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

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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 paleoclimatic 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.yrrc.gov.cn/hbyl/bhkg/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 雅类) (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   | Andaqha    | 1195 | 5400–4500         | Qinghai, Hualong                 | Majiayao Culture                | Ren, 2017                                      |
| 3   | Jinchankou | 2689 | 4000–3700         | Qinghai, Huzhu                   | Qiya Culture                     | Ren, 2017                                      |
| 4   | Maojiaping | 1016 | 3000–2700         | Gansu, Tianshui                  | Western Zhou Dynasty            | Liu, 2019                                      |
| 4   | Maojiaping | 4208 | 2700–2400         | Gansu, Tianshui                  | Chunqi 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    | 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–Qiya 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, Lintong                 | Quanhu Culture Phase II          | Hu et al., 2012                                 |
| 10  | Huoshilang | 1111 | 4150–3900         | Shaanxi, Yulin                   | Late Longshan Culture–Early Xia Dynasty | Hu et al., 2008                                 |
| 11  | Shimaow     | 1527 | 4300–3800         | Shaanxi, Shennu                   | 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  | 344  | 6500–5900         | Shaanxi, Longshao                 | Yangshao Culture–Shijia Type    | Qi, 1988                                       |
| 16  | Lingkoucun | 331  | 7300–6600         | Shaanxi, Lintong                 | Yangshao Culture–Xiwangcun Type | Qi, 1988                                       |
| 17  | Lingkoucun | 119  | 6600–6200         | Shaanxi, Lintong                 | Yangshao Culture                | Zhao, 2009                                     |
| 18  | Bajiacun   | 747  | 7300–7000         | Shaanxi, Lintong                 | Miaodigou culture               | Hu, 2014                                       |
| 19  | Quanhucun  | 4245 | 5600–5100         | Shaanxi, Hua county              | Miaodigou Culture               | Hu et al., 2011a                                |
| 20  | Xingfiegang| 318  | 5900–5600         | Shaanxi, Huayin                  | Miaodigou Culture               | Ma, 2007                                       |
| 21  | Taosi      | 5573 | 4300–3900         | Shanxi, Linfen                   | Longshan Culture               | Liao et al., 2016                              |
| 22  | Zhoujiazhuang | 5170 | 4300–3900        | Shanxi, Yuncheng                 | Longshan Culture               | Liao et al., 2016                              |
| 23  | Longshangang | 7440 | 6000–5000        | Henan, Nanyang                  | Yangshao Culture                | Lin, 2011                                      |
| 24  | Longshangang | 1285 | 5200–4400        | Henan, Nanyang                  | Qijia Culture                   | Lin, 2011                                      |
| 25  | Longshangang | 1523 | 4400–4100        | Henan, Nanyang                  | Shijiahe Culture                | Lin, 2011                                      |
| 26  | Erlitou    | 11794| 3700–3600        | Henan, Yanshi                    | Erlitou Culture Phase II        | Yang J., 2006                                  |
| 27  | Erlitou    | 5910 | 3600–3500        | Henan, Yanshi                    | Erlitou Culture Phase III       | Yang J., 2006                                  |
| 28  | Erlitou    | 15344| 3600–3500        | Henan, Yanshi                    | Erlitou Culture Phase IV        | Yang J., 2006                                  |
| 29  | Erlitou    | 951  | 3600–3300        | Henan, Yanshi                    | Lower Erligang Culture         | Yang J., 2006                                  |
| 30  | Erlitou    | 4569 | 3600–3300        | Henan, Yanshi                    | Upper Erligang Culture         | Yang J., 2006                                  |
| 31  | Meishan    | 299  | 3900–3600        | Henan, Pingdingshan              | Longshan Culture               | You et al., 2017                               |
| 32  | Haizidui   | 4373 | 3800–3700        | Henan, Gongyi                   | Xinzhai Culture                | Liu, 2014                                      |
| 33  | 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 |
| 34  | 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 |
| 35  | 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 |
| 36  | Xihan      | 5720 | 5500–4700        | Henan, Zhengzhou                | Yangshao Culture               | Chen, 2006                                     |
| 37  | Shangpo    | 1013 | 3800–3500        | Henan, Zhumadian                | Erlitou Culture                | Yang, 2018                                     |

(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, Jinan| Longshan Culture                    | Lu and Zhou, 1990   |
| 34  | Yinjiacheng            | 171   | 3800–3500         | Shandong, Jinan| Yueshi Culture                      | 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| Yinfang Phase I                     | Song et al., 2010   |
| 38  | Qiankou                | 664   | 3600–3000         | Shandong, Huantai| Late Yinfang                         | Song et al., 2010   |

ID corresponds to the number shown in Figure 1.

Table 1 continued.

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 compared 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
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 percentage 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, Kangjiia 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 agropastoral 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 the transformed natural environment in that period. Additionally, the NISP percentage for forest wildlife also rose during 4000–3000 BP and declined during 3000–2000 BP (Figure 3C). Regionally, the multi-proxy record for the upper YRV (Zhou et al., 2010), the loess-paleosol 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 3C), 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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