archaeozoological remains from the fort occupation. By combining data from old and new excavations and using a more integrated archaeozoological approach, it became possible to compare animal use and consumption in the fort and in the *vicus* throughout time. There was no significant difference between the analysed remains from the fort and the vicus, and animal use and consumption was most likely quite similar in the two parts of the settlement. Cattle remains were the most abundant within all samples and within all time periods of the settlement.

Although in some ways difficult to compare with other sites in Alphen aan den Rijn, Bodegraven and Woerden, the archaeozoological data from Zwammerdam showed a similarity in animal exploitation among sites where cattle is always the most abundant species. There were some differences between the samples in the percentage of sheep/goat and pig compared to cattle, although it is not yet clear how these differences can be best explained.

Although new insights in animal exploitation in the *vicus* and fort of Zwammerdam – *Nigrum Pullum* have been revealed, new questions were additionally brought to light. The first step to answer these new questions would be to re-analyse the remaining archaeozoological material from the old excavations in order to gain a broader archaeozoological sample. Most importantly, further research, or a re-analysis of older data, should be as interdisciplinary as possible as is the intention of the *Romeinse vicus aan de Rijn* project. Without the inclusion of other types of archaeological data, needed for chronology and contextual information, a detailed analysis of the remains from Zwammerdam would not have been possible. Without this data, the information gained from the archaeozoological analysis will always remain just a small part of the total picture.

The analysis of the archaeozoological remains from Zwammerdam has brought forward new information about the Roman settlement and more is known now about *Nigrum Pullum* than 50 years ago. With this new information, new opportunities for further research have come to light. A few pieces of the puzzle have been added, waiting for more to be discovered.

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.

Data availability

The data have been made available as supplementary data to this article.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jasrep.2022.103728.

Table S1: Catalogue of studied material with reference to taxonomical, anatomical, biological (sex, age) and taphonomical data. Codes following Lauwerier (1997). Table S2: Dental data for age estimation. Codes following Lauwerier (1997) and Grant (1982). Table S3: Taphonomical and pathological data. Codes following Lauwerier (1997). Table S4: Osteometrical data. Codes following Lauwerier (1997) and von den Driesch (1976). Table S5: Association. Codes following Lauwerier (1997)

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