



Live on the land and fed by the sea: diverse subsistence economies in the Neolithic Dawenkou Period in Shandong Peninsula, China

Minghao Lin¹ · Yanbo Song² · Fen Wang² · Zebing Wang³ · Songtao Chen^{4,5}

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Abstract

The Dawenkou Culture, centered in Shandong, is a typical Neolithic period featured by its unique local customs and influential inter-regional expansions. While a series of its social and cultural evolutions have been recognized, subsistence economies that could have fundamentally driven these social changes have not been fully explored. Here, we apply zooarchaeological analyses, in a modelled chronological framework, to faunal remains at the sites of Beiqian, Geduiding and Dongchu, all of which are close to the sea in eastern Shandong Peninsula. Pigs dominate the terrestrial mammals while mollusks are the most frequently recorded maritime animals, indicating a combined subsistence strategy employed by the local populations. Half of the pigs are culled older than 2 years, so their well-developed canines could be harvested by the local societies to fulfill their cultural and ritual demands. Apart from domestic pigs, wildlife resources including wild boars, deer, small carnivores and rodents, as well as marine mollusks and fishes, have also been exploited to supplement human dietary spectrum. The maritime adaptive knowledge accumulated through harvesting sea resources could finally facilitate the dispersal of agriculture in the following millennia in the East Asia.

Keywords Dawenkou Culture · Shandong Peninsula · Zooarchaeology · Pig husbandry · Subsistence

Introduction

The Shandong Peninsula is located in the Lower Yellow River region in eastern China. Since the early Neolithic, this region, together with the Liaodong Peninsula, has been involved in dynamic evolutionary trajectories with the dispersal of agriculture, linguistics, cultures and populations to

help reshape ancient societies in Northeast Asia (Miyamoto 2019; Robbeets et al. 2021). Compared to the preceding Houli (c. 8500–7500 BP) and Beixin (c. 7000–6100 BP) societies in Shandong, the Dawenkou Culture (c. 6100–4600 BP) is a critical period that witnessed the initiation of such long-distance exchanges (Luan 1997: 375–407). Thus, its economic and social evolutions that could have supported its expansion are worthy of investigation.

Previous literature has revealed that the Dawenkou Culture is well featured by intensified social organizations (e.g. arrangement of row-house foundations), settlement and burial hierarchies (differentiation regarding their sizes), labor-intensive ornaments (e.g. hook-shaped objects made of deer canines) and special ritual and ceremonial customs (e.g. extraction of maxillary lateral incisors and carrying a small ball in the mouth) (Luan 1997: 54–68; 2013; Underhill 2001). However, the Dawenkou subsistence economies, which are the baselines to support a society, have not been fully explored. In particular, we need to understand the missing adaptive subsistence strategies in eastern Shandong Peninsula, which sits in-between the sea and the terrestrial highlands, and is the critical transition point for initiating interaction over the sea.

✉ Yanbo Song
Songyb@sdu.edu.cn

✉ Fen Wang
32680449@qq.com

¹ Department of History, School of Humanities, Shanghai Jiao Tong University, Shanghai, China

² School of History and Culture, Shandong University, Jinan, China

³ Underwater Archaeology Research Centre Shandong, Jinan, China

⁴ Key Laboratory of Alpine Ecology, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing, China

⁵ CAS Center for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences, Beijing, China

To shed light on the living economies of Dawenkou people near the sea, we focused on analyzing faunal remains unearthed from the three sites of Beiqian, Geduiding and Dongchu in eastern Shandong (Fig. 1). Both terrestrial and marine remains were investigated to reveal the socio-economic dynamics based on which the local communities developed and expanded.

Archaeological contexts

The Beiqian site is located in Jimo City in the south-eastern part of Shandong Peninsula. It sits in-between Yuhuang and Fenghuang Mountains, covering an area of

c. 5 ha. Its closest distance to the current coastline is about 5 km to the east. A series of excavations have been carried out in 2007, 2009, 2011 and 2013, uncovering prehistoric features of moats, ashpits, houses and tombs as well as remains of stone tools, pottery sherds and faunal bones affiliated to the Dawenkou Period (F. Wang et al. 2011). Remains of the historic Zhou Dynasty have also been recognized, but faunal assemblage analyzed at this site is all from cultural remains (e.g. cultural layers, ashpits and tombs) of the prehistoric Dawenkou Period. Previous work has yielded carbonized crop remains of broomcorn millets (*Panicum miliaceum*), foxtail millets (*Setaria italica*) and rice (*Oryza sativa*) at Beiqian (Wu 2018: 24–32), and revealed a major contribution of C₄

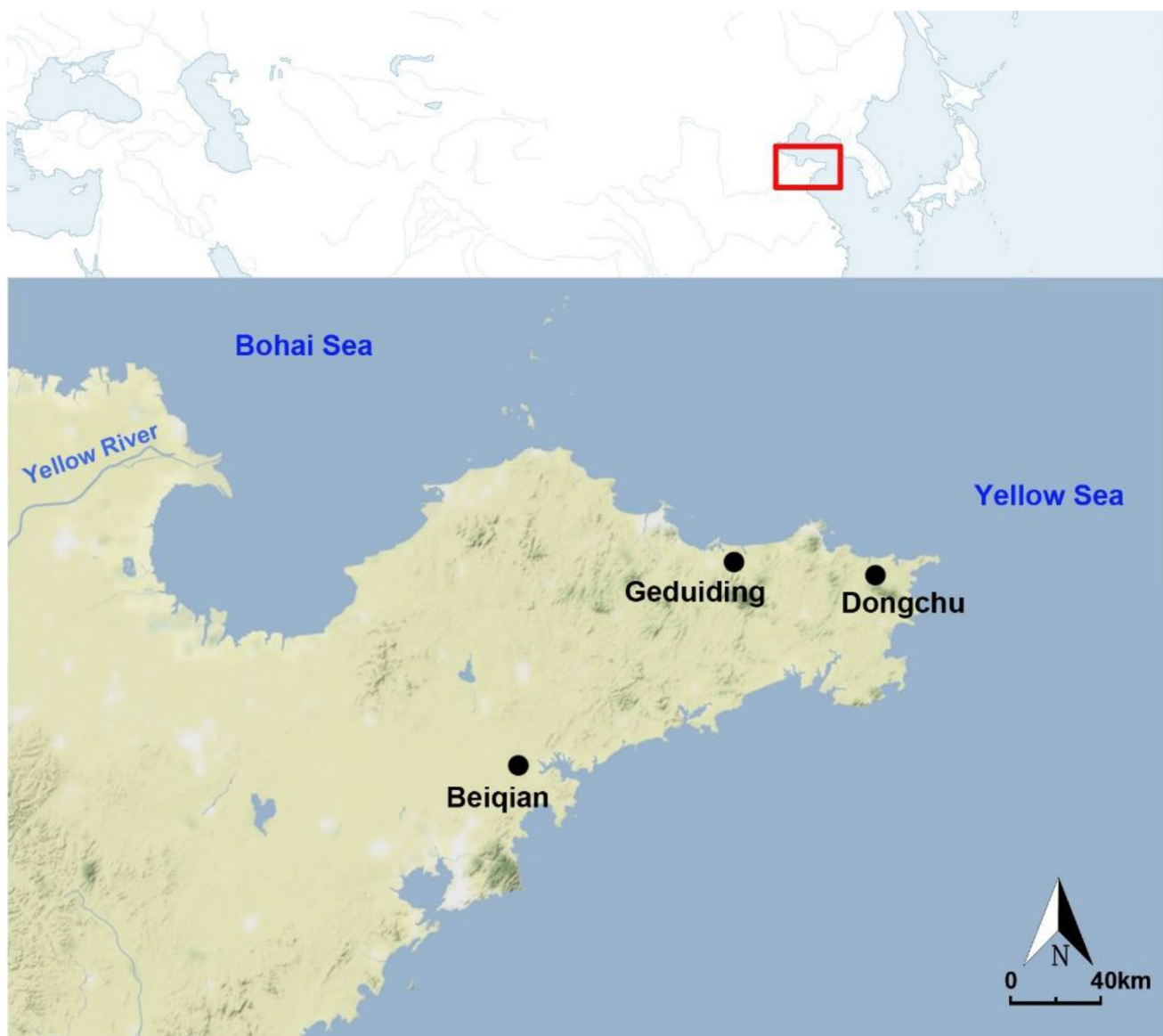


Fig. 1 Location of the Beiqian, Geduiding and Dongchu sites in Shandong, China

foods in the dietary structure of local humans (F. Wang et al. 2014), so this research provides valuable information from the other perspective of zooarchaeology.

The site of Geduiding is situated in Yantai City, the northern side of Shandong Peninsula. The Yellow Sea in the north is only about 1.5 km to the site, allowing the acquisition of sea resources within the walking distance for local people. The site is about 200 m long from north to south and 150 m wide from east to west, covering an area of 3 ha (CASS IA 1999: 154). In 2013, Shandong Provincial Archaeological Institute excavated the site, uncovering a great number of faunal remains that were predominantly from the Dawenkou cultural layers. Features of moats, burnt grounds and remains of pottery sherds and stone tools were also unearthed from this Dawenkou settlement site (CASS IA 1999: 154–165; Z. Wang et al. 2013a, b), allowing Geduiding to serve as a valuable case to understand ancient societies near the sea.

The Dongchu site sits in Rongcheng City in the easternmost part of Shandong Peninsula, with a short distance about 5 km to the sea in the north. It covers an area of 2.9 ha with 175 m from east to west and 170 m from north to south (CASS IA 1999: 102–104). The Dawenkou features of burnt grounds as well as remains of pottery sherds and stone tools were recognized at this site (Nie 2013: 150; YCRB and CASS IA 1997). In 2011, a pilot survey excavation uncovered the Dawenkou ashpits from which a certain number of faunal bone elements including a large proportion of shells were unearthed for this study.

Materials and methods

Research materials included faunal assemblages collected from sieved soil through a c. 7 mm screen from prehistoric Dawenkou features at the three sites of Beiqian, Dongchu and Geduiding in Shandong. At the Dongchu site, a number of 430 faunal bone pieces were collected for analysis. In contrast, much more bone elements were recorded and analyzed from the Beiqian ($n=280,582$) and Geduiding ($n=61,024$) sites.

We identified these faunal elements to a maximum extent to the species level by referring to modern comparative collections in the Zooarchaeological Lab in Shandong University. Meanwhile, criteria illustrated in a series of reference books, e.g. Hillson (2009), Hou and Ma (2021), Schmid (1972) and S. Zhang (2008), were also followed to supplement the taxon identification work. The counting of MNI (Minimum Number of Individuals) and NISP (Number of Identified Specimens), as well as necessary measuring for key bone parts such as molars, was carried out by following the standard setup

by Von Den Driesch (1976). Moreover, mammal tooth eruption and wear stages as well as epiphyseal fusion information were recorded, as demonstrated by previous scholars (Bull and Payne 1982; Grant 1982; Hillson 1986; Rolett and Chiu 1994; Schmid 1972; Silver 1969), to help estimate the age profiles of interested animals at these sites.

To put these faunal assemblages within an absolute chronological framework, we attempted to model the Dawenkou chronology based on 15 radiocarbon dating results from the sites of Beiqian and Geduiding. These ^{14}C data included one new input and 14 published ones (Jin et al. 2016; Song et al. 2017), but the calibration curve of IntCal20 and analysis program of OxCal v4.4 were applied, aiming to produce an updated chronology.

Results

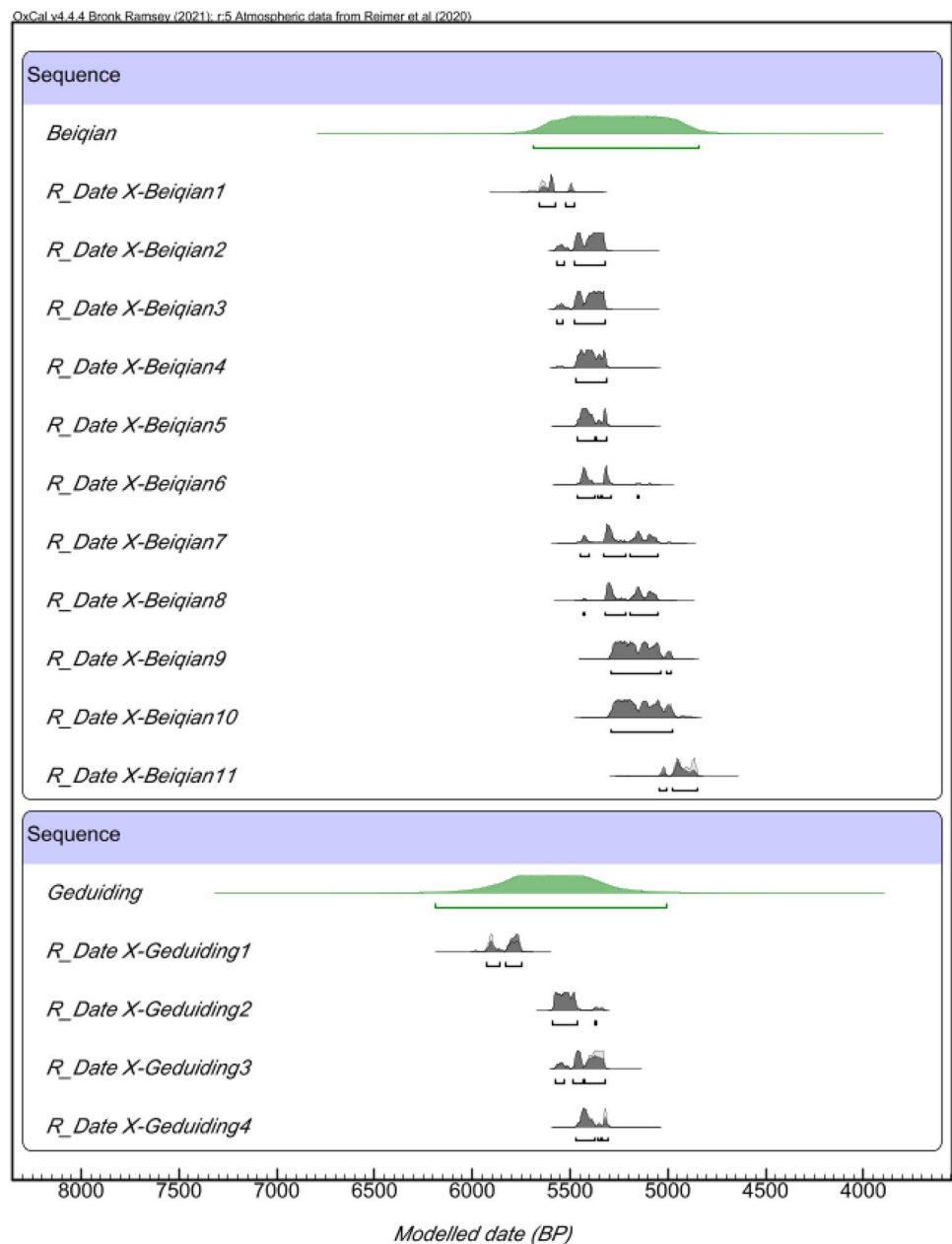
Chronology

According to the pottery typology, the Dawenkou Culture was recognized at the three sites of Beiqian, Geduiding and Dongchu. As is seen in Fig. 2, our modelled chronology for Beiqian and Geduiding is 5686–4845 cal. BP and 6190–5005 cal. BP with 95.4% confidence interval, respectively, both of which fall within the traditional Dawenkou Period of c. 6100–4600 BP. Thus, the radiocarbon dates confirm the reliability of previously proposed chronology, despite the fact that pottery typology becomes less accurate when being applied to further decide delicate sub-phases (Jin et al. 2016). There is no radiocarbon dating data available from Dongchu, but the consistence of chronology revealed by typology and radiocarbon at Beiqian and Geduiding lends credence to the Dawenkou occupation at Dongchu based on its pottery typological analysis.

Taxon structure

Broadly speaking, both terrestrial and marine resources have been identified in this study (Fig. 3). The identified taxa at the Beiqian site include mollusks, mammals, arthropods, fishes, reptiles, amphibians and birds, among which mollusks are the absolutely predominant ones by occupying more than 92% of the whole assemblage, followed by mammals at 7.1%, as seen in Table 1. In contrast, birds and fishes account for only 0.1 or 0.2% proportion of the whole assemblage. These mollusks are overwhelmingly represented by razor clams (*Sinonovacula*) and

Fig. 2 Modelled chronology (cal. BP) of the Dawenkou Culture at the sites of Beiqian and Geduiding. IntCal20 and OxCal v4.4 were used for this analysis



oysters (*Ostrea*), while only 0.2% are freshwater mussels (e.g. *Corbicula*, *Unio*) (Table 2). Likewise, after excluding those unable to be further identified, an unequal distribution of recognized mammals, in both NISP and MNI counting systems, is also recorded at Beiqian, in which pigs (*Sus*) are the predominating animals followed by deer (*Cervus*) (Table 3). The prevalence of pigs and mollusks is consistent with general taxon representation frequency recorded in prehistoric China (Lin 2016).

At Geduiding, the amount of recorded faunal skeletal elements is less than that found at Beiqian, but mollusks and mammals are still the most frequently observed animal

types. Mollusks take up 61.4% in the whole faunal assemblage, followed by mammals whose proportion is about half of mollusks (Table 1). Table 2 further demonstrates components of those mollusks, including both marine oysters (*Ostrea*), Asian rapa whelks (*Rapana*), small snails (e.g. *Chlorostoma rustica*, *Lunatia gilva*) and other clams (e.g. *Ruditapes philippinarum*), as well as freshwater mussels (e.g. *Corbicula fluminea*). A big number of Manila clams (*Ruditapes philippinarum*) ($n = 25,426$) are recognized in the group of “Other clams”. In terms of mammals, terrestrial animals of pigs (*Sus*) and deer (*Cervus*) are the two predominating ones by occupying more than

Fig. 3 Animal bones of Dawenkou Culture in eastern Shandong Peninsula (1. deer (*Cervus*) mandible, Geduiding; 2. dog (*Canis familiaris*) mandible, Geduiding; 3. pig (*Sus*) mandible, Geduiding; 4. hare (*Lepus*) mandible, Geduiding; 5. oyster (*Ostrea*), Geduiding; 6. Asian rapa whelk (*Rapana venosa*), Geduiding; 7. Asian hard clam (*Meretrix lusoria*), Geduiding; 8. Seabream (*Pagrus major*) premaxilla, Geduiding)

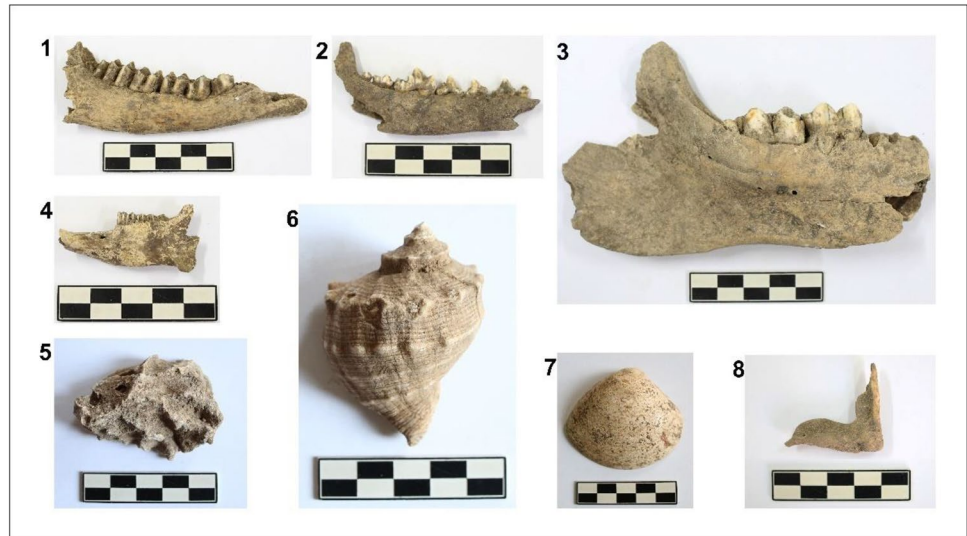


Table 1 Taxon representation at the sites of Beiqian, Geduiding and Dongchu

	Beiqian		Geduiding		Dongchu	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Mollusks	260,039	92.7%	37,440	61.4%	388	90.2%
Mammals	19,888	7.1%	19,969	32.7%	37	8.6%
Fishes	421	0.2%	3129	5.1%	2	0.5%
Birds	206	0.1%	482	0.8%	1	0.2%
Reptiles	14	0.0%	-	-	2	0.5%
Arthropods	9	0.0%	2	0.0%	-	-
Amphibians	5	0.0%	2	0.0%	-	-
Total	280,582	100.0%	61,024	100.0%	430	100.0%

Table 2 Mollusk types found at the sites of Beiqian, Geduiding and Dongchu

	Beiqian		Geduiding		Dongchu	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
Oysters (<i>Ostrea</i>)	54,925	21.1%	436	1.2%	90	23.2%
Asian rapa whelks (<i>Rapana</i>)	695	0.3%	188	0.5%	-	-
Razor clams (<i>Sinonovacula</i>)	203,695	78.3%	-	-	-	-
Sepia (<i>Sepia</i>)	48	0.0%	-	-	-	-
Other clams*	125	0.0%	27,215	72.7%	295	76.0%
Freshwater mussels (e.g. <i>Corbicula</i> , <i>Unio</i>)	449	0.2%	11	0.0%	-	-
Small snails	99	0.0%	9590	25.6%	3	0.8%
Others	3	0.0%	-	-	-	-
Total	260,039	100.0%	37,440	100.0%	388	100.0%

* includes clams such as Manila clams (*Ruditapes philippinarum*) and Asian hard clams (*Meretrix lusoria*).

80% and 10% respectively in both NISP and MNI counts (Table 3). This is very similar to the model we observe at contemporary Beiqian.

As opposed to Beiqian and Geduiding, only a smaller database is available at the Dongchu site, but its taxon structure models are much similar to those recorded at

the other two sites (Tables 1, 2 and 3). At Dongchu, the whole assemblage is significantly occupied by mollusks and mammals. While oysters (*Ostrea*) and clams (mainly Manila clams (*Ruditapes philippinarum*)) dominate the mollusk group, mammals are especially represented by pigs (*Sus*) and deer (*Cervus*).

Table 3 NISP and MNI counts of identified mammals at the sites of Beiqian, Geduiding and Dongchu

		Beiqian		Geduiding		Dongchu	
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
NISP	Pigs (<i>Sus</i>)	5973	78.3%	5923	84.6%	21	77.8%
	Deer (<i>Cervus</i>)	1546	20.3%	847	12.1%	5	18.5%
	Cattle (<i>Bos</i>)	2	0.0%	-	-	-	-
	Dogs (<i>Canis familiaris</i>)	21	0.3%	-	-	1	3.7%
	Rodentia/Lagomorpha	52	0.7%	22	0.3%	-	-
	Other carnivores	38	0.5%	207	3.0%	-	-
	Total	7632	100.0%	6999	100%	27	100%
		<i>n</i>	%	<i>n</i>	%	<i>N</i>	%
MNI	Pigs (<i>Sus</i>)	236	62.8%	333	80.8%	2	40%
	Deer (<i>Cervus</i>)	99	26.3%	61	14.8%	2	40%
	Cattle (<i>Bos</i>)	1	0.3%	-	-	-	-
	Dogs (<i>Canis familiaris</i>)	5	1.3%	-	-	1	20%
	Rodentia/Lagomorpha	19	5.1%	5	1.2%	-	-
	Other carnivores	16	4.3%	13	3.2%	-	-
	Total	376	100.0%	412	100%	5	100%

Discussion and conclusions

Pig husbandry

As the most prevalent mammals found at the three Dawenkou sites of Beiqian, Geduiding and Dongchu, it seems pigs have played a marked role at that time. Whether pigs being successfully domesticated or managed could significantly shed light on understanding ancient exploitation of animals in human societies. Thus, based on these available datasets (bigger databases mainly from Beiqian and Geduiding), it is worth investigating pig husbandry from the following perspectives of its relative frequency, mortality profile, morphometrics and dietary analyses.

First, faunal ratio frequency may indicate the significance of specific animals in human societies. For pigs, they could have played an important role for humans if their proportion was 7% or above within a faunal assemblage (Grigson 2007). As revealed in previous sections about taxon structures, both NISP and MNI analyses show the absolute leading role of

pigs in the food mammal populations at the three sites by generally occupying 60–85 percentage, despite deer share the same proportion of 40% with pigs with their very limited MNI counts ($n = 2$) at the Dongchu site. Such proportions are much greater than the suggested 7%, indicating a markedly close human-pig relationship. Considering that wild boars, especially during their rut seasons, could be more aggressive and lead to fatal attack injuries (Manipady et al. 2006), it is very unlikely for the local humans to harvest such greater ratios of wild boars at a site. Instead, it becomes more plausible to believe some of these pigs are domestic and thus, to some extent, mild.

Second, faunal mortality profile is another possible indicator for herd management since age at death for animals under human interference might differ from that under the “natural selection” (Reitz and Wing 2008: 192; Vigne et al. 2000). As shown in Table 4, more than half of the pigs were culled at mature adult ages more than 2 years old from all the three sites in this study, which does not fit well the classic meat-oriented production profiles of harvesting 80%

Table 4 Mortality profiles of pigs at the sites of Beiqian, Geduiding and Dongchu

Age at death	Beiqian		Geduiding		Dongchu	
	<i>n</i>	%	<i>n</i>	%	<i>n</i>	%
< 6 months	10	4.2%	25	7.5%	-	-
7–12 months	49	20.8%	42	12.6%	-	-
13–18 months	33	14.0%	31	9.3%	-	-
19–24 months	25	10.6%	53	15.9%	-	-
> 25 months	119	50.4%	182	54.7%	2	100.0%
Total	236	100.0%	333	100.0%	2	100.0%

This analysis is based on the MNI counts.

immature pig individuals (Greenfield 1991). Actually, many worked pig canines were found at Beiqian and Geduiding, as well as most of other previously excavated Dawenkou sites (Nanjing Museum 1981; Shandong Cultural Relics Bureau and Jinan Museum 1974: 13–35), revealing a preferred prevalent culture practiced at that time. For example, at least 18 worked pig canines out of the total 31 tooth artefacts were uncovered predominantly from tombs at Beiqian, indicating continuing keeping such canines to the afterlife was a certain held belief for some of the local groups. Thus, keeping pigs to adulthood to acquire well-developed canines becomes a perfect combination of cultural and economic choices since other resources such as pork could also be used after the canine collection.

Third, body size generally decreases with human activities of taming animals of pigs and cattle, so metrical analyses of their teeth, especially the third molars, have been widely employed to recognize pig domestication in prehistory (Davis 1987: 135–140; Rowley-Conwy et al. 2012). No complete third molar is found at Dongchu, but

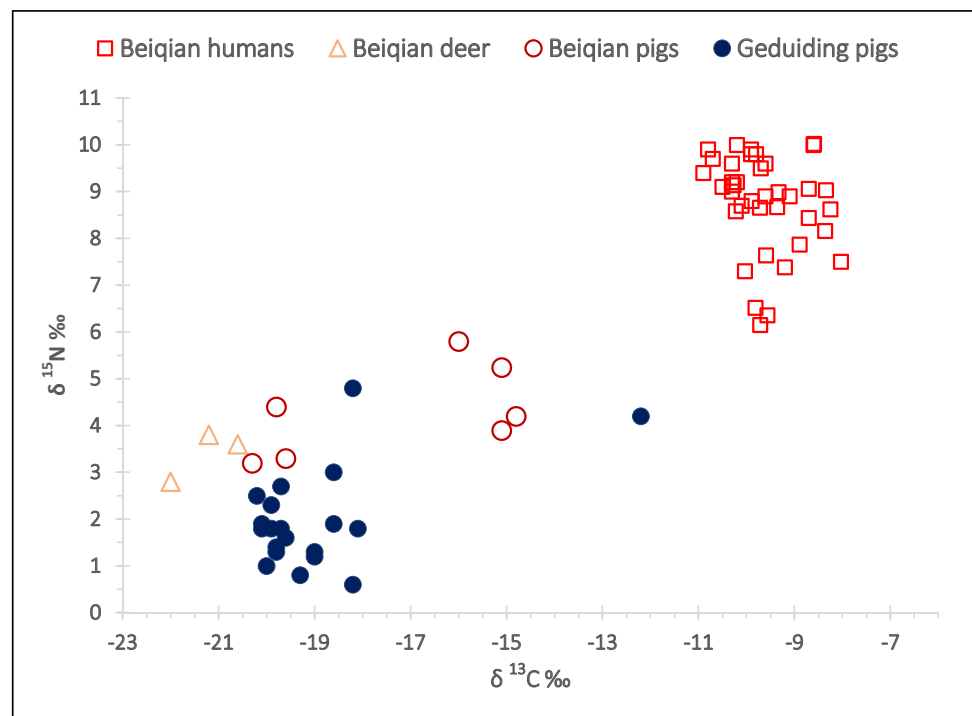
measurements of many of them are available at Beiqian and Geduiding, as summarized in Table 5. The lower third molars averaged at 36.72 and 35.63 mm long respectively for Beiqian and Geduiding assemblages, which are smaller than the established separation values at about 39 mm between Chinese wild and domestic ones (Luo 2012: 27–29). Meanwhile, some individuals are recorded with values greater than 39 mm at Beiqian (31%, $n = 11$) and Geduiding (14%, $n = 13$), indicating they are likely wild boars. Thus, metrical analyses at both sites suggest local Dawenkou people should have domesticated pigs while still hunting some wild individuals.

Fourth, the dietary profile built from stable isotopic data is also a good indicator to understand human-pig relationships (Hu et al. 2009). Based on summarized data collected from previous work (Chen under review; F. Wang et al. 2012; F. Wang et al. 2014), we produced the isotopic models of pigs, deer and humans at Beiqian and Geduiding (Fig. 4). Diverse groups of pigs are revealed from both sites. At Beiqian, three pigs are clustered with

Table 5 Measurements of the upper and lower third molars of pigs at Beiqian and Geduiding sites

	Beiqian		Geduiding	
	M ³ length (mm)	M ₃ length (mm)	M ³ length (mm)	M ₃ length (mm)
Mean	35.20	36.72	32.92	35.63
<i>n</i>	62	36	40	91
Min	27.90	30.3	26.41	29.46
Max	40.99	42.95	41.30	43.70

Fig. 4 Plot of stable carbon and nitrogen isotopic values of humans, deer and pigs at Beiqian, and of pigs at Geduiding



deer and show typical terrestrial diet intake, indicating their wild or feral nature. The other pig group demonstrates greater $\delta^{13}\text{C}$ values at c. -15% , reflecting some inputs of C_4 foods, which are strongly reflected on local human diets. This group might, to some extent, have been fed with kitchen wastes, suggesting its closer bond with local humans. At Geduiding, there is one individual measured at -12.2% for $\delta^{13}\text{C}$, suggesting a large input of C_4 foods in the natural C_3 environmental context. The other population of pigs has consumed a great number of C_3 resources, but many of their $\delta^{15}\text{N}$ values are even lower than 2% . As the legume seed is found at the site (*pers. commun. with Prof. Guiyun Jin*), it is possible such plant might have been used to feed those managed pigs, leading to the expression of their extreme low $\delta^{15}\text{N}$ values.

Therefore, according to diverse lines of evidence including faunal ratio frequency, mortality profile, morphometrics and isotopic dietary analyses, pig management could have been practiced by the Dawenkou people at Beiqian and Geduiding. Meanwhile, a certain number of wild boars seem also have been harvested, reflecting complex pig husbandry activities at that time.

Subsistence strategies

In ancient times, daily subsistence in a society mainly relies on exploiting available resources in the vicinity of local dwellings (Higgs and Vita-Finzi 1972). According to site catchment analyses carried out at a series of coastal sites in Shandong (Q. Wang et al. 2013a, b; H. Wu and Song 2017), the Dawenkou people at the three sites of Beiqian, Geduiding and Dongchu could reach diverse terrestrial and oceanic biotopes within an easy walking distance. Those surrounding resources could to a large extent ensure a variety of food supplies for local communities.

As aforementioned, pigs should have been to some extent managed by the Dawenkou people at the eastern end of Shandong Peninsula. Although earlier domesticated pigs had emerged at other places such as Jiahu in the Central Plains region (Cucchi et al. 2011; Luo and Zhang 2008), much more diverse uses of pigs might have been practiced by the Dawenkou people. Apart from acquiring pork, the local communities could have also collected well-developed canines from pigs being kept older than 2 years to meet their cultural and ritual demands. Complete pigs have also been sacrificed in prepared pits during this period (F. Wang and Song 2019), indicating the established close and special relationship between humans and pigs. According to site catchment analysis, the sites of Beiqian and Geduiding were close to a series of hills with shrubs and trees (Q. Wang et al. 2013a, b; H. Wu and Song 2017), in which free-ranged pigs could have consumed many C_3 resources and demonstrated similar $\delta^{13}\text{C}$ values to terrestrial wildlife

such as deer. Even domestic pigs could go wild or feral after escaping from human controls (Albarella et al. 2007: 1–12; Rowley-Conwy et al. 2012), making a subsistence economy relied solely on domestic pigs, to some extent, risky and unstable. As such, some wild boars, together with other terrestrial wildlife such as deer and hares, might have also been harvested, to secure protein supplies and supplement various demands for local human communities.

Meanwhile, the period of c. 6000–5000 BP also witnessed the postglacial rise of sea level (Zhao et al. 1979), which should place these sites directly at the edge of ancient coast lines. Apart from attaining faunal proteins on the land, the local Dawenkou people had also taken the full advantage of being close to the sea by exploiting a significant number of different types of marine mollusk and fish resources. Such broad-spectrum strategies could have largely enriched the dietary resources for local people, while at the same time helped learn valuable knowledge about the laws of the ocean (e.g. tides and currents) (C. Zhang and Hong 2016). This could be a starting point for accumulating more maritime knowledge, which, together with required sailing skills, enabled the exchanges of, e.g., pottery and artefacts among archaeological cultures across the sea to the Liaodong Peninsula (Luan 1997: 375–407; Xu 2019).

The exploitation of faunal proteins does not indicate unevolved farming practices at these Dawenkou sites. On the contrary, a well-developed millet agriculture should have been established from archaeobotanical findings (Jin et al. 2016; Wu 2018: 24–32). The high $\delta^{13}\text{C}$ values recorded on the Beiqian humans also suggest that the floral resources of millets might have been largely consumed. Rice, albeit not as significant as millets, had also been cultivated at Beiqian (Jin et al. 2016). Findings of rice remains in the earlier Houli and Beixin periods have been sparsely reported at the Yuezhuang, Xihe and Dongpan sites, but none of them is located in this region (Jin et al. 2017), making the Beiqian site one of the earliest locations for cultivating rice in the eastern end of Shandong Peninsula. Eventually, this practice of rice cultivation, together with human accumulated maritime knowledge from collecting oysters and clams, might have facilitated the waves of spread of rice agriculture from eastern China to the Korean Peninsula and Japanese Archipelago in the following millennia (Luan 2005; Ma et al. 2015; Miyamoto 2019; Udatsu et al. 2018).

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Declarations

Conflict of interest The authors declare no competing interests.

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