



Reevaluation of early Holocene chicken domestication in northern China



Masaki Eda ^{a,*}, Peng Lu ^b, Hiroki Kikuchi ^c, Zhipeng Li ^b, Fan Li ^{b,1}, Jing Yuan ^{b,**}

^a Hokkaido University Museum, Hokkaido University, Kita 10, Nishi 8, Kita-ku, Sapporo, Hokkaido 060-0810, Japan

^b Institute of Archaeology, Chinese Academy of Social Sciences, 27 Wangfujing Dajie, Beijing 100710, China

^c Institute for Research in Humanities, Kyoto University, Yoshidahonmachi, Sakyo-ku, Kyoto 606-8501, Japan

ARTICLE INFO

Article history:

Received 3 September 2015

Received in revised form

18 January 2016

Accepted 23 January 2016

Available online xxx

Keywords:

Chicken

Domestication

Morphology

Zooarchaeology

ABSTRACT

The chicken (*Gallus gallus domesticus*) is the most widespread domestic animal in the world. However, the timings and locations of their domestication have remained debatable for over a century. China, and particularly northern China, has been claimed as one of the early centers for the domestication of chickens, because many chicken remains have been discovered at a number of archaeological sites. However, the identification of archaeological domestic chicken bones from early Holocene sites in China remains contentious. In this study, we analyzed 1831 bird bones, which included 429 bones previously recorded as “domestic chicken” from 18 Neolithic and early Bronze Age sites in central and northern China. Although morphological species identification criteria for the bones of 55 modern Chinese Phasianidae species, including the domestic chicken and wild red junglefowls, have not yet been fully established, upon reanalysis none of the “domestic chicken” bones were derived from chickens. In addition, bones determined to be candidate chicken bones were found at only 2 of the 18 sites, suggesting that chickens were neither widely kept nor distributed in central and northern China during the early and middle Holocene period. Further studies that combine analyses of morphology, ancient DNA, and radiocarbon dating are required to fully reveal the origin and history of the domestic chicken in northern China.

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1. Introduction

Chickens (*Gallus gallus domesticus*) are the most widespread domestic animals in the world, providing meat and eggs on every continent and even some remote islands (Serjeantson, 2009). They appear to have been used for religious activities, cockcrowling and cockfighting at the earliest stages of their domestication. The domestic chicken principally originates from the red junglefowl *G. gallus*, which is distributed throughout Southeast Asia and China and is proposed to have been domesticated in multiple regions of the area (Akishinonomiya et al., 1994; Liu et al., 2006; Miao et al., 2013).

Some authors claimed that China, and particularly northern

China, appears to be one of the early centers for chicken domestication because many alleged chicken remains have been recorded at a number of archaeological sites (Bellwood, 2005; Serjeantson, 2009; Xiang et al., 2014). To date, chicken bones have been discovered in at least 52 archaeological layers from 44 Neolithic sites and 18 layers from 12 Bronze Age sites in China (Deng et al., 2013; Li et al., 2015; West and Zhou, 1988). In addition, the oldest domestic chicken bones in the world have been discovered in northern China: at Cishan Site, Hebei Province, and Peiligang Site, Henan Province (Institute of Archaeology CASS, 1984; Zhou, 1981). Radiocarbon dating of the layers where chicken bones have been found has dated them to approximately 6000 BC. Furthermore, recent analyses of ancient DNA have discovered mtDNA haplotypes of *G. gallus* in samples from Nanzhuangton (Hebei Province), Cishan, and Wangyin (Shandong Province), suggesting that domestic chicken farming began approximately 10,000 BP in northern China (Xiang et al., 2014). However, some studies have challenged the discovery of early Holocene chicken bones in the northern China: Benecke (1994) and Peters (1997a, 1997b) pointed out that the purported chicken bones from Cishan are not in fact from

* Corresponding author.

** Corresponding author.

E-mail addresses: edamsk@museum.hokudai.ac.jp (M. Eda), yuanjing@cass.org.cn (J. Yuan).

¹ Current address: School of History, Zhengzhou University, Science Road 100, Zhengzhou, Henan 450001, China.

chickens but rather are from pheasants, although they failed to explain how they identified the bones as such, while Yuan (2010) and Deng et al. (2013) indicated that the identification criteria for domestic chicken bones have not yet been fully established for northern China, and thus a reexamination of the early Holocene chicken bones is necessary. There are 55 Phasianidae species in China, including such as red junglefowl, common pheasant (*Phasianus colchicus*), Koklass pheasant (*Pucrasia macrolopha*), and brown-eared pheasant (*Crossoptilon mantchuricum*) (Zheng, 2011), therefore the criteria for discriminating the bones of chicken from those of indigenous birds in northern China are required.

To uncover the origin and early history of the domestic chicken throughout the world, a reevaluation of chicken bones from early Holocene China, especially northern China, is essential. Unfortunately, most of the recorded chicken bones are not fully available. Therefore, it is difficult or, in many cases impossible, to reanalyze them. However, many other bird bones have been found alongside these reported bones at Neolithic and Bronze Age sites in China. By studying them using clear identification criteria for chicken bones, it is possible to reevaluate the early Holocene history of domestic chickens in northern China.

In this study, we analyzed 1831 bird remains from 18 Neolithic and Bronze Age sites in central and northern China. Combining morphological identification with histological analysis of Phasianidae bones, we found that chickens and red junglefowls were absent, or at most very rare, during the early and middle Holocene in central and northern China. We discuss the large discrepancies between this study and previous studies.

2. Materials and methods

In total, 1,831 bird bones from 18 Neolithic and Bronze Age Chinese archaeological sites were studied (Table 1, Fig. 1). The time period for each sample was estimated from the layer in which it was found. Although bird bones from five sites at Wangyin (Zhou, 2000), Zengpiyan (Yuan, 2003), Cishan (Zhou, 1981), Jiahu (Huang, 1999) and Nanzhuangtou (Hebei Provincial Institute of Cultural Relics et al., 2010) had already been recorded, all of the accessible samples were reevaluated as part of this study.

Taxonomic identification was conducted by ME with unaided eye observation of materials. For family-level identification, reference collections at the zooarchaeology laboratory in the Institute of Archaeology, Chinese Academy of Social Sciences, and the personal collection of ME were used. More detailed identification within the family Phasianidae was conducted on femora, tibiotarsi, and tarsometatarsi, according to the identification criteria by Eda and Inoué (Eda and Inoué, 2011), which focused on the discrimination of chickens and red junglefowls from Japanese indigenous pheasants (common pheasant and copper pheasant *S. soemmerringii*). There are 55 Phasianidae species in China, including the red junglefowl and common pheasant (Zheng, 2011), therefore these criteria were not enough to distinguish chickens and red junglefowls from the other 53 indigenous Phasianidae. However, the criteria are effective for excluding the bones of non-chicken or non-red junglefowl and identifying candidate bones of chicken or red junglefowl. The presence or absence of pneumatic foramina of the greater trochanter (femur (Eda and Inoué, 2011)), a medial plantar crest (tarsometatarsus (Nishida and Hayashi, 1981)), and the shape of the posterior ligament of the tibiofibular joint (tibiotarsus) were recorded for each sample.

The developmental stage of the bones (nestling or adult) and the presence or absence of medullary bone were recorded via unaided eye observation. We defined a nestling bone as a bone with at least one incomplete ossification. Although the production of glass slides and staining with Alcian blue is a reliable method for the

identification of archaeological medullary bone, careful unaided eye observation is also useful for identifying stereotypic medullary bone with a developed woven bony structure (Eda et al., 2010).

3. Results

Of the 1831 bird remains, a total of 1215 Phasianidae bones were found at 18 Neolithic and Bronze Age sites in central and northern China (Table 1, Fig. 1). Except Phasianidae, the bones included at least nine other families: Anatidae, Podicipedidae, Ciconiidae, Ardeidae, Gruidae, Rallidae, Laridae, Accipitridae, and Corvidae. The discriminating characteristics of femur, tibiotarsus, or tarsometatarsus were observed in 280 of the 1215 Phasianidae bones and were used for further analyses.

Five tarsometatarsi from Cishan, which were exhibited at the Handan City Museum, Hebei, northern China, as “the oldest domestic chicken in the world” were analyzed (Fig. 2a). All of the tarsometatarsi had a medial plantar crest (Nishida and Hayashi, 1981), which was completely absent from the bones of chicken and red junglefowl, and were therefore identified as “non-chicken” bones. From Wangyin, 55 femora and 15 tarsometatarsi were reanalyzed (Fig. 2b). All of the tarsometatarsi had a medial plantar crest while all of the femora had pneumatic foramina of the greater trochanter (Eda and Inoué, 2011), which is absent from the bones of chicken and red junglefowl, and were identified as non-chicken bones. Among the bones from Nanzhuangtou, three tarsometatarsi, two femora, and one tibiotarsus were reanalyzed (Fig. 2c). All of the femora and tarsometatarsi had a medial plantar crest and pneumatic foramina of the greater trochanter, while the tibiotarsus exhibited a rounded posterior ligament of the tibiofibular joint similar to common pheasants and copper pheasants but different from chicken and red junglefowl (line-shaped) (Eda and Inoué, 2011). Again, all three skeletal parts were identified as non-chicken bones.

The majority of the other Phasianidae bones under scrutiny were similarly identified as non-chicken bones: 45 of 46 femora had pneumatic foramina of the greater trochanter, 25 of 27 tibiotarsi had rounded posterior ligaments of the tibiofibular joint, and 125 of 126 tarsometatarsi had medial plantar crests. Ultimately, only three chicken bone candidates were identified by the discriminating characteristics: one femur from Xiawanggang (found in the Longshan layer dating to between 3000 and 2000 BC, at Henan, Fig. 3a) and two tibiotarsi from Zaoshugou (dating from the Proto-Zhou culture, 1200–1050 BC, Shaanxi, Fig. 3b). An immature femur from Xiawanggang was found to have no pneumatic foramina of the greater trochanter and was thus recognized as a candidate chicken bone. The pneumatic foramina of the greater trochanter is evident in the immature femora of *P. colchicus* (Supplementary Data 1). Two tibiotarsi from Zaoshugou exhibited line-shaped posterior ligaments of the tibiofibular joint and were identified as candidate chicken bones. One of the two candidate chicken bones from the site included medullary bone. Apart from the tibiotarsus from Zaoshugou, the presence of medullary bone was rare but was also found in another tibiotarsus from Zaoshugou (Fig. 3c), a radius from Xiawanggang (Fig. 3d) and a tibiotarsus from Tengjiagang (Bronze Age, Heilongjiang), although none had the characteristics needed to discriminate among chicken and indigenous pheasants and so be morphologically recognized as candidate chicken bones. An un-fused tarsometatarsus without a medial plantar crest was identified from Zhoujiazhuang (Taosi Culture, 2300–1900 BC, Shanxi). However, the tarsometatarsus was neither classified as a candidate chicken bone nor as non-chicken because the medial plantar crest is absent from a tarsometatarsus of nestling non-chicken Phasianidae birds (Eda and Inoué, 2011). Except for the femur from Xiawanggang and

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