Archaeological Research in Asia 38 (2024) 100514

Contents lists available at ScienceDirect

Archaeological Research in Asia

journal homepage: www.elsevier.com/locate/ara

Full length article

Animal use in Han dynasty cities: Zooarchaeological evidence from Yishengci, Nanyang (China)

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ARTICLE INFO

Keywords:
Yishengci
Nanyang
Han dynasty
Urban zooarchaeology
Animal exploitation

ABSTRACT

Using zooarchaeological methods, this article examines and discusses the faunal remains recovered from a Han dynasty non-elite residential site in Yishengci, situated in the southeastern corner of the ancient city of Wan (Nanyang, Henan Province). Despite its limited size, the assemblage provides valuable insights into the local economy, which the relative taxonomy suggests was predominantly agricultural, with pigs, cattle, and dogs being the most prevalent species. Pigs played a crucial role as meat producers, with cattle and dogs also contributing to a lesser extent. The evidence points to the exploitation of animals for traction in addition to the manufacture of animal-derived products including the use of horns and antlers for tool-making. Patterns in faunal mortality and biometry suggest that animals served as a meat source for the urban population and supported intensive small-scale agriculture in the surrounding area. Population size, land management and high-yield farming production were important factors that shaped, and were shaped by animal use at Yishengci. This research contributes to a better understanding of the subsistence strategies that supported the increasing urbanization during the early empire, supplementing what is predominantly known from historical texts and iconography.

1. Introduction

Chinese zooarchaeology has largely focused on the pre-imperial period (i.e. prior to 221 BCE) with studies of ancient domestication (Lu, 2010; Yuan and Flad, 2002), regional trajectories (Flad et al., 2007; Yuan et al., 2007; Dong and Yuan, 2020), secondary products (Yu, 2020; Brunson et al., 2016; Li et al., 2014) and craftsmanship (Hou et al., 2018; Campbell et al., 2011). More recently, the relationship between animal resources exploitation strategies and evolving socio-economic complexity in early China has been investigated through provisioning of prehistoric villages economies (Festa et al., 2023; Li et al., 2020; Hou et al., 2019) and large elite centers in the Central Plain and the Guanzhong region (Campbell et al., 2011; Flad, 2008; Yuan and Flad, 2005).

The main objective of most of these studies, however, seems to be understanding the domestication process and early exploitation of the *six livestock* (liu chu) (cattle, horse, sheep, pig, dog, chicken) (Yuan, 2015). As a result, the research focus has been on the prehistoric (5000–3000 BCE) and ancient (2000–221 BCE) ages, leaving a large gap in our understanding of the role of animals in the socio-economic dynamics of early Imperial China (221 BCE-220 CE) (Table 1).

As of now, zooarchaeological research pertaining to the Han Dynasty era (206BCE-220CE) remains scant. Recent scholarly endeavors, however, have begun to shed light on animal exploitation practices in Northwest China (Li et al., 2023; Dong et al., 2022; Wang et al., 2023; Zong et al., 2021). Despite these advances, research is still predominantly confined to brief sections within archaeological reports, which usually include limited data on the bones with only basic identification analyses conducted (Liu and Jiao, 2019; Hu and Yang, 2010; Hu et al., 2006; Chen et al., 2021). In the majority of cases, these faunal remains are from mortuary contexts rather than residential.

The scarcity of zooarchaeological studies for Imperial China can be attributed to the prevailing assumption that the empire primarily relied on agrarian production, relegating animal husbandry to a marginal role (Yü, 1977; Lu, 2014). There is also an underlying belief that the necessary information on animal exploitation strategies can be found in

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https://doi.org/10.1016/j.ara.2024.100514
Received 16 October 2023; Received in revised form 12 February 2024; Accepted 29 February 2024
Available online 12 March 2024
2352-2267/

Table 1
Chronology of Northern China associated with this study.

Period	Date	Age
Yangshao	5000–3000 BCE	Prehistoric
Longshan	3000–2000 BCE	Prehistoric
Erlitou	2000–1500 BCE	Ancient
Shang	1600–1050 BCE	Ancient
Western Zhou	1050–772 BCE	Ancient
Eastern Zhou	772–474 BCE	Ancient
Warring States	475–221 BCE	Ancient
Qin	221–206 BCE	Imperial
Han	207 BCE-220 CE	Imperial

textual references and by examining funerary art, especially figurines portraying domestic and wild animals, and murals painted with scenes illustrating everyday-life activities (Falkenhausen, 1993). This material, however, usually reflects the biased perspective of the elites, and rarely addresses the role of animals in the lives of ordinary people. Since non-elites would have made up the majority of the population, an understanding of their daily activities is essential to understanding how historical economies and societies functioned.

Despite its limited size, our zooarchaeological analysis of the faunal remains from the Yishengci non-elite site, located in the Wancheng district of Nanyang city, Henan Province (Fig. 1), provides valuable insights into the local animal economy. It suggests that animals served as a meat source for the urban population and supported intensive small-scale agriculture in the surrounding area. This study contributes to a more solid understanding of the subsistence strategies that underpinned the growing urbanization during the early empire and enhances the limited zooarchaeological information available from Han urban contexts.

1.1. Cities and subsistence strategies in the Han dynasty period

The Han dynasty period is considered one of the most economically, technologically, culturally and socially thriving in Chinese history (Jian, 2019). Such prosperity had far-reaching ramifications, including population growth, peaking at nearly 60 million people in 2 CE. This figure then declined to 21 million during the Western Han collapse, before recovering to over 50 million by 100 CE (cfr. Glahn von, 2016 and the references therein). Large part of the population lived in or around cities and settlements of various size in the Central Plains (Glahn von, 2016). This era saw a shift from the kinship-based Zhou dynasty urban system (1046–221 BCE) to an imperial, centralized administration with the capital at its core (Lincoln, 2021; Fu and Cao, 2019; Lewis, 2005). Below the capital sat commanderies from which officials directly appointed by the emperors controlled territories of different sizes. The Nanyang commandery, from its seat in Wan city, controlled an area of around 50,000 km^2 (Liang, 2008).

It is understood that during the Han Dynasty multi-crop millet, wheat and rice agriculture sustained these densely inhabited urban centers (Xia et al., 2022; Liao et al., 2022; Zhao, 2020; Zhao and Chang, 1999). Small-scale intensive farming by peasants, either as landowners or renters, became the backbone of the Han socio-economic development (Qin et al., 2019; Sadao, 1986; Twitchett and Loewe, 1986; Hsu, 1980). Numerous innovations, such as the introduction of iron plows and the widespread use of cattle both for traction and the use of their manure for fertilizer, enhanced agricultural productivity and allowed for the expansion of arable land (cfr. Hsu, 1980; Bray, 1979; Shen, 1998; Yang, 2001; Peng, 2010). Images of these innovations have been found depicted on funerary murals, further documenting the importance of agriculture to the rise and continuity of the Han empire (Jiang and Yang, 2001; Wang, 2009; Chen, 2018) (Fig. 2B).

Although most research to date has viewed animal husbandry as a marginal activity in the agrarian Han society (Yü, 1977; Lu, 2014), its socio-economic and cultural importance has gained recognition in recent years (Wang and Song, 2019; Zhou et al., 2017; Sterckx, 2002, 2005; Hou et al., 2012). Historical written records detail the treatment, trade, and ritual use of animals, particularly focusing on the socio-economic and military value of horses, and the role of dogs as household guardians and companions (Stercxk, 2006; Wang, 2006; Bray, 2018; Xie, 1977; Morgan, 1974). The broader aspects of domestic (and wild) animal exploitation remain, however, relatively underexplored in these records. Funeral art, including tomb figurines portraying domestic and wild animals and tomb murals painted with domestic scenes provide further insights into the diverse use of animals, from meat consumption, to aid in agriculture and hunting (Yang, 1991; An and Wang, 1972; Wang, 2009; Guo and Wang, 2020; Jiang et al., 2007) (Fig. 2). Yet, these figurines and murals found in prestigious graves likely reflect the practices and extent of animal use among Han society's elite rather than the non-elite.

1.2. Study area

Yishengci is situated between the Weiliang and the Bai rivers in present-day Wancheng (literally Wan city) district of Nanyang City,

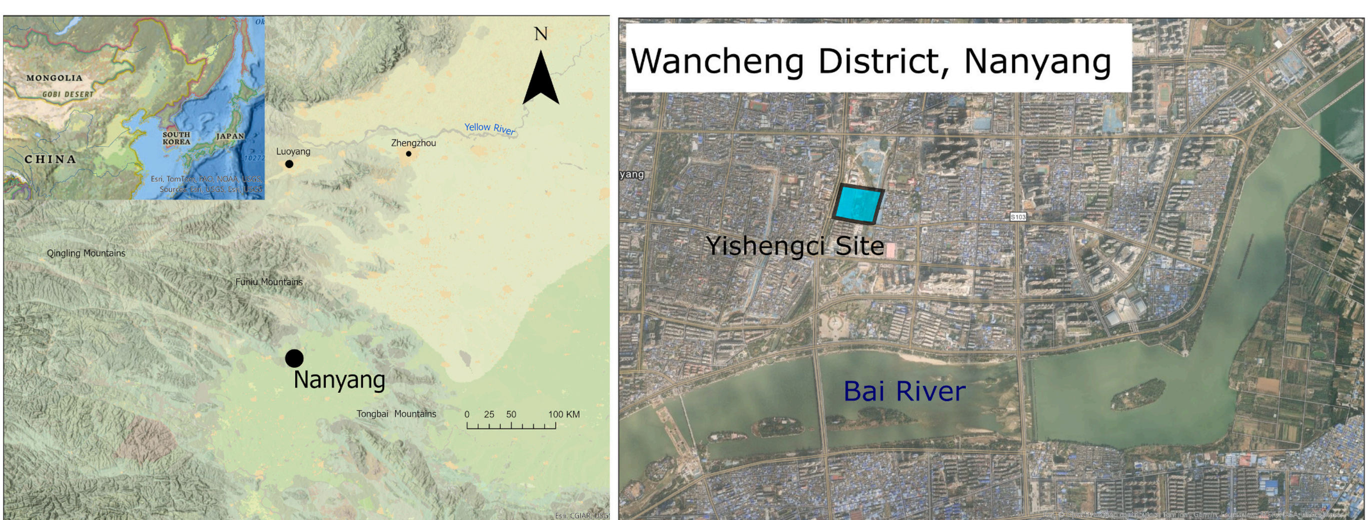

Fig. 1. Maps showing the location of Yishengci site in Wancheng district of Nanyang city. This figure was made by F.M. using ArcGIS Pro version 3.1.0 (www.esri.com).

Fig. 2. Archaeological material portraying animals: A) Ceramic model of a pigsty excavated from a Western Han tomb in Jiyuan, Henan (Henan Museum); B) Section of a Han dynasty grave stone, unearthed from Mizhi, Shaanxi, showing a farmer with a cattle plowing in the fields (Wang, 2009: 276); C) Rubbing of a Eastern Han stone relief from Yingzhuang, Nanyang, Henan, representing dogs hunting hares (Stercxk, 2006: 37); D) Hunting scene engraved on the lintel of an Eastern Han tomb in Dabaodang, Shenmu, Shaanxi (Guo and Wang, 2020: 245).

Henan Province (Fig. 1). The area is part of the Nanyang Basin, a rich agricultural plain surrounded by mountains on three sides – the Qinlin Mountains in the west, the Funiu Mountains in the north, and the Tongbai Mountains in the east. It has a high water table which is drained (and frequently flooded) by two main rivers, the Dan and the Huai, and their tributaries. The surrounding mountains are covered by woodlands, while the foothills and plains have been used for dry- and paddy-field agriculture since the early Neolithic period (Zhang, 2020; Chen, 2005). The Nanyang Basin has a sub-tropical monsoonal climate, with relatively reliable rainfall (700–1200 mm average per annum) (Jia et al., 2021; Zhang, 2020), which has allowed the cultivation of a variety of crops and plants. In the modern day these include wheat, corn, sorghum, tobacco, pepper, and potatoes. The main livestock are pigs and cattle, in addition to some caprines.

During the Han dynasty period, Wan city was the seat of the Nanyang commandery which has been traced to be located in the western section of the present-day Wancheng district of Nanyang city (Zhou, 2014; Li, 2010). The Nanyang commandery controlled 36 counties during the Western Han dynasty (206 BCE - 24 CE) and 37 counties during the following Eastern Han period (25 BCE – 220 CE), distributed across an area of ca. 50,000 km^2 (Liang, 2008). By pre-modern standards Nanyang was densely populated. *The Book of Han* (Hanshu, 28) and the *Book of the Later Han* (Hou Hanshu, 112) record a population of nearly 2 million people (ca. 360.000 households) in 2 CE, with an increase to 2.4 million (ca. 530.000 households) by 140 CE (cfr. Liang, 2008). Although Wan is reported to have been an agricultural focus and an important manufacturing center, which hosted an Iron Office, there are only the most basic references to the city in official historical texts (Zhou, 2001; Chen, 1993).

The degree of urban development has restricted the potential for excavation, and such archaeological work that has been conducted has not been fully published. The sites of iron and bronze foundries, as well as a workshop for ceramics have been excavated in the northern and eastern sides of the city providing a rare insight into pre-industrial manufacturing in Early Imperial China (Yang, 2001; Wang, 1994; Li, 1991; Han and Wang, 1956). The southern and western sections of ancient Wan are critically under-investigated, as a consequence, the exact borders of the ancient city remain uncertain (see Li, 2010). From such traces as do exist, it is believed that the settlement would have been roughly square, ca. 1.4 km per side, and surrounded by ca. six-meters wide walls and a moat, making it a fair sized urban center in the Han dynasty period (Li, 2010; Zhou, 2001).

From April to August 2021 the School of Cultural Heritage of Northwest University and the Nanyang Institute for the Preservation of Cultural Heritage undertook a rescue archaeology project in the Yishengci neighborhood of Wancheng district (Northwest University School of Cultural Heritage, Nanyang Institute for the Preservation of Cultural Heritage, 2024). During the preliminary survey, a residential site was identified in what is believed to have been the south-eastern corner of the Han city of Wan. Four locations (T1-T4) were selected for excavation, with a total area of 250m^2 being cleared. Features discovered at the site included houses, ash pits and wells (Fig. 3A).

Numerous artifacts characteristic of the Han dynasty, including pottery sherds, coins, and metal utensils, were discovered alongside animal bones in both the features and layers. The absence of later findings suggests that the deposit was undisturbed. These remains have been dated to the Han period through stratigraphic analysis and taxonomic typologies of the unearthed structures, earthenware, stoneware, and coins (Figs. 3B-E), with the distinctively Han materials serving as key indicators of the era.

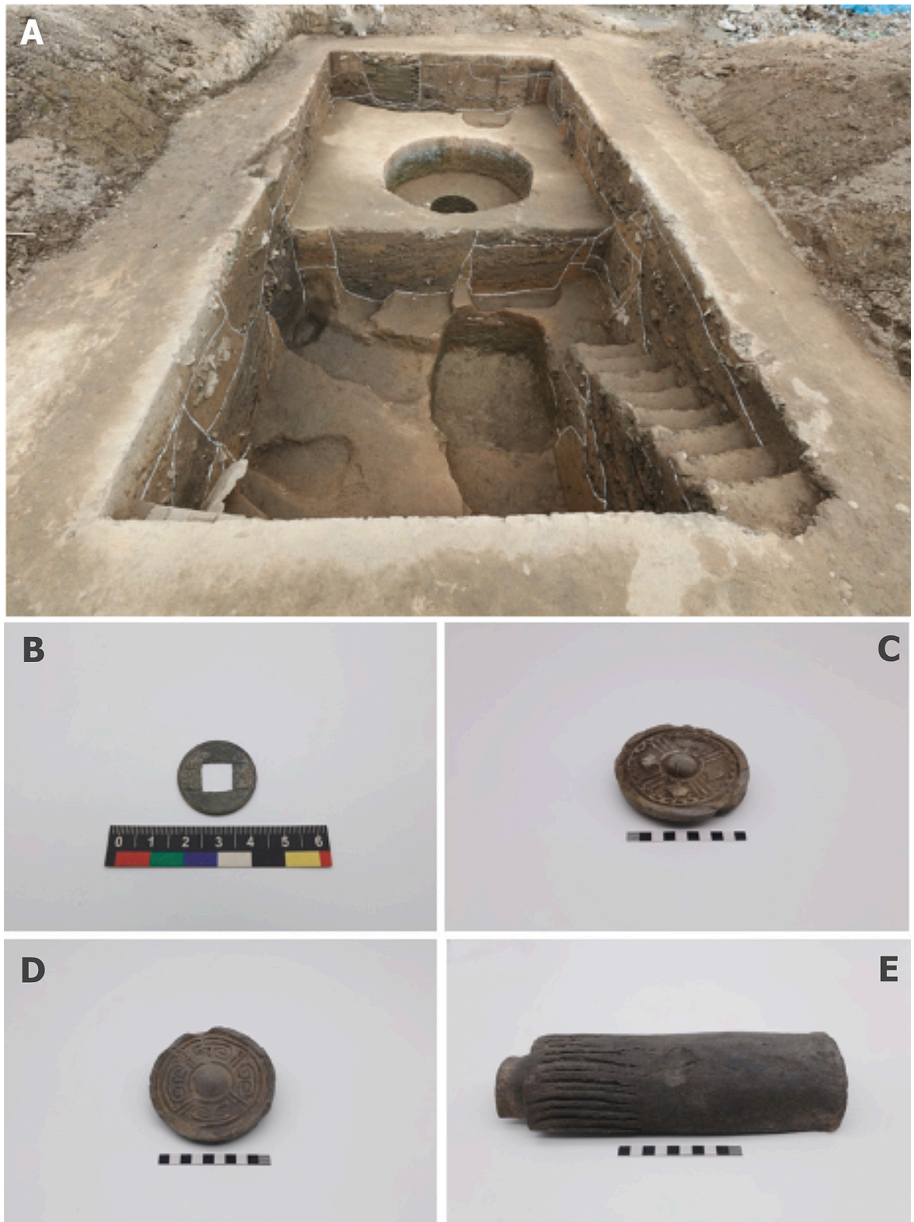

Fig. 3. Excavation site (partial) and cultural material unearthed from Yishengci: A) T2 seen from southwest; B) Han dynasty copper coin; C, D, E) Han dynasty tiles.

2. Materials and methods

Faunal remains used in this study were recovered from 4 locations (T1, T2, T3 and T4) at Yishengci, in Wancheng district of present-day Nanyang city (Henan Province) in 2021. Hand selection was employed during excavation, but no sieving. The faunal assemblage totaled 973 fragments, 70 of which were worked elements or debris of bone working. The analysis of the bones was conducted at the School of Cultural Heritage at Northwest University (Xi'an). Taphonomic processes – fragmentation, sub-aerial weathering (Behrensmeyer, 1978), burning (Stiner et al., 1995), gnawing (Fisher, 1995) – and human modifications (Costamagno et al., 2019) were quantified on all fragments. The completeness of bones was recorded differently for identified and non-identified bones: the former was measured according to proportion of the whole bone (≤25%, 25%–50%, 50%–75% and ≥ 75%); for non-identified specimens, maximum length was recorded (≤5 cm, 5 cm–10 cm, 10 cm–15 cm, ≥15 cm).

Identification was attempted for every fragment using our reference collection at the School of Cultural Heritage of Northwest University, online reference resources (e.g., archaeozoo.org, boneID.net) and published identification manuals (e.g., France, 2009; Hillson, 1992; Schmid, 1972). All identified bones were used to calculate the Number of Identified Specimens (NISP) and Minimum Number of Individuals (MNI). We employed Clason's (1972) method, which limits the risk of counting fragments from the same element more than once and, therefore, reduces the boost of large-size specimens. Because of the limited availability of specimens in our reference collection and the uncertainties surrounding the standards to distinguish sheep and goats (Salvagno and Albarella, 2017; Zeder and Lapham, 2010; Zeder and Pilaar, 2010), the two were combined into the "caprine" category. Two deer species, Sika (*Cervus nippon*) and Siberian Roe deer (*Capreolus pygargus*) were identified on the basis of sufficiently well-preserved antlers, while the rest of the remains were classified as "Unidentified deer". MNI and MNE (Minimum Number of Elements) for domestic animals was calculated on the basis of diagnostic zones present according to Dobney and Rielly (1988).

Mortality profile for pigs was generated on the basis of tooth eruption and wear using Lemoine et al.'s (2014) which allows both mandibles and maxillae to be considered. We specifically employed their "Simplified A Age System" as it is appropriate for the size of our sample. The results were cross-referenced with few bone epiphyseal fusion data, which were obtained using Zeder et al.'s (2015). Age-at-death for cattle was calculated through bone epiphyseal fusion analysis (O'Connor, 2003) and cross-referenced with information from the dental analysis of only 9 elements available. Given the scarcity of complete mandibles (n = 2), we employed Jones and Sadler (2012)'s method, which works relatively well with loose teeth. Dogs' age-at-death was calculated using epiphyseal fusion and dental data (Silver, 1969).

Bones measurements were taken using an electronic caliper according to von den Driesch (1976) standard measurements, and examined through Log Size Index (LSI) method, which is particularly efficient when few measurable specimens are available (Meadow, 1981, 1984). Limitations of this method include possible variations in shape, which in turn may affect body proportions, and systematic variations in proportions caused by a variety of factors such as age, sex, and local environment. The latter could partially be mitigated by using standard animals from a close and environmentally similar region. In particular, pigs are rather regionally variable in size and shape (Albarella et al., 2009), therefore a reference specimen from Northern China should ideally be used. Comprehensive skeletal measurements for pigs in Northern China are not available, however, Luo (2012) has provided average length measurements of the distal humerus (n = 117), distal tibia (n = 65), and proximal radius (n = 42) of domestic pigs from Heihelu, Anyang, dating to the Late Shang period. Since our sample predominantly includes these three skeletal elements, Luo's measurements were utilized to assess the size of pigs at Yinshengci against a regionally relevant standard. However, the criteria for Luo's measurements remain unclear, rendering the results not entirely reliable. To address this, we cross-referenced our findings with measurements of a mature, medium-large sized female wild boar from Central Europe (Russel, 1993) for which von den Driesch, 1976 had been used as standard.

Lower M3 measurements were also taken to investigate pig domestication status, and cross-examined against the values in Yuan (2001), which provides geographically-relevant comparative standard sizes.

For cattle, we firstly used the late Pleistocene (likely female) aurochs from Dabusu (Jilin Province) as standard animal, whose biometrical data are currently the only available for bovines in Northern China (Tang et al., 2003). However, only 24 measurements, which were distributed on 7 elements, are available for this Chinese specimen. In order to increase our sample size, we also used Degerbol and Fredskild (1970) Mesolithic wild bovine's size values as reference, which allowed more measurements to be considered.

Dog, caprine, and horse evidence was either unsuitable or insufficient for biometrical analysis.

Worked skeletal elements were identified into the lowest identifiable taxonomic unit and, when possible, classified according to their possible function considering shape, size and use-wear.

3. Results

The faunal assemblage consisted of 973 fragments, 70 of which were worked specimens. These were considered along with unworked elements in the distribution and taphonomic analysis, but their taxonomic examination was conducted separately, as well as the analysis of anthropogenic taphonomy.

3.1. Distribution and taphonomy (Table 2)

Most of the skeletal elements were discovered in T2 (39.8%) and T3 (47%), with considerably less specimens found in T4 (8.8%) and even less in T1 (4.4%). The number of finds does not appear to correlate to the size of the trenches, as T1, T2 and T4 all measured around 50m^2, and only T3 was wider, measuring ca. 100m^2. T2, T3 and T4 were richer in features related to anthropomorphic activities, while T1 was almost void (Northwest University School of Cultural Heritage, Nanyang Institute for the Preservation of Cultural Heritage, 2024). Unfinished worked elements were not clustered, but sparsely distributed across the four excavated units. Although the micro-environment may influence bone preservation rates, the observed consistency in non-anthropogenic taphonomic factors across different locations, taxa, and elements suggests that the uneven distribution of faunal remains is more strongly related to variations in human utilization of space.

Table 2
Quantification of the taphonomic processes affecting the faunal remains in Yishengci (* worked bones have been excluded from the count).

Taphonomic process	Degree	Number	%
Fragmentation (Identified elements)	≤25%	302	31.0
	25%–50%	153	15.7
	50%–75%	99	10.2
	≥75%	146	15.0
Fragmentation (Non-identified elements)	≤5 cm	119	12.2
	5-10 cm	117	12.0
	10-15 cm	30	3.2
	≥15 cm	7	0.7
Total		**973**	**100.0**
Weathering (Behrensmeyer, 1978)	L-0	543	55.8
	L-1	104	10.7
	L-2	246	25.3
	L-3	73	7.5
	L-4	6	0.6
	L-5	1	0.1
Total		**973**	**100.0**
Gnawing	Yes	138	14.2
	No	835	85.8
Total		**973**	**100.0**
Burning	Yes	35	3.6
	No	938	96.4
Total		**973**	**100.0**
Butchery*	Yes	201	22.3
	No	702	77.7
Total		**903**	**100.0**

The assemblage was characterized by a fairly high fragmentation rate, with around a half of the identified specimens being <50% of the original bones. Extensive light to moderate weathering was observed, with some elements more heavily weathered, probably as a result of the exposure to varying micro-environmental conditions (Behrensmeyer, 1978).

Rate of gnawing was fairly high (14.2% of the fragments)There appear to have been various taxa gnawing, including carnivores (dogs, pigs and cats, 13.5% of the fragments), rodent (0.2%) and possibly sheep (0.5%) (Fisher, 1995). This could be explained by the presence of almost all of these animals in the assemblage, the lack of rodents likely being due to recovery bias against small animals and elements. 3.6% of the elements from Yishengci were burned to different degrees from brown to black (Stiner et al., 1995).

Anthropogenic taphonomy included a relatively high frequency of butchery marks (22.3% of the specimens) (Costamagno et al., 2019). These marks mostly consisted of chops and cuts on long bones shafts, although they were occasionally present on other elements, such as skulls, mandibles, vertebrae and horns.

The fairly high rate of fragmentation, old breaks and gnawing, combined with the presence of cultural features, including residential structures, bones and antlers unfinished artifacts, suggests that our assemblage was consumption and production waste.

3.2. Taxonomy

By considering fragments that could be cross-mended as one (Clason, 1972), we counted 903 specimens (excluded worked bones). Mammals dominated the assemblage (98% of the fragments), with the remaining finds consisting of birds (1.4% of the fragments), mollusks (0.3% of the fragments), reptiles (0.2% of the fragments) and fish (0.1% of the fragments) (Table 3).

The overall paucity of remains of small-size animals and small bones can be explained by recovery bias, especially the overall lack of sieving. 66.8% ($n = 604$) of the skeletal elements could be identified to family and beyond (Table 4).

Domestic mammals prevailed, with pig being the best represented taxon by NISP (43.9% NISP) followed by cattle (28.9% NISP) and dog (10.4% NISP). A smaller percentage of horses (5.5% NISP) and caprines (4.5% NISP) was identified, while all other taxa were comparatively under-represented at <1% NISP. NISP and MNI were quite consistent, although cattle were better represented by NISP than by MNI (6.8% MNI) (Table 4). Cattle MNI was considerably lower compared to pigs (42.2% MNI), and even slightly lower than dogs (8.2% MNI). This is could partially be due to the fairly high rate of fragmentation of our assemblage which had more likely affected larger cattle bones rather than smaller elements of medium-size mammals. Fragmentation attrition and interdependence of skeletal elements can also explain the better representation of small mammals and non-mammals by MNI than by NISP. Smaller elements are usually less fragmented than bigger ones, resulting in the boosting of their proportion and the overrepresentation of “rare” species, such as turtles and fish (Lyman, 1994; Grayson, 1984).

Wild mammals included deer, and few wild canids, such as fox (*Vulpes vulpes*), racoon dog (*Nyctereutes procyonoides*), dhole (*Cuon alpinus*) and wolf (*Canis lupus*), and cats (*Felis* sp.). As we believe that our faunal remains were consumption waste, some bones of wild and semi-wild medium mammals, and potentially some birds, may have ended up in our assemblage as the result of scavenging activities, although the practice of small-scale hunting should also be considered.

3.3. MNE (Fig. 4)

MNE analysis results for pigs indicate an over-representation of cranial elements, a fair representation of the front limbs and a significantly lower frequency of other elements. Cattle MNE results show that, while denser bones, such as metapodial shafts and scapula, were unsurprisingly slightly better represented, all skeletal elements were consistently present. Dog specimens were also proportionally represented in the assemblage, the over-representation of the mandible possibly due to preservation bias (Fig. 4).

MNE patterns for cattle and dogs notably differ from that observed for pigs. The uneven representation of pig elements can be explained by a combination of biases: the small size of our sample ($n = 90$) may have distorted the results; density attrition can explain the high number of mandibles, which were the best represented element (Lyman, 1994); lack of feet and axial bones can be motivated by recovery bias against small elements. Specific butchery practices and consumption preferences might have also contributed to the unbalanced body parts representation of suids at the site (Dobney et al., 1996); however, the relatively small sample sizes (pig, $n = 90$; cattle, $n = 61$; dog, $n = 35$) mean that, although the evidence cannot be completely dismissed, it is somewhat limited in fully supporting this conclusion.

Table 3
Faunal composition of the Yishengci assemblage.

Category	Number	%
Mammals	883	98
Birds	14	1.4
Mollusks	3	0.3
Reptiles	2	0.2
Fish	1	0.1
Total	**903**	**100**

Table 4
NISP and MNI of faunal remains from Yishengci (worked elements have been excluded). Numbers in parentheses are antler fragments, included in counts.

Taxon	NISP	NISP %	MNI	MNI%
Mammals	**584**	**96.7**	**57**	**78.1**
Pig *Sus scrofa domesticus*	265	43.9	31	42.4
Cattle *Bos taurus*	175	28.9	5	6.8
Dog *Canis familiaris*	63	10.4	6	8.2
Horse *Equus caballus*	33	5.5	3	4.1
Caprine *Ovis aries/Capra hircus*	27	4.5	2	2.7
Racoon dog *Nyctereutes procyonoides*	4	0.7	2	2.7
Red Fox *Vulpes vulpes*	4	0.7	1	1.4
Water Buffalo *Bubalus* sp.	1	0.2	1	1.4
Siberian roe deer *Capreolus pygargus*	(1)	0.2	1	1.4
Sika deer *Cervus nippon*	(1)	0.2	1	1.4
Unidentified deer	2 (5)	1.2	1	1.4
Dhole *Cuon alpinus*	1	0.2	1	1.4
Wolf *Canis lupus*	1	0.2	1	1.4
Cat *Felis* Sp.	1	0.2	1	1.4
Birds	**14**	**2.3**	**8**	**11**
Goose *Anser* sp.	4	0.7	2	2.7
Curlew *Numenius* sp.	1	0.2	1	1.4
Unidentified anatid	1	0.2	1	1.4
Unidentified phasianid	1	0.2	1	1.4
Unidentified galliformers	2	0.3	2	2.7
Unidentified bird	5	0.8	1	1.4
Fish	**1**	**0.2**	**1**	**1.4**
Common carp *Cyprinus carpio*	1	0.2	1	1.4
Reptiles	**2**	**0.3**	**2**	**2.7**
Soft shell turtle Trionychidae	2	0.3	2	2.7
Mollusks	**3**	**0.3**	**3**	**4.1**
Unidentified shell	3	0.5	3	4.1
Total	**604**	**100**	**73**	**100**

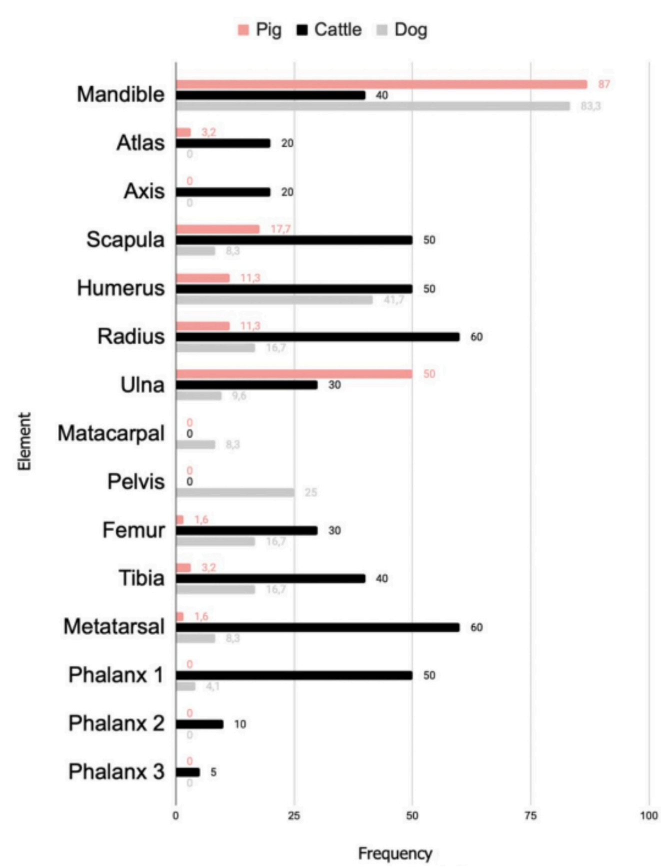

Fig. 4. Skeletal elements distribution for pigs, cattle and dogs from Yishengci.

3.4. Age-at-death

Since the assemblage was relatively small, mortality profiles were only created for sufficiently well-represented domestic taxa, i.e., pig, cattle and dog.

The results of pig tooth eruption and wear analysis (Lemoine et al., 2014) showed a fairly early killing pattern, with around 65% of the specimens slaughtered before 1.5 years of age (Fig. 5A). Long bone fusion analysis of a small-size sample ($n = 19$) showed a comparable trend, although several age groups were missing (Fig. 5B). This profile is consistent with the production of meat and lard, with the small group which survived to an older age potentially being kept for breeding and animal capital.

Cattle long bone epiphyseal fusion analysis results display a rather late killing pattern (Fig. 6A). Only 2 mandibles and 7 loose teeth were available for dental analysis, and although the outputs cannot be considered representative, they too indicated the presence of adult and elderly specimens (Jones and Sadler, 2012). These results suggest that the primary use of cattle was for secondary products. Mural images of cattle working in the fields discovered in graves dating to the Han dynasty period points at traction and transportation as significant exploitation strategies for this species (Fig. 2B). We observed some deformations on metapodials and phalanxes ($n = 15$), which could be consistent with persistent pulling (Fig. 6B) (Bartosiewicz, 2008; Armour-Chelou and Clutton-Brock, 1985). We cannot completely rule out that cows were milked, but there is little evidence of substantial dairy production and consumption in the Han period in the Central Plains (Sabban, 1986). Adult specimens were also exploited for meat, as suggested by bones breakage patterns and the fairly high rate of butchery marks (Fig. 6C) (Costamagno et al., 2019).

Dog epiphyseal fusion analysis results (Silver, 1969) were rather nonsensical, which was expected given the small size of the sample ($n = 20$; Fig. 7A). There were only 9 mandibles usable for teeth eruption and wear analysis. They all carried permanent teeth, implying that our specimens were older than 8 months (Silver, 1969). As a whole, our results reveal the presence of individuals at various age stages, but we did not find evidence of potentially human-driven killing practices.

3.5. Size

Our assemblage did not comprise a sufficient number of long bones with fused proximal and distal epiphyses, which would have been optimal specimens for measurement (von den Driesch, 1976). The analysis was largely conducted on partial long bones shafts with one of the two epiphyses fused and phalanges.

There were very few measurable pig bones, as detailed in Tables S1 and S2. LSI results highlighted some size variations among the Yishengci pig specimens, with several being larger than Luo (2012)'s Chinese domestic pig (Fig. 8A). These observations are consistent with those obtained using measurements from Russel (1993), which showed several specimens as large as, or even larger than, the reference wild boar, hinting at the possible inclusion of wild suids in the assemblage (Fig. 8B). Further evidence supporting the existence of large pigs, and possibly wild specimens, at the site is provided by the size of eight lower third molars (M3). When compared with Yuan (2001)'s standards for domestic suids in Northern China (maximum length: 31.4 mm; maximum width: 14 mm), the results suggest the presence of a mixed pig population at Yishengci (Table S3).

Postcranial elements of cattle measured and examined through LSI method against the standard aurochs from Dabusu (Tang et al., 2003) showed that the size of all of the specimens at Yishengci were smaller than the reference animal, with two bones being around the size of the wild standard bovine's counterparts (Fig. 8C; Table S4). The sample of bones usable for this analysis was small (n = 15), however, as few measurements are available for the reference animal from Northern China. A larger pool of measurements ($n = 31$) could be used when they were examined using Degerbol and Fredskild (1970)'s aurochs as a standard animal (Table S5). Cattle metrical analysis results show that some specimens were fairly large, most of them being only slightly smaller than the wild bovine reference. Smaller cattle elements included one particularly small metatarsal bone (Fig. 8D).

The presence of values larger than Degerbol and Fredskild (1970) 's standard female bovine would suggest that wild specimens were present in this assemblage (Fig. 8D). It has however been previously demonstrated that wild bovines played a limited role in Northern Chinese subsistence and agriculture after the Neolithic (Yu, 2020). Regional size variability could provide an explanation for our large specimens. For instance, the measurement of the GLP of the scapula ID 754 from our study is negative (i.e. likely domestic) when using the Chinese animal reference, but it is positive (i.e. possibly undomesticated) when compared to the European aurochs standards (Tables S4, S5). As Tang et al. (2003)'s specimen is more geographically relevant, there is a significant chance that large bovine bones from Yishengci represent larger domestic animals. In addition, the 2 values that are positive in the LSI analysis using Degerbol and Fredskild (1970) bovine as the standard animal are from one phalanx 1 (ID 87) and one scapula (ID 754)

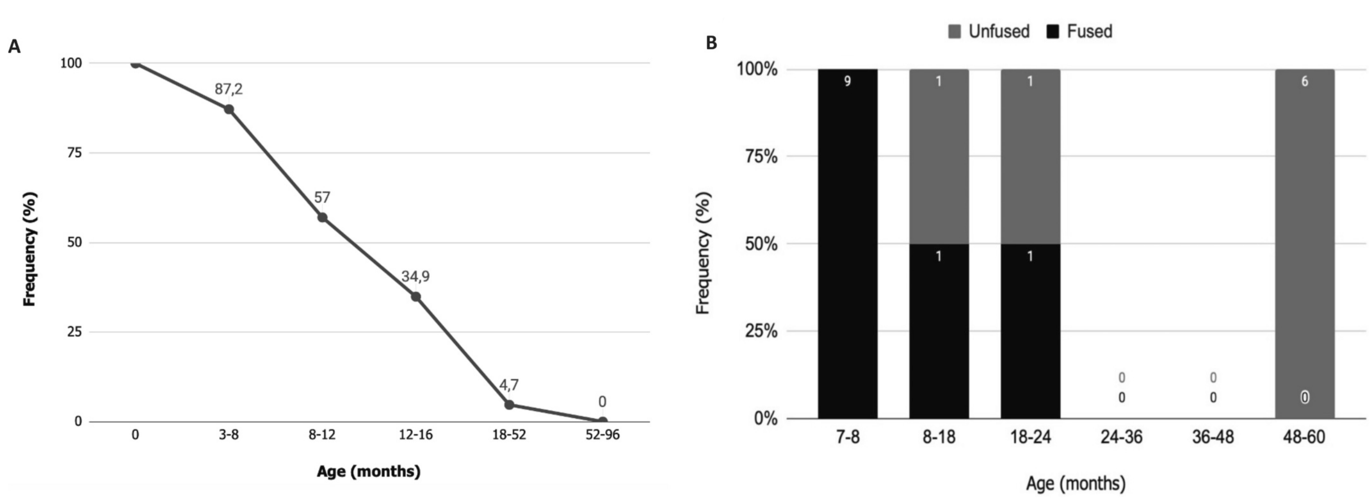

Fig. 5. A) Pig survivorship from dental eruption and wear ($n = 86$) using Lemoine et al. (2014); B) Age-at-death from epiphyseal fusion (n = 19) using Zeder et al. (2015). Age class 7–8 was defined by the fusion status of the proximal radius (n = 6), and the scapula ($n = 3$); Age class 8–18 was defined by the fusion status of the distal humerus ($n = 2$); Age class 18–24 was defined by the fusion status of the distal tibia (n = 2); Age class 48–60 was defined by the fusion status of the proximal tibia (n = 2), the distal radius (n = 1) and the ulna (n = 3).

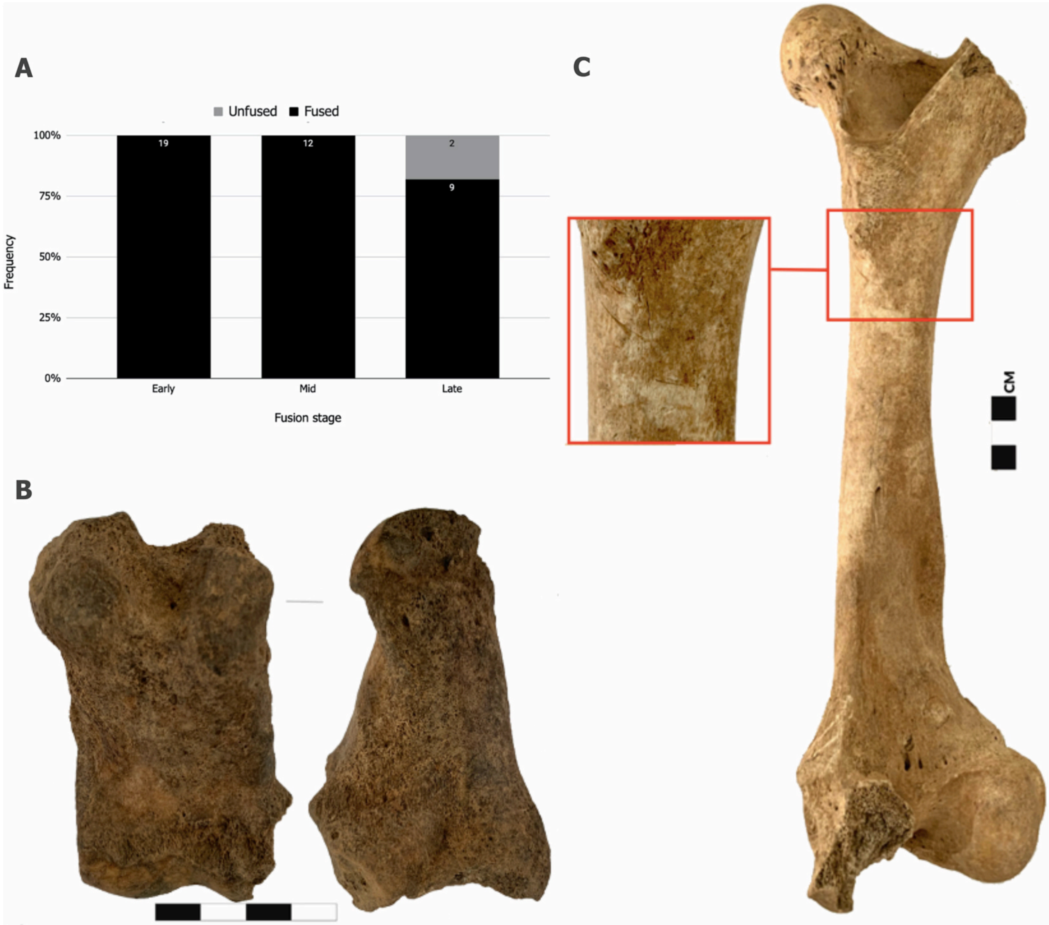

Fig. 6. A) Cattle survivorship from epiphyseal fusion (n = 42), using O'Connor (2003). Age class "Early" was defined by the fusion status of the proximal radius (n = 4), the distal humerus (n = 3), scapula (n = 3) and the first (n = 8) and second phalanges (n = 1); Age class "Mid" was defined by the fusion status of the calcaneus (n = 2), the metacarpus (n = 5), the metatarsus (n = 3) and the distal tibia (n = 2); Age class "Late" was defined by the fusion status of the femur (n = 4), proximal tibia (n = 2), proximal humerus (n = 2), ulna (n = 1) and distal radius (n = 2). B) Deformed cattle first phalanx; C) Cuts on cattle femur.

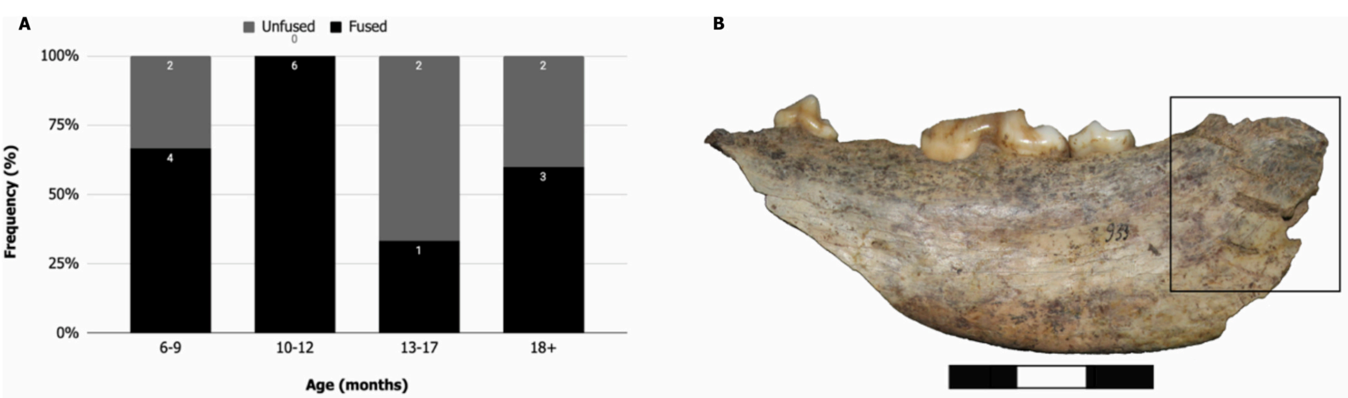

Fig. 7. A) Dog survivorship from epiphyseal fusion (n = 20) calculated on the basis of Silver (1969). Age class 6–9 was defined by the fusion status of the distal humerus (n = 5) and the first phalanx (n = 1); Age class 10–12 was defined by the fusion status of the radius (n = 3) and ulna (n = 3); Age class 13–17 was defined by the fusion status of the proximal humerus (n = 2) and the distal tibia (n = 1); Age class 18+ was defined by the fusion status of the proximal tibia (n = 3) and the femur (n = 2). B) Butchery marks on canid mandible.

(Table S5). Foot elements are affected by sub-pathologies related to persistent pulling, sometimes manifesting as enlargements of the proximal surface (Bartosiewicz, 2008). Deformations relating to stress and haulage were observed on some bones from Yishengci, including phalanges (Fig. 6B), which, when identified, were naturally excluded from the biometrical analysis. Animal use for draught can also result in alterations of the shape of the scapulae, although few studies have been conducted on this specific matter (Vuure van, 2005). As the identification of domestic Bos, wild Bos, and Bubalus is challenging due to the morphological similarity of the bones (Brunson et al., 2016), the presence of larger buffalo could potentially explain the large bones we have discovered (Yang et al., 2008). Considering all the above, we believe

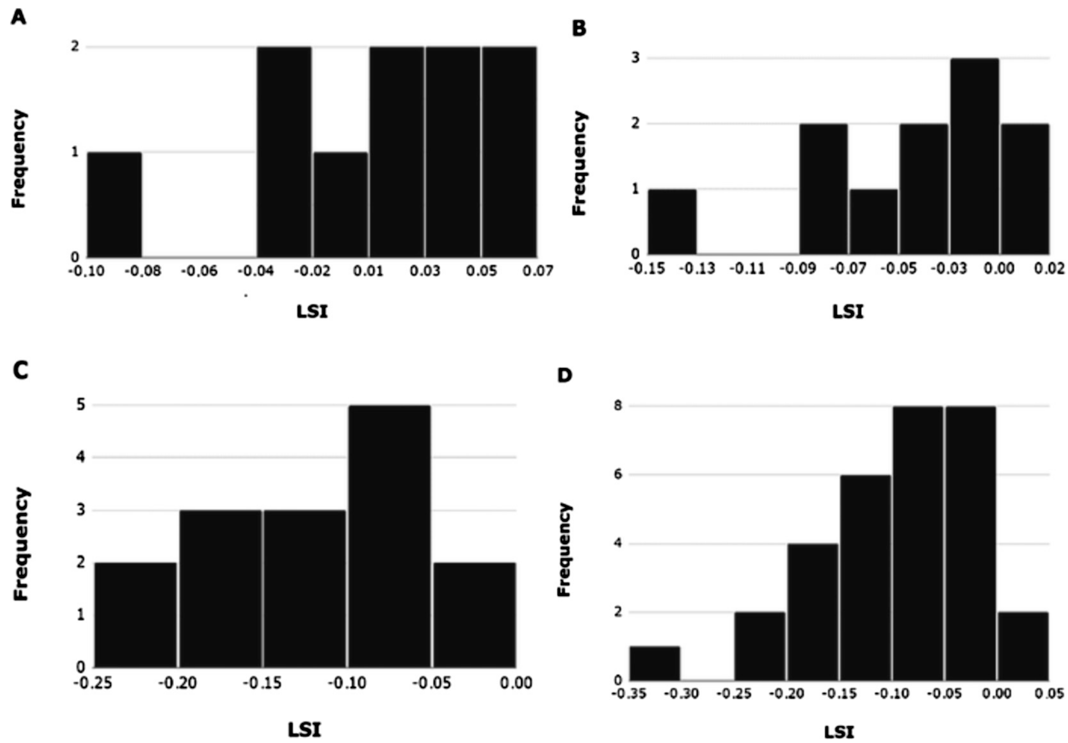

Fig. 8. Distribution of LSI values for pig (A, B) and cattle (C, D). Standard animal data from Luo (2012), Russel (1993), Tang et al. (2003) and Degerbol and Fredskild (1970), respectively.

Fig. 9. Worked elements from Yishengci. A) Cut and polished antler; B, C, D) Broken bone awls; E) Sickle-like semi-worked and semi-polished tool made out of a mammal ulna; F) Debris of bone working (distal cattle metatarsal).

that our assemblage most likely included particularly large domestic bovines, potentially even oxen, used for heavy work.

3.6. Worked bones

Animal exploitation in Yishengci included the production of artifacts. Our assemblage included 70 specimens which were either broken worked bones or debris of bone working. No intact and complete artefact was found at the site, which supports our argument that the assemblage represents consumption and production waste. The worked assemblage largely consisted of pig teeth (37.2% NISP), mammals' long bones (28.5% NISP) and cervid antlers (21.6% NISP). The former had been cut and sometimes polished and scraped perhaps with the intention of making some decorative item or simple scraping tools. Broken awls had been made of mammals' long bones, and polished to various degrees (25.8% NISP). Cervid antlers had been partially polished and sometimes cut, the intended object being uncertain. Other items included unfinished chisel-like and scraper-like bone tools (Fig. 9; Table 5).

4. Discussion

Our faunal assemblage was unearthed from the southeastern corner of the Han Dynasty city of Wan and was associated with non-elite structures (Liu, 2002; Northwest University School of Cultural Heritage, Nanyang Institute for the Preservation of Cultural Heritage, 2024). It displayed old breaks, various types of gnawing, butchery marks, and included bone-working debris, suggesting that the deposit included both consumption and production waste.

4.1. Animal exploitation strategies at Yishengci

Domestic fauna was prevalent at the site, the best represented species being those typically found in predominantly agricultural economies in Northern China, meaning pig, cattle and dog (Festa and Monteith, 2022). The frequency of these faunal taxa at Yishengci was similar to those observed at other Han dynasty sites in the agricultural Guangzhong region, such as Xitou (Wang et al., 2023) and Gongbeiya (Zong et al., 2021). However, this pattern starkly contrasted with the pastoral-based taxonomic composition found at Shichengzi in Xinjiang (Dong et al., 2022). This variation suggests a consistent approach to animal exploitation across agricultural regions during the Han dynasty period.

Pigs were the primary livestock used in Yishengci, reflecting their longstanding socio-economic importance in the agricultural societies of the Yellow and Yangzi River valleys since the Neolithic period (Yuan, 2015; Liu and Chen, 2012; Luo, 2012). The pigs from Yishengci were killed relatively early, the majority being slaughtered between one and two years of age. This implies a fairly systematic exploitation for meat and lard, with some older individuals, possibly kept for breeding and capital.

Table 5
Taxonomic frequency of worked bones in Yishengci.

Taxon	Element	NISP	NISP%
Suid	Tooth	26	37.2
Cervid	Antler	15	21.6
Cervid	Metatarsus	1	1.4
Canid	Tooth	1	1.4
Horse	Metacarpus	1	1.4
Horse	Radius	1	1.4
Bovine	Metacarpus	1	1.4
Bovine	Metatarsus	1	1.4
Mammal	Rib	2	2.8
Mammal	Scapula	1	1.4
Mammal	Ulna	1	1.4
Mammal	Horn	1	1.4
Mammal	Long bone	18	25.8
Total		**70**	**100**

Compared to pigs, there were relatively few cattle at Yishengci. This concurs with the context of their discovery: unlike pigs cattle cannot be sustained on human waste products and require significant amounts of water and extensive grazing land, such resources being scarce in core agricultural areas like the Nanyang Basin (Xia et al., 2022; Huang, 2007). Moreover, cattle have a much longer cycle and lower rate of reproduction than pigs, making their husbandry less able to provide for the meat demand of an urban population. In addition to meat, however, bovines could provide hides and horns to manufacture, and, most importantly, aid in agriculture (Yu, 2020; Lin et al., 2018; Wang, 2009; Jiang and Yang, 2001; Bray, 1979). The high frequency of butchery marks on various skeletal elements ($n = 71$; 40.6% cattle NISP) (Fig. 6C) implies that these animals were slaughtered for their meat, yet the late killing pattern indicates that the primary use of this taxa was for secondary products. Multiple lines of evidence hint at the importance of this taxon for traction. Basic pathological observations have highlighted exostoses on the bovine metacarpals and phalanges in this assemblage which is consistent with the persistent stress inherent in haulage (Bartosiewicz, 2008) (Fig. 6B). Similar traces have been identified on cattle bones from Xitou, further supporting the use of bovines for draught during the Han dynasty (Wang et al., 2023). The exploitation of draught animals has been evidenced zooarchaeologically in China at least from the Shang dynasty period (1600–1046 BCE) (Lin et al., 2018; Lin, 2022). In addition, there are numerous sources which indicate that cattle were used for traction, including references in the official histories (Hsu, 1980), depictions on murals found on stone tomb walls in Northern China (Wang, 2009; Jiang and Yang, 2001) and archaeological evidence of plows, charts and chariots (Lin, 2022) (Fig. 2B).

Butchery marks on 11 canid bones in our assemblage (15.1% canid NISP) indicate that they may have been eaten (Fig. 7B). However, we found no evidence for human management strategies consistent with specialized meat production. Dogs were likely used for other purposes, including hunting, guarding, companionship, entertainment, and as sacrifices, of which we have knowledge through iconographic (Liu, 2008) and textual evidence (Stercxk, 2006; Liu, 2020) (Fig. 2C), but which may not be discernible through our zooarchaeological analysis.

Domestic birds were expected in our assemblage as their presence in residential and burial sites is well documented for the prehistory and early history of China (Eda et al., 2022; Barton et al., 2020). In the Han dynasty period's Heishuiguo cemetery, for example, poultry made up >50% of the faunal assemblage (Li et al., 2023). Like pigs, fowl are low-maintenance, and the rural and urban households alike would have been able to keep small flocks for meat, eggs and feathers (Wei, 2014). The relative low frequency of birds in Yishengci is likely due to recovery bias against small elements. Recovery bias might also account for the significantly small quantity of wild aquatic fauna in our assemblage (Tables 3, 4). Han dynasty funerary and residential contexts excavated in the area around present-day Xi'an have revealed a fair proportion of mollusks and fish (Hu and Yang, 2010; Hu et al., 2006). In addition, textual sources report that freshwater animals, including turtles and some kinds of fish, were either captured in local rivers or farmed to be consumed as food or for medical purposes (e.g., *[Writings of] the Huainan Masters* [Huainanzi], 7.242, 8.264; cfr. Read, 1937).

The appearance of a small variety of small and medium terrestrial predators and scavengers in our urban context aligns with expectations, as they maintain commensal relations with humans (O'Connor, 2003), although we cannot exclude the practice of some small-scale hunting. A modest number of deer remains were identified, underscoring the anticipated scarcity of large wild mammals. Historical trends from the Early Neolithic onwards show a decrease in the reliance on these animals for meat in Central China (Zong et al., 2021; Festa and Monteith, 2022). The deer finds at Yishengci included antlers and only 3 bone fragments. While some antlers might have been collected in the surrounding rural area, 5 specimens with bone attached further suggest that some hunting was practiced in the woodlands outside Wan.

Antlers, along with domestic animals teeth and bones were used to make a small variety of items, implying small-scale bone manufacturing activities at Yishengci.

4.2. Drivers of animal exploitation strategies

Our zooarchaeological study supports and enhances the existing textual and iconographic documentation on animal exploitation methods, while also providing new insights into the driving factors behind these practices in the Han urban setting of Yishengci.

Domestic and potentially wild animals were utilized for meat at the site, with pigs being the primary source. Faunal abundance in Yishengci is consistent with that observed in the Han dynasty's larger agricultural centers in the Guanzhong region (Wang et al., 2023; Hu et al., 2023; Zong et al., 2021), potentially reflecting the expected demands of areas with denser populations and higher food consumption. Yuan (2015) has argued that population size influences meat consumption, with increased food demand often leading to boosted meat production. Textual and isotopic evidence suggests a rise in meat consumption during the Han dynasty compared to previous periods, possibly in relation to the demographic growth of the Central Plains (Sterckx, 2002, 2011; Sadao, 1986; Hou et al., 2012; Zhou et al., 2017). Pig husbandry is efficient in both rural and urban contexts, due to their high rate of reproduction, low space needs, the ability to feed on household waste, and manure production for fertilization. This means that pigs would have served as an optimal meat source for the expanding urban populations (Sheng et al., 2021; Cucchi et al., 2016; Xie, 2020; Xiao, 1986; Bray, 1979).

The presence of older pigs in our assemblage implies the absence of large-scale, specialized pig production. This trend matches observations from other Han Empire agricultural sites like Xitou (Wang et al., 2023) and Gongbeiya (Zong et al., 2021), yet significantly contrasts with the mortality patterns observed at Heishuiguo in the Hexi corridor, where approximately 95% of pigs were culled before reaching six months (Li et al., 2023; Chen et al., 2021). This contrast indicates that the lack of systematic pig farming in Yishengci might have stemmed from the prevalent intensive, small-scale agricultural practices in the Central Plains during the Han era. Small plots of land were owned and farmed by individuals or small groups of households. State-owned and private large fields were often divided and farmed by hired landless laborers (or sometimes slaves), or rented to peasant households, each cultivating small tracts of land (for an extensive discussion, see Twitchett and Loewe, 1986). Within this fragmented agricultural landscape, animal husbandry likely followed a similar small-scale flexible model, with ordinary households managing a few animals for either subsistence or local markets. Wei (2014)'s study of the combination and frequency of zoomorphic pottery figurines in Han dynasty graves in present-day Sichuan suggests a similar approach to animal husbandry. Our findings align with those of Cucchi et al. (2016), who, through observations of variations in animals' diets and sizes, indicate evolving household-based pig husbandry practices from the Longshan to the Han period in Northern China. Isotopic analysis of pig remains from the Eastern Zhou elite's cemetery at Songzhuang and the commoners' cemetery at Tianli reveal a broad spectrum of rearing and feeding approaches within these pig populations. This variety suggests that adaptable and diverse pig exploitation strategies were well-established in the Central Plains prior to the emergence of the Han Dynasty (Zhou et al., 2018). Contemporary varied forms of pig husbandry in Northern China continue to reflect this pattern (Chen et al., 2016).

The economic and demographic growth of the Han dynasty period sustained, and was sustained by, intensive multi-crop agriculture, with millets, wheat and rice becoming the mainstays of the population diet (Xia et al., 2022; Zhao, 2020). As crop cultivation was the primary source of subsistence and wealth (Liao et al., 2022), it is not surprising that the animal exploitation strategies identified in Yishengci reflect the interest of the farming production. Intensive pig herding would have secured not only a crucial source of animal protein, but also a regular provision of organic fertilizer to sustain intensive agricultural regimes (Xie, 2020; Yang et al., 2022). The exploitation of large uneaten cattle for traction, and potentially sowing, was a critical application within the suite of secondary animal products, as it could create agricultural surplus wealth by enhancing the productivity of the land (Lin et al., 2018; Lin, 2022; Cui, 1935; Jiang, 1981). Cattle could also have contributed to transportation in everyday life and for military purposes, by carrying provisions and weapons (Zhou, 2002).

Intensive farming likely benefited from the exploitation of larger cattle, which, due to their strength, were better suited for demanding agricultural tasks (Lin et al., 2016; Holmes et al., 2021). The considerable size of the bovines at Yishengci was suggested through LSI analysis against two prehistoric aurochs (Tang et al., 2003; Degerbol and Fredskild, 1970). This finding receives additional substantiation when compared with data from cattle bones in the Jin River Valley dating back to the Proto-Zhou period: at the agro-pastoralist site of Sunjia, cattle were generally smaller than those at Yishengci, yet the bones from Yishengci were comparable in size to those at the nearby Xitou site, associated with more intensive agricultural practices (Festa et al., 2023: Table S1, Fig. 7). Our cattle were also larger than those found at the Iron Age pastoralist site of Shirenzigou, in the Eastern Tianshan Mountains (Wang, 2023) This observation might suggest that a higher reliance on agriculture could correlate with the presence of larger cattle. If that is true, we would have expected these big bovines in rural areas. In more confined urban agricultural systems, such as Wan, smaller, low-maintenance cows would have been more practical, serving light labor tasks and facilitating the short-distance transport of goods and people (Festa et al., 2023; Trentacoste et al., 2021). The presence of large cattle at Yishengci could suggest that they were raised and primarily used in the surrounding countryside, only to be consumed in the city once they had reached the end of their working lives. Within the urban setting, these animals could have been slaughtered for their meat, glue, and leather, all of which would have held importance in such an environment. Settlement archaeology research results indicate that in the Qin and Han dynasties small villages developed organically or deliberately near large walled settlements and cities, catering to the needs of urban residents (Han and Zhang, 2015; Liu, 2017; for a discussion on cities and villages in ancient China see Lincoln, 2021). The *Book of Han* (Han shu, 24) reports that intensive agriculture was practiced just outside the city walls of Chang'an (cfr. Sadao, 1986), indicating an integration of city life and agricultural practices. Another explanation for the presence of large cattle in Yishengci is that the city was able to maintain large specimens to work its environs. Cattle was also a major domestic animal in burial contexts (Liu and Jiao, 2019; Hu and Yang, 2010) and the occurrence of big specimens at the site could also be related to ritual and cultural preferences.

The presence of large pigs and wild boar in Yishengci was established through comparisons with domestic specimens from the Shang dynasty at Heihelu (Luo, 2012) and a European wild suid (Russel, 1993). The size of our pigs notably exceeds that of pigs found at Proto-Zhou agro-pastoralist sites in the Jing River Valley, such as Sunjia and Xitou (Festa et al., 2023:Table S1, Fig. 7). Our finding aligns with the study by Cucchi et al. (2016), which utilized geometric morphometric and isotopic analysis to document large pigs in urban settlements from the Longshan to the Han period. They suggested these pigs were herded on a free-range basis in rural areas before being brought into the city. While this pattern may be relevant to the suids in our study, in Yishengci there is no evidence for systematic pig farming, and the lack of comprehensive data from rural sites prevents us from drawing definitive conclusions. Another possibility is that wild boars may have been hunted in the rural areas surrounding Wan before being transported to the city. This hypothesis is supported by some depictions of wild boar hunting scenes on tomb murals (Shaanxi and Yulin, 2004). Another scenario could involve large pigs being reared in a free-range manner in more ruralized urban areas. Albarella et al. (2019) suggest that the ruralization of certain urban areas could account for both the presence of large domestic specimens and wild boar, the latter possibly drawn to these areas in search of food. Studies on the imperial city of Chang'an has revealed that there was a wide belt of low population density semi-urban land extending along its southern edge, which could have been used for small-scale farming and herding (Dong, 1983; Kiang, 2014). Yishengci was situated in the southern part of Wan, at the confluence of the Wenliang and Bai rivers in an area of the city that, due to its susceptibility to flooding, would likely have had a lower population density (Li, 2010) and could have been used for small-scale free-range animal herding. While previous research highlights the diversity and adaptability of pig husbandry practices in ancient Northern China (Zhou et al., 2018; Chen et al., 2016; Cucchi et al., 2016), additional archaeological and zooarchaeological data are needed to better understand the potential association between pig management and urban development.

Archaeological and textual evidence highlights the social importance of hunting in Han China, primarily a pursuit of the elite in specially designed parks near cities, with commoners facing government restrictions and taxes on hunting (Lowe, 1983; Schafer, 1968; *The Book of Han* [Hanshu] 24; Ebrey, 1986; Swann, 1950). Findings at Yishengci would, however, imply the involvement of ordinary people in small-scale hunting of small mammals, wild boar and deer. Remains from Gongbeiya, near Xi'an, include a fair proportion of wild species (ca. 20% NISP, Zong et al., 2021). In the Han dynasty period stage of the site of Xitou in the Jing River Valley, 8,3% of the identified specimens was wild (Wang et al., 2023). Medieval texts such as the *Three Dynasties, Qin, Han, Three Kingdoms, to the Six Dynasties* (Quan shanggu Sandai Qin Han Sanguo Liuchao wen) also mention commoners and servants hunting and fishing during the Early Empire (Sterckx, 2002), raising further uncertainties regarding the precise impact of government restrictions on the everyday life of the ordinary population. At the Bronze Age site of Zhongba, in the Sichuan Basin, specialized production has been related to hunting and fishing, which would have offered a less labor-intensive alternative to traditional husbandry for meat procurement (Flad, 2005). This would have enabled the local population to focus on salt production. Han dynasty bricks from Sichuan show iron pan salt production alongside deer and bird hunting (Rawson, 2001), but there is no evidence that Yishengci was a production hub. In addition, while hunting might have been an alternative meat source for the ordinary population, the overwhelming predominance of domestic animals at the site renders this hypothesis unlikely. Limited findings from Yishengci suggest the occasional hunting of wild animals in nearby Wan city forests for additional meat and crafting materials.

Unfinished and broken worked bones found at Yishengci imply manufacturing activities at the site. Although the sample size was limited and the final products of some items are uncertain, the bone manufacturing process seems to have been relatively simple, both in terms of product diversity and the selection of raw materials, which were chosen from a variety of readily available species. In comparison, results of the investigation of the workshop in Niejiagou (Xianyang) dating to the Qin-Han dynasties period reveal a targeted use of cattle and deer bones and antlers in the production of a wide range of objects, including domestic tools, horse-related items, games, parts of musical instruments, and various different ornaments (Shaanxi Provincial Institute of Archeology et al., 2019). While it is possible that in Yishengci bone manufacturing was organized and carried out in dedicated urban workshops, this remains to be demonstrated. Although iron and bronze foundries and a ceramic workshop have been located and excavated in Wancheng (Zhou, 2001; Wang, 1994; Li, 1991; Han and Wang, 1956), dedicated spaces for bone manufacturing have yet to be discovered in the city.

5. Conclusion

Animal economies during the Han dynasty period are largely known from written sources and limited archaeological evidence excavated from elite funerary contexts. Our data on animal exploitation strategies in the non-elite residential site of Yishengci are generally in line with the information from textual and iconographic evidence, showing that domestic and wild species were used for different purposes to meet the varied needs of an urban population. Pigs were crucial meat producers, followed by cattle and dogs, though to a significantly lesser extent. Moreover, our study found evidence of secondary uses of animals, including their role in providing traction strength and the utilization of bones and antlers for tool-making.

This study's results indicate that diverse uses of animal resources and the emergence of specific exploitation strategies at the site were influenced by a combination of factors, notably population size, land management and high-yield agriculture. Animals were not only a source of meat for the urban population, but also supported the intensive small-scale agricultural system which underpinned the urban economy of the Han dynasty period.

While this study has demonstrated that faunal exploitation strategies can inform the development of the Han socio-economic urban landscape in the Nanyang Basin, the relatively small sample size, lack of sieving, limited contextual information and the paucity of comparative zooarchaeological analysis results have complicated, and necessarily limited the evaluation and interpretation of the data. More evidence from urban contexts could reveal further information on the relationship between animal exploitation strategies and social stratification, as well as specialized productions. The lack of zooarchaeological results for Imperial China has so far prevented the establishment of a "zooarchaeological context" against which results from single sites can be evaluated. More zooarchaeological data from urban and rural sites would shed light on trade networks between the two areas, which are currently known only from textual evidence (Lincoln, 2021; Sandao, 1986). Research on the Roman Empire has demonstrated that the integration of written records and zooarchaeological data has the potential to illuminate aspects of the past that might otherwise be missed, misinterpreted or that remain unclear (MacKinnon, 2001, 2010; Albarella et al., 2019). This article will hopefully inspire further zooarchaeological work in historic China, to create a more nuanced narrative of the lifeways of the urban population which can complement (and challenge) the macro-narratives that are documented in the written sources.

Fundings

Financial support was provided by the National Foreign Young Talents Program (QN203152300001) and the Regional Archaeological Investigation of Nanyang Ancient City Site Project (Yu Wenwu Bao [2022]188).

CRediT authorship contribution statement

Marcella Festa: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Miao Wu:** Visualization, Investigation, Data curation. **Gaomin Qin:** Visualization, Data curation. **Batong Qiao:** Resources, Project administration, Funding acquisition, Data curation. **Wei Wang:** Resources, Project administration, Data curation. **Yiheng Xian:** Resources, Project administration. **Francesca Monteith:** Writing – review & editing, Visualization. **Chun Yu:** Validation, Resources, Project administration, Funding acquisition, Data curation.

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.

Acknowledgments

Thanks are due to Professor Wen Rui of the School of Cultural Heritage, Northwest University, for the insightful suggestions on the first draft of the article. The contribution of the various workers, drivers and other support personnel involved in the excavation and processing of these bones is also acknowledged. We also thank Northwest University for providing the environment conducive for writing the article. We are grateful to the two anonymous reviewers for their constructive and thoughtful comments.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ara.2024.100514.

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