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How Did Human Activity and Climate Change Influence Animal Exploitation During 7500–2000 BP in the Yellow River Valley, China?

Linyao Du[1], Minmin Ma[1]*, Yiwen Lu[1], Jiajia Dong[1] and Guanghui Dong[1,2]

[1] MOE Key Laboratory of Western China's Environmental Systems, College of Earth and Environmental Sciences, Lanzhou University, Lanzhou, China, [2] CAS Center for Excellence in Tibetan Plateau Earth Sciences, Chinese Academy of Sciences (CAS), Beijing, China

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***Correspondence:**
Minmin Ma
mamm@lzu.edu.cn

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The mid-late Holocene witnessed the rapid development of Neolithic and Bronze cultures in the Yellow River Valley (YRV) of northern China. Spatio-temporal patterns of plant utilization during this period and its influencing factors have been intensively discussed, whereas the variation in animal exploitation in relation to climate change and human activities has not been adequately studied. In this paper, we reviewed zooarchaeological data obtained from 38 Neolithic and Bronze sites in YRV, and compared them with paleoclimate and archaeological records, to reconstruct the trajectory of animal utilization in this area between 7500 and 2000 BP and discern the influencing factors driving it. The results revealed that animal exploitation was mainly sourced from wildlife between 7500 and 6000 BP, shifting to omnivorous livestock sources in the period of 6000–4000 BP except in the northeast Tibetan Plateau. During 4000–2000 BP, however, omnivorous and herbivorous livestock had come to dominate humans' subsistence on animals, which nonetheless showed substantial spatio-temporal variation in the YRV. Further analysis suggests that animal exploitation in the Neolithic and Bronze YRV were both directly affected by human activities, while climate change might have influenced the environment surrounding human settlements and, indirectly, their choice of animals to exploit. This work provides new perspectives for exploring the changing patterns of human-environment interactions in the YRV during the mid-late Holocene.

Keywords: zooarchaeological analysis, human adaptation, human-environment interaction, Yellow River Valley, Neolithic and Bronze periods

INTRODUCTION

Interactions between human activity and environmental change in prehistoric and historical periods are topics of increasing concern over the last two decades (Dearing et al., 2006; Walsh, 2013; Dong, 2018; Feng et al., 2019), especially the influence of climate change on the evolution of civilizations and human behavior during the mid-late Holocene (Staubwasser et al., 2003; Kuper and Kröpelin, 2006; Bevan et al., 2017; Wu et al., 2018). During this pivotal period, when human populations grew and civilizations developed at an unprecedented speed, the climate also changed significantly (McEvedy and Jones, 1985; Mayewski et al., 2004; Fagan and Scarre, 2016). Human lifestyles in different areas of the Old World had evidently become transformed in the late Neolithic period (ca. 7000–5000 BP), largely due to the diffusion of new technologies (especially agricultural and livestock production) across Eurasia (Chen et al., 2015a; Pokharia et al., 2017; Liu et al., 2019), which significantly influenced human-environment interactions and the trajectory of social development (Primavera et al., 2017; Dong et al., 2019).

The Yellow River Valley (YRV) in northern China is one of the planet's earliest cradles for the origin and development of Neolithic cultures. Broomcorn and foxtail millet, and pig and dog, were all domesticated in the YRV and its surrounding areas during the early Holocene (Luo and Zhang, 2008; Li et al., 2010; Zhao, 2011), while intensive rain-fed agriculture based on millet-cultivation had been established in the YRV's middle areas during 7000–6000 BP (Zhao, 2014; Dong et al., 2016b). Then Neolithic cultures expanded, synchronously and extensively, along the YRV with the diffusion of farming groups (Dong G. et al., 2017; Li et al., 2019); this could have been promoted by favorable climate during the middle Holocene (Jia et al., 2013; Chen et al., 2015b). Crops and livestock that were first domesticated in West Asia (wheat, barley, cattle, and sheep, to name a few) had been introduced into the YRV at ca. 4000 BP (Lee et al., 2007; Long et al., 2018), after which the human subsistence strategy differentiated in various regions of the YRV during the Bronze Age (Cheung et al., 2019; Li et al., 2020), when declines in both overall temperature and precipitation occurred (Marcott et al., 2013; Chen et al., 2015b).

Spatial-temporal variation in the subsistence on plants and human diets in northern China during Neolithic and Bronze periods, including the YRV, has been intensively discussed in recent years, leading to the view that it was apparently affected by both climate change and culture evolution during the mid-late Holocene (Ma et al., 2016; Dong Y. et al., 2017; An et al., 2019). However, the spatial-temporal pattern of animal exploitation in the YRV during that period and its relationship with climate variation and human activities remain understudied. Therefore, here we systematically reviewed the published zooarchaeological data from Neolithic and Bronze sites in the YRV, comparing them with high-quality paleoclimate records and archaeological evidence currently available, to investigate the history of changes to animal exploitation in the YRV, and how this may have been influenced by climate change and human activities during the period of ca. 7500–2000 BP.

DATA SOURCES

Complete zooarchaeological data from 38 excavated mid-late Neolithic and Bronze sites in YRV were amassed, which includes nine sites with animal remains that were unearthed from archaeological strata of different phases (**Table 1**). It is now a common practice to use NISP (i.e., Number of Identified Specimen) and MNI (Minimum Number of Individuals) to describe such faunal remains. However, the corresponding systematic MNI data can be hardly found in some early-published studies (e.g., Lu and Zhou, 1990; Zhou, 1994; Liu et al., 2001). According to existing reports that are complete, the trends reflected by either NISP or MNI are usually similar (e.g., Hu et al., 2011a; Yu, 2011; Wang H., 2019). Accordingly, here we used NISP to discuss patterns of animal exploitation on a larger spatial-temporal scale. To ensure the data collected in this work were valid for their statistical analysis, all 38 sites referred to in this study are settlement sites, from which at least 100 identified NISP of faunal remains are cataloged. The respective age of these sites is ca. 7500–2000 BP, determined primarily by published radiocarbon dates, and secondly by the attributes of their artifact assemblages. Geographical locations and detailed information of those 38 selected sites are shown in **Figure 1** and **Table 1**.

To explore spatial patterns of animal exploitation in different phases of the YRV, we divided the study area into three major geographical zones: the upper YRV encompassing Qinghai, Gansu, and Ningxia Provinces; the middle YRV, encompassing mid-southern Inner Mongolia, Shaanxi, and Shanxi Provinces and most of Henan Province; and the lower YRV, consisting of Shandong Province and the eastern region of Henan Province (http://www.yrcc.gov.cn/hhyl/hhgk/hd/lyfw/201108/t20110814_103452.html). To facilitate assessment of the spatio-temporal distribution of animal exploitation in the YRV, we divided the zooarchaeological data into six stages, according to the limitation of temporal resolution of the current zooarchaeological and relative palaeo-vegetation data set.

Furthermore, we selected a North China temperature reconstruction profile (Hou and Fang, 2012), a precipitation record from Gonghai Lake (Chen et al., 2015b) and a proxy of vegetation condition (Zhao and Yu, 2012) to construct the paleoclimate and paleoenvironment of YRV during 8000–2000 BP. Based on the summary of radiocarbon dates from archaeological sites of China (refer to Dong et al., 2019), radiocarbon dates from sites in the YRV were selected to build a summed probability distribution (SPD) for revealing the fluctuations and trends of people population in this area during 8000–2000 BP. For the analysis of the assemblage of wild mammals, they were classified as forest wildlife (e.g., spotted deer, wild boar, rhinoceros), grassland wildlife (e.g., hare, wild horse, marmot), wetland wildlife (e.g., elk, water buffalo, river deer) and other wildlife according to their living habits. In making these categorizations, we referred to the primary literature on taxonomic identification and also the *Chinese Animal Atlas-Mammals* (中国动物图谱 兽类) (Xia and Gao, 1988). The detailed information can be found in the **Supplementary Table S1**.

RESULTS AND DISCUSSION

The variation in animal exploitation during the Neolithic and Bronze periods is closely related to the domestication and diffusion of livestock across the Old World. The domestication of dog can be traced back to ca. 33 000 BP (Wang et al., 2016), while the earliest remains of domestic dog in northern China have been identified from the Nanzhuangtou site (ca. 10000 BP) (Yuan, 2010). Pig was also independently domesticated in China (Larson et al., 2005), as humans began to utilize the domestic pig at the Jiahu site, located in Henan Province, during 9000–8000 BP (Luo and Zhang, 2008). Sheep/goat and cattle were firstly

TABLE 1 | Names, NISP (Number of Identified Specimen), major periods, locations, cultural phases, and references of all sites included in this study.

ID	Site	NISP	Major period (BP)	Location	Cultural phase	References
1	Zongri	880	4600–4000	Qinghai, Tongde	Zongri Culture	Ren, 2017
2	Andaqiha	1195	5400–4500	Qinghai, Hualong	Majiayao Culture	Ren, 2017
3	Jinchankou	2689	4000–3700	Qinghai, Huzhu	Qijia Culture	Ren, 2017
4	Maojiaping	1016	3000–2700	Gansu, Tianshui	Western Zhou Dynasty	Liu, 2019
4	Maojiaping	4208	2700–2400	Gansu, Tianshui	Chunqiu Period	Liu, 2019
4	Maojiaping	2384	2400–2200	Gansu, Tianshui	Warring States Period	Liu, 2019
5	Xishan	417	5500–5000	Gansu, Li county	Yangshao Culture	Yu, 2011
5	Xishan	1867	3000–2700	Gansu, Li county	Western Zhou Dynasty	Yu, 2011
5	Xishan	1769	2700–2200	Gansu, Li county	Eastern Zhou Dynasty	Yu, 2011
6	Dadiwan	974	7800–7300	Gansu, Tianshui	Early Yangshao Culture	Qi et al., 2006
6	Dadiwan	5116	6500–5900	Gansu, Tianshui	Yangshao Culture	Qi et al., 2006
6	Dadiwan	3581	5500–4900	Gansu, Tianshui	Late Yangshao Culture	Qi et al., 2006
6	Dadiwan	4566	4900–4800	Gansu, Tianshui	Yangshao Culture–Qijia Culture	Qi et al., 2006
7	Wayaogou	6094	6500–6000	Shaanxi, Tongchuan	Yangshao Culture	Wang, 2011
8	Yangjiesha	403	5020–4890	Shaanxi, Yulin	Late Yangshao Culture	Hu et al., 2013
9	Dagujie	138	4900–4400	Shaanxi, Yulin	Quanhu Culture Phase II	Hu et al., 2012
10	Huoshiliang	1111	4150–3900	Shaanxi, Yulin	Late Longshan Culture–Early Xia Dynasty	Hu et al., 2008
11	Shimao	1527	4300–3800	Shaanxi, Shenmu	Longshan Culture–Xia Dynasty	Hu et al., 2016
12	Xicha	5830	3600–2200	Inner Mongolia, Hohhot	Shang Dynasty–Zhou Dynasty	Yang C., 2006
13	Yangguanzhai	385	5600–4900	Shaanxi, Gaoling	Miaodigou Culture	Hu et al., 2011b
14	Kangjia	445	4200–4100	Shaanxi, Lintong	Longshan Culture	Liu et al., 2001
15	Jiangzhai	2278	6700–6300	Shaanxi, Lintong	Yangshao Culture Banpo Type	Qi, 1988
15	Jiangzhai	342	6500–5900	Shaanxi, Lintong	Yangshao Culture Shijia Type	Qi, 1988
15	Jiangzhai	588	5600–4900	Shaanxi, Lintong	Yangshao Culture Xiwangcun Type	Qi, 1988
15	Jiangzhai	334	4300–4000	Shaanxi, Lintong	Keshengzhuang Culture Phase II	Qi, 1988
16	Lingkoucun	331	7300–6600	Shaanxi, Lintong	Lingkoucun Culture	Zhao, 2009
16	Lingkoucun	119	6600–6200	Shaanxi, Lintong	Yangshao Culture	Zhao, 2009
17	Baijiacun	747	7300–7000	Shaanxi, Lintong	Baijiacun Culture	Zhou, 1994
18	Quanhucun	4245	5600–5100	Shaanxi, Hua county	Miaodigou Culture	Hu, 2014
19	Xinglefang	318	5900–5600	Shaanxi, Huayin	Miaodigou Culture	Hu et al., 2011a
20	Xipo	414	5900–5550	Henan, Sanmenxia	Miaodigou Culture	Ma, 2007
21	Taosi	5573	4300–3900	Shanxi, Linfen	Longshan Culture	Brunson et al., 2016
22	Zhoujiazhuang	5170	4300–3900	Shanxi, Yuncheng	Longshan Culture	Brunson et al., 2016
23	Longshangang	7440	6000–5000	Henan, Nanyang	Yangshao Culture	Lin, 2011
23	Longshangang	1285	5200–4400	Henan, Nanyang	Qujialing Culture	Lin, 2011
23	Longshangang	1523	4400–4100	Henan, Nanyang	Shijiahe Culture	Lin, 2011
24	Erlitou	11794	3700–3600	Henan, Yanshi	Erlitou Culture Phase II	Yang J., 2006
24	Erlitou	5910	3600–3500	Henan, Yanshi	Erlitou Culture Phase III	Yang J., 2006
24	Erlitou	15344	3600–3500	Henan, Yanshi	Erlitou Culture Phase IV	Yang J., 2006
24	Erlitou	951	3600–3300	Henan, Yanshi	Lower Erligang Culture	Yang J., 2006
24	Erlitou	4569	3600–3300	Henan, Yanshi	Upper Erligang Culture	Yang J., 2006
25	Meishan	299	3900–3600	Henan, Pingdingshan	Longshan Culture	You et al., 2017
26	Huadizui	4373	3800–3700	Henan, Gongyi	Xinzhai Culture	Liu, 2014
27	Xinzhai	494	4000–3900	Henan, Xinmi	Xinzhai Culture Phase I	Aurora Center for the study of Ancient Civilizations, Peking University and Zhengzhou Municipal Institute of Archaeology and Cultural Relics, 2008
27	Xinzhai	3510	3800–3700	Henan, Xinmi	Xinzhai Culture Phase II	Aurora Center for the study of Ancient Civilizations, Peking University and Zhengzhou Municipal Institute of Archaeology and Cultural Relics, 2008
27	Xinzhai	600	3750	Henan, Xinmi	Xinzhai Culture Phase III	Aurora Center for the study of Ancient Civilizations, Peking University and Zhengzhou Municipal Institute of Archaeology and Cultural Relics, 2008
28	Xishan	5720	5500–4700	Henan, Zhengzhou	Yangshao Culture	Chen, 2006
29	Shangpo	1013	3800–3500	Henan, Zhumadian	Erlitou Culture	Yang, 2018

(Continued)

TABLE 1 | Continued

ID	Site	NISP	Major period (BP)	Location	Cultural phase	References
30	Yinxu Xiaomintun	41720	3300–3000	Henan, Anyang	Late Shang Dynasty	Li, 2009
30	Yinxu Baijiafen	9451	3300–3000	Henan, Anyang	Late Shang Dynasty	Li, 2009
30	Yinxu Dasikong	13360	3300–3000	Henan, Anyang	Late Shang Dynasty	Wang H., 2019
31	Yuezhuang	823	7800–7000	Shandong, Jinan	Houli Culture	Song, 2016
32	Zhuanglixi	7594	4600–4000	Shandong, Zaozhuang	Longshan Culture	Song et al., 2012
33	Daxinzhuang	458	3600–3000	Shandong, Jinan	Shang Dynasty	Song, 2010
34	Yinjiacheng	193	4600–4000	Shandong, Jining	Longshan Culture	Lu and Zhou, 1990
34	Yinjiacheng	171	3800–3500	Shandong, Jining	Yueshi Culture	Lu and Zhou, 1990
34	Yinjiacheng	133	3600–2200	Shandong, Jining	Shang Dynasty–Zhou Dynasty	Lu and Zhou, 1990
35	Jiaojia	7382	5000–4500	Shandong, Jinan	Middle–late Dawenkou Culture	Wang J., 2019
36	Dinggong	8059	4600–4000	Shandong, Binzhou	Longshan Culture	Rao, 2014
37	Tangshan	606	3600–3000	Shandong, Huantai	Yinshang Phase I	Song et al., 2010
38	Qianbu	664	3600–3000	Shandong, Huantai	Late Yinshang	Song et al., 2010

ID corresponds to the number shown in ***Figure 1****.*

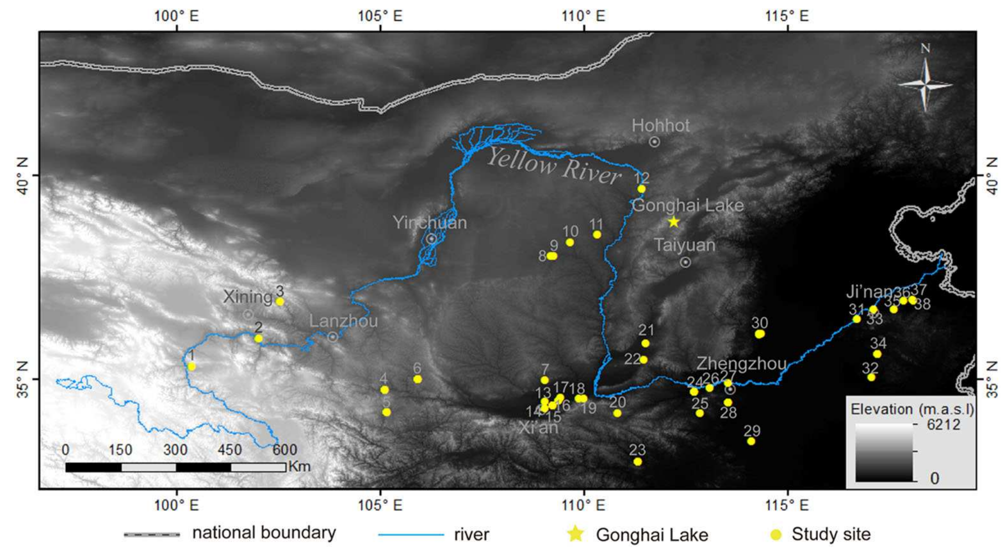

FIGURE 1 | Settlement site locations in China's Yellow River Valley referred to in this study. 1. Zongri; 2. Andaqiha; 3. Jinchankou; 4. Maojiaping; 5. Xishan; 6. Dadiwan; 7. Wayaogou; 8. Yangjiesha; 9. Dagujie; 10. Huoshiliang; 11. Shimao; 12. Xicha; 13. Yangguanzhai; 14. Kangjia; 15. Jiangzhai; 16. Lingkoucun; 17. Baijiacun; 18. Quanhucun; 19. Xinglefang; 20. Xipo; 21. Taosi; 22. Zhoujiazhuang; 23. Longshangang; 24. Erlitou; 25. Meishan; 26. Huadizui; 27. Xishan; 28. Xinzhai; 29. Shangpo; 30. Yinxu Xiaomintun, Yinxu Baijiafen and Yinxu Dasikong; 31. Yuezhuang; 32. Zhuanglixi; 33. Daxinzhuang; 34. Yinjiacheng; 35. Jiaojia; 36. Dinggong; 37. Tangshan, and; 38. Qianbu.

domesticated in West Asia ca. 10 000 BP, and introduced between 5600 and 4000 BP into northern China (Flad et al., 2007); but there, the remains of these herbivorous livestock were frequently identified only from sites younger than 4300 BP (Brunson et al., 2016; Hu et al., 2016). The horse could have been domesticated in Kazakhstan ca. 5500 BP (Outram et al., 2009), after which it was imported into northern China during 4000–3000 BP (Yuan, 2010). Although other livestock including chicken and camel were also brought into northern China before 2000 BP (Deng et al., 2013; You et al., 2014), their remains have been sporadically identified from Bronze sites in the YRV, and the NISP totals of those livestock at the 38 sites examined in this paper are negligible when compare to those of pig, dog, sheep, cattle and horse, thus we excluded them from this present work's discussion.

Spatial-Temporal Changes in Animal Exploitation in the YRV During 7500–2000 BP

Based on the NISP assemblages of animal remains identified from 38 Neolithic and Bronze sites in the YRV (**Table 1**), the spatial patterns of animal exploitation in the study area were

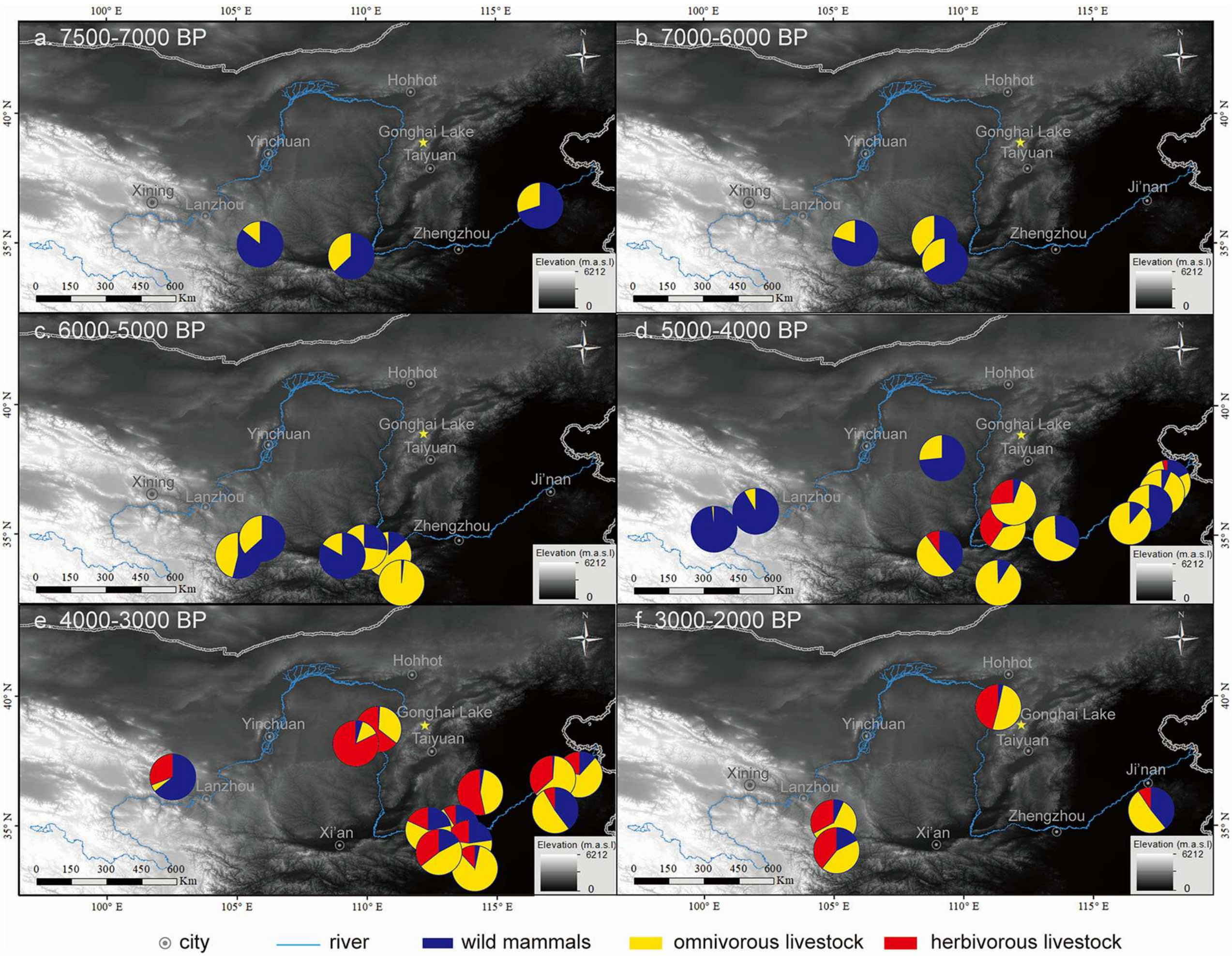

FIGURE 2 | Spatial-temporal patterns of animal assemblages (Number of Identified Specimen) from sites dating to 7500–2000 BP in Yellow River Valley. **(a)** Animal assemblages from sites dating to 7500–7000 BP. **(b)** Animal assemblages from sites dating to 7000–6000 BP. **(c)** Animal assemblages from sites dating to 6000–5000 BP. **(d)** Animal assemblages from sites dating to 5000–4000 BP. **(e)** Animal assemblages from sites dating to 4000–3000 BP. **(f)** Animal assemblages from sites dating to 3000–2000 BP.

obviously different among 7500–6000, 6000–4000 and 4000–2000 BP (**Figure 2**).

The NISP percentage of wildlife remains in all but one (6/7) site dated to 7500–6000 BP exceeded those of livestock remains (**Figures 2a,b**), which suggested that hunting was the most important strategy of animal exploitation in the YRV during this period. Yet, at this time, the human subsistence strategy also differentiated markedly across areas of the YRV, in that humans mainly engaged in hunting-gathering activity in the upper YRV before 6000 BP (Rhode et al., 2007), while foxtail and broomcorn millet were cultivated in the middle and lower reaches of the Yellow River (Crawford et al., 2013; Zhao, 2017), even though intensive rain-fed agriculture had not been well-established in northern China (Dong et al., 2016b; Zhao, 2019). Thus, hunting game was an essential livelihood even for Neolithic groups during the 7500–6000 BP period in the YRV.

Millet cultivation became the primary subsistence strategy of humans in the middle YRV at ca. 6000 BP (Barton et al., 2009), followed by rain-fed agriculture that widely expanded with the diffusion of farming groups in the YRV (Dong G. et al., 2017; Zhao, 2019). Millet farmers had settled in the area below 2,500 m a.s.l. (above sea level) of the upper YRV, where they raised pig and dog between ca. 5200 and 4000 BP (Qi et al., 2006; An et al., 2010). The NISP percentages for remains of wild mammals and omnivorous livestock (pig and dog) from 4 sites dated to 6000–4000 BP in the upper YRV were 74.81% and 25.19%, respectively, suggesting hunting remained the primary strategy of animal exploitation, especially in areas lying above 2,500 m a.s.l. which were unsuitable for cultivating cold-sensitive millets (An and Chen, 2007; Ren et al., 2020). However, the NISP percentage of omnivorous livestock exceeded wild mammals in most contemporaneous sites (14/19) in the middle and lower parts of the YRV, indicating animal husbandry had replaced hunting as the primary animal exploitation strategy in these areas during late Neolithic period. Sheep/goat and cattle were adopted as important animals for subsistence at several Longshan period (4600–4000 BP) sites, namely Taosi, Zhoujiazhuang, Kangjia and Dinggong; however, these imported herbivorous livestock were not yet widely utilized in the YRV before 4000 BP (**Figure 2**).

The NISP percentage for herbivorous livestock remains from sites dating to 4000–2000 BP underwent a remarkable increase, while that of wild mammals conspicuously declined, in comparison with the Neolithic periods (**Figure 2**). In the upper YRV, the NISP percentage for herbivorous livestock, omnivorous livestock, and wild mammal remains were, respectively, 30.65%, 4.97%, and 64.38% from sites dated to 4000–3000 BP, changing correspondingly to 36.34%, 52.13%, and 11.53% from sites of 3000–2000 BP. This result suggests animal husbandry gradually became the major subsistence strategy, as the proportions of herbivorous livestock—sheep/goat, cattle, horse and yak—in the remains were evidently enhanced in the study area during the Bronze Age. Yet domestic pig and dog were continually utilized as the major subsistence animals in the middle and lower YRV during 4000–2000 BP, as inferred from the NISP percentage of those omnivorous remains reaching 51.95% from 22 Bronze sites. Remains of herbivorous livestock could also be identified from all 22 Bronze sites, for which their NISP percentage was 32.83%, indicating those imported animals were thoroughly integrated into human livelihoods in the YRV since 4000–2000 BP.

Impact of Human Activity on Animal Exploitation in the YRV During 7500–2000 BP

Human activity significantly influenced natural fauna on a regional scale since the late Pleistocene (Pushkina and Raia, 2008), and humans might have altered the species composition and geographical distribution of animals on continental–global scales during the Neolithic and Bronze periods (Tabata et al., 2018). Domesticated animals were spread widely into different areas of Afro-Eurasia by the diffusion of populations since the middle Holocene (Boivin et al., 2016), and this expansion of human settlements also destroyed natural habitats of various wild animals in late prehistoric periods (Ruddiman and Ellis, 2009; Lyons et al., 2015).

Human settlement intensity in the YRV was evidently low during 8000–6000 BP, as indicated by the SPD of radiocarbon dates (**Figure 3D**)—widely used as the index to reconstruct the intensity of human settlement during prehistoric periods (Rick, 1987; Wang et al., 2014; Yang et al., 2019)—which could have been sustained by hunting game, low-intensity crop cultivation, and breeding of omnivorous livestock. The impact of human activity on the natural environment in northern China during 8000–6000 BP was also limited (Dong et al., 2016b), further facilitating the maintenance of wildlife habitats on the landscape and presumably the prevalence of hunting activities in the YRV during that period.

On the one hand, intensive rain-fed agriculture emerged in the middle YRV ca. 6000 BP (Pechenkina et al., 2005; Barton et al., 2009), which triggered a rapid rise in the human settlement intensity (**Figure 3D**) and increased expansion of farming groups in the YRV during 6000–4000 BP (Dong et al., 2016b; Li et al., 2019). Together, this led to a greater dependence on animal husbandry that can provide a more steady meat resource than hunting game, especially on the northern China plain where conditions for the development of rain-fed agriculture are favorable. On the other hand, progress in livestock breeding technology could also have contributed to farming groups developing a reliance on more livestock resources. In northern China, farming groups expanded significantly in this period. The northernmost latitude of agricultural production reached southern West Liao River Basin, about 43.5°N (Jia et al., 2016a). And in the YRV, farming groups expanded to the marginal areas of the northeast Tibetan Plateau at ca. 5200 BP, but they mainly settled below 2,500 m a.s.l. during the late Neolithic period (Chen et al., 2015a). Since the mountainous and high-cold environment of the Tibetan Plateau is unsuitable for the production of millet crops, hunting game was the major recourse before the introduction of cold-tolerant barley and sheep varieties, accordingly then, wildlife continued to be the dominant animal for subsistence in the area during 6000–4000 BP.

Human settlement expanded toward higher elevation and latitude in China during the period of 4000–2000 BP (Dong et al., 2019), a shift promoted by the emergence of agro-pastoral activities between 4000 and 3000 BP (Chen et al., 2015a). While imported barley and wheat were adopted in the upper YRV as major staple much faster than in the middle and lower YRV, the flourishing of imported herbivorous livestock across the entire YRV can also be detected from its compiled zooarchaeological evidence (**Figures 2e,f**). Agriculture innovation promoted clear increase in the human settlement intensity of the upper YRV during 4000–3000 BP (Chen et al., 2015a), followed by evermore dependence on domestic animals, and the herding of herbivorous livestock in high elevation areas (Dong et al., 2016a). According to existing archaeological evidence (Li et al., 2009), the human settlement intensity in the middle and lower YRV increased continuously during the Bronze Age, which probably strengthened the significance of animal husbandry while diminishing the relevance of hunting activities in animal exploitation in that area during 4000–2000 BP.

Impact of Climate Change on Animal Exploitation in the YRV Between 7500 and 2000 BP

Climate fluctuations during the mid-late Holocene are considered an important influencing factor for the evolution of Neolithic and Bronze cultures, as well as vegetation change in the YRV (An et al., 2003; Tang et al., 2007; Hou et al., 2009), which further affected human activities and wildlife habitats. Here we summarized the NISP percentages for different animal assemblages in the YRV during 7500–2000 BP, and compared it with paleoclimate records and SPD of radiocarbon dates in the study area (**Figure 3**), to explore the impact of climate change on animal exploitation in YRV during 7500–2000 BP.

According to the temperature and precipitation reconstructions by Hou and Fang (2012) and Chen et al. (2015b), despite temperature fluctuations, the climate was warm and humid during 7500–6000 BP (**Figures 3A,B**), a period when forest cover in the East Asian monsoon margin region was relatively high while human settlement intensity in the YRV was low (**Figures 3C,D**). Similar climate patterns for the same period were reported by Xu et al. (2010) and Pei et al. (2019). The NISP

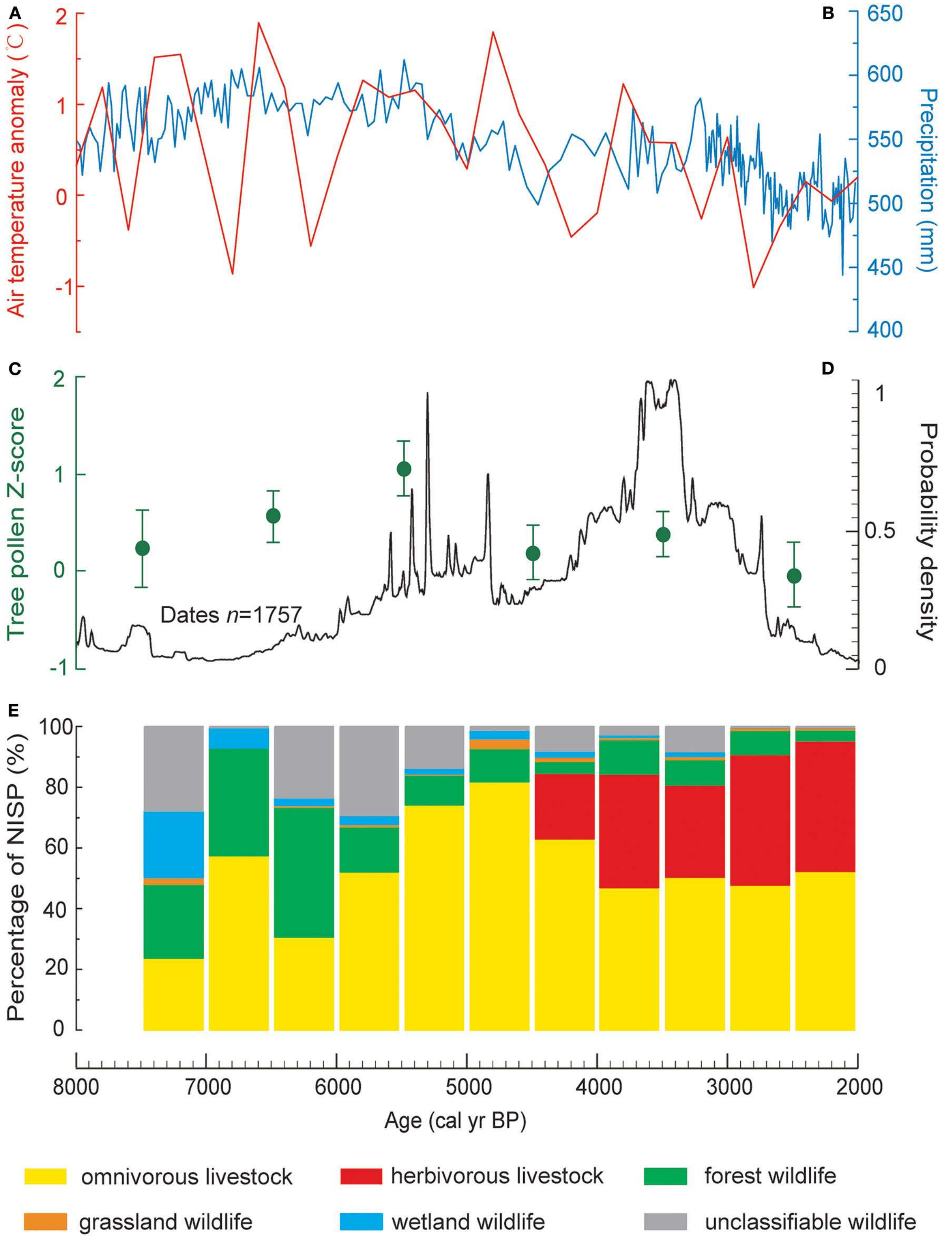

FIGURE 3 | Variation in the NISP (Number of Identified Specimen) percentages of faunal remains representing different habitats, compared with climate and vegetation changes, and the summed probability distribution of original radiocarbon dates from 8000 to 2000 BP. **(A)** North China temperature record (Hou and Fang, 2012). **(B)** Pollen-based annual precipitation regime, reconstructed from Gonghai Lake (Chen et al., 2015b). **(C)** Synthesized standard curve of tree pollen percentages in the monsoon margin region (lying between forest and steppe) (Zhao and Yu, 2012). **(D)** Summed probability distribution of original radiocarbon dates from 8000 to 2000 BP, revealing the trends and fluctuations in human population (Dong et al., 2019). **(E)** NISP percentage of livestock remains and wild mammal remains representing different habitats.

percentage was obviously higher for remains of wild mammals than livestock during 7500–6000 BP, when the prevalence of forest and wetland wildlife was also much higher than found in the 6000–2000 BP period (**Figure 3E**) (detailed information can be found in the **Supplementary Table S1**). This result suggests the warm and wet climate during 7500–6000 BP provided habitats for wild animals before the intensification of rain-fed agriculture in the YRV, thereby facilitating hunting activities in this area.

In 6000–5000 BP, the climate was still relatively warm and wet, and forest cover in the East Asian monsoon margin region reached its maximum (**Figures 3A–C**), results consistent with other climate records (Yi et al., 2003; Xu et al., 2010; Pei et al., 2019). In the context of stable and suitable environmental conditions, human settlement intensity in the YRV evidently increased during that period (**Figure 3D**). As a result, the NISP percentage for omnivorous livestock increased remarkably (**Figure 3E**), especially in the middle and lower YRV (**Figure 2c**) which had been extensively settled by farming groups during 6000–5000 BP (Zhao, 2019). Temperature and precipitation clearly declined during the 5000–4000 BP period (**Figures 3A,B**), corresponding to the substantial reduction of forest in eastern monsoon China (Tarasov et al., 2006) and the East Asian monsoon margin (**Figure 3C**), and human settlement intensity in the YRV (**Figure 3D**). The NISP percentages for grassland wildlife and herbivorous livestock in the YRV significantly increased during 5000–4000 BP, probably due to the transformed natural environment in that period. Moreover, climate deterioration during 5000–4000 BP might have induced the shrinkage of habitats for wildlife, and consequently enhanced of significance of animal husbandry in the YRV, expect in its high elevation areas in northeast Tibetan Plateau (**Figure 2d**).

The climate has changed significantly during 4000–2000 BP. A dramatic climate deterioration occurred in North China around 3000 BP, with temperature and precipitation decline (**Figures 3A,B**). Meanwhile, forest cover in the East Asian monsoon margin region increased to some extent during 4000–3000 BP but then evidently dropped during 3000–2000 BP (**Figure 3C**). Regionally, the multi-proxy record for the upper YRV (Zhou et al., 2010), the loess-palaeosol sequence in the middle YRV (Zhao et al., 2007), and the pollen record from the lower YRV (Li et al., 2016) also suggest this dramatic climate change occurred. The NISP percentage for forest wildlife also rose during 4000–3000 BP and declined during 3000–2000 BP (**Figure 3E**), roughly tracking the variation in climate and forest cover. Both the living space and intensity of human settlement in northern China increased markedly during 4000–2000 BP (Dong et al., 2019), due to agriculture innovation brought via the trans-Eurasian exchange during the Bronze Age (Chen et al., 2015a), a period characterized by a relatively cold and dry climate (**Figures 3A,B**). For instance, the successful integration of imported crops (wheat and barley) and herding animals (sheep/goats, cattle, and horse, among others) in the indigenous subsistence system across the YRV (Zhou and Garvie-Lok, 2015) (**Figures 2e,f**) ensured the stability and prosperity of Bronze Age societies, by providing stable and sufficient crops and meat. Accordingly, the NISP percentage for herbivorous livestock underwent a notable increase between 4000 and 2000 BP. Though diversified agricultural production supported the human living, this climate deterioration event still influenced the human society in northern China, for example, the spatial distribution of human settlement (Jia et al., 2016b), which could result in the animal assemblage variation. Moreover, climate deterioration during the Bronze Age likely triggered an expansion of rangeland in the monsoon margin region, which is characterized by sensitivity to climate change (Xu et al., 2004; Feng et al., 2006), namely in the Hetao Region and western Loess Plateau, and this, too, probably promoted the flourishing of herbivorous livestock in both of those regions (**Figures 2e,f**).

CONCLUSIONS

Based on the analysis of zooarchaeological evidence from 38 Neolithic and Bronze sites in the YRV, we detected changing spatial patterns of animal exploitation during its different key phases. (1) Humans primarily relied on hunting game, accompanied by raising omnivorous livestock (pig and dog), to obtain meat in the YRV during 7500–6000 BP. Omnivorous livestock became the most important animal subsistence in the middle and lower YRV, whereas wildlife dominated in the upper YRV in 6000–4000 BP. However, during 4000–2000 BP, the significance of hunting game substantially declined, while that of imported herbivorous livestock (sheep/goat, cattle, and horse) evidently increased in the YRV, with omnivorous livestock still relied upon as the major source of meat during that period. (2) The occupied space and intensity of human settlement in the YRV rapidly increased since ca. 6000 BP, which triggered reductions in wildlife habitats and greater dependence on animal husbandry in the YRV during the late Neolithic and Bronze periods. Climate change could have influenced the evolution of vegetation and human societies in the YRV during the mid-late Holocene, thereby influencing variation in the habitats available for wild animals, as well as promoting the adoption of imported livestock. The interaction between climate change and human activities eventually shaped the spatial-temporal patterns of animal exploitation in the YRV during 7500–2000 BP.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

AUTHOR CONTRIBUTIONS

The study was designed by GD and MM. The data was collected by LD and analyzed by LD, YL, and JD. LD, MM, and GD wrote the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fevo.2020.00161/full#supplementary-material

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