



Food and more than food: Potential anuran consumption at the Changshan site (AD 916–1234), Northeast China

Zhe Zhang ^{a,b,1} , Xiaohong Lv ^{a,b}, Zhongwei Jing ^a, Sen Lin ^a, Chunxue Wang ^{a,b,*}

^a Research Center for Chinese Frontier Archaeology of Jilin University, Changchun, China

^b Bioarchaeology Laboratory, School of Archaeology, Jilin University, Changchun, China

ARTICLE INFO

Keywords:

Anuran remains
Element frequency
Liao and Jin Dynasties
Northeast China

ABSTRACT

The presence of anuran motifs on Neolithic pottery and references in historical documents suggest the deep-rooted significance of anurans in China's history, both economically and symbolically. However, the role of anurans in the subsistence economy remains underexamined in zooarchaeological research. This study presents zooarchaeological evidence of potential anuran consumption at the Changshan site in Lishu County, northeastern China. A total of 1350 anuran bones were recovered from Liao and Jin Dynasty (AD 916–1234) features, with more than 80% concentrated in trench G006. Most identified specimens belong to Ranidae (including *Pelophylax nigromaculatus* and Ranidae indet.), with limb bones being the most commonly represented elements. The predominance of a single species, the preference for limb bones, the male-biased sex ratio, and concentrated deposition suggest possible human selection and consumption. This study represents the first detailed zooarchaeological analysis of anuran remains in China and highlights the need for further comparative studies to better understand the historical use of anurans.

1. Introduction

Anuran bones have received little attention in zooarchaeological research in China. Previous studies suggest that this is either due to their small size, which makes them difficult to recover in the absence of floatation or fine screening, or because they are often regarded as intrusive in most faunal reports. The unusually large number of anurans bones recovered from the Changshan site has prompted a reconsideration of their role in the ancient human diet and their potential contribution to reconstructing past human behavior and social life.

In many cultures, frogs and toads have long been regarded as sources of food, medicinal ingredients, and components in ritual practices (see Table 1 in the [Supplementary Material](#)). This also held true in ancient China. In central China, anuran motifs were commonly used as decorative elements on pottery across various archaeological sites (Zhang, 2018; Zhang, 2010; Łakomska, 2021). The earliest evidence of such decoration may be a frog motif depicted on a pottery bowl from the Jiangzhai site, associated with the early Yangshao culture (Banpo phase 5000–4000 BCE) ([Xi'an Banpo Museum, 1988](#)). During the subsequent Miaodigou phase (4000–3000 BCE) and the Machang period (2300–2000 BCE) ([Łakomska, 2021](#)), frog motifs became increasingly

abstract but remained prevalent as decorative features, reflecting the continued symbolic and ritual importance of anurans in Neolithic Chinese culture (Fig. 1). In Northeast China, researchers discovered a relief sculpture of toad on a pottery vessel at the Chahai site, a Neolithic settlement dating back approximately 7600 years, suggesting an early tradition of anuran iconography in the study region (Li, 2012).

In addition to anuran motif decorations on pottery vessels, numerous historical documents attest to the use of frogs and toads in cooking, medicine, and ritual practices throughout Chinese history. Since the Han Dynasty, frogs and toads have been regarded as valuable food resources in southern China (see Table 2 in the [Supplementary Material](#)). Parallel to their symbolic meanings as expressed in material culture, these amphibians were also used as ritual offerings in ceremonial contexts, as recorded in historic texts (Yang, 1968). Even in modern times, frog worship persists among some ethnic minority groups in southern China (Qin, 1999; Wang, 2022). In contrast, historical references to anuran use in Northeast China appear much later. A notable Qing Dynasty account by Yang Tonggui (1968) describes how the Manchu worshipped their ancestor using *hasma* (a certain *Rana* species) in Liaoning Province. The Manchu also consumed *hasma* as a delicacy and believed that its fat had medicinal properties, particularly for the kidneys and lungs. Over time,

* Corresponding author at: Research Center for Chinese Frontier Archaeology of Jilin University, Changchun, China.

E-mail address: chunxuewang@jlu.edu.cn (C. Wang).

¹ First author.

Table 1

Taxonomic attribution and the number of identified specimens (NISP) of the different burial contexts from Changshan.

	ditch	pit	burial	unit	NISP	%NISP
Bivalvia	23	25	1	5	54	2.24
Actinopterygii	13	83	0	2	98	4.06
Amphibia (Anura)	1253	83	11	3	1350	55.88
Aves	38	67	0	1	106	4.39
Reptilia (Testudines)	6	0	0	0	6	0.25
Mammalia	408	355	1	38	802	33.20
Total					2416	100

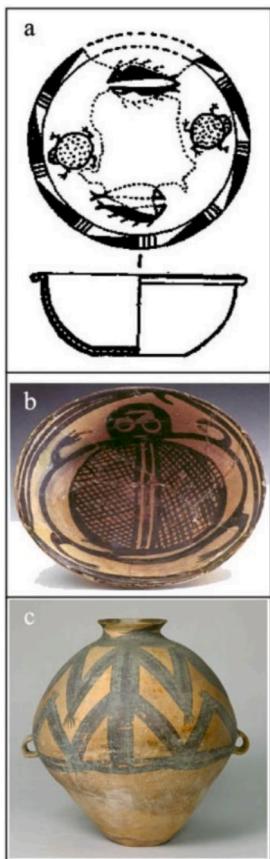


Fig. 1. Painted potteries with frog designs from Neolithic sites in China. (a) Jiangzhai, Shaanxi. Yangshao culture (Banpo phase 5000–4000 BCE), modified from [Xi'an Banpo Museum, 1988](#); (b) Shizhaocun, Gansu. Yangshao culture (Miaodigou phase 4000–3000 BCE), modified from [Łakomska 2021](#); (c) Majiayao, Gansu. Majiayao culture (Machang phase 2300–2000 BCE), the Palace Museum.

Northeast China has been inhabited by various groups including Xianbei, Khitan and Tungusic-speaking peoples ([Siska et al., 2017](#)). The Manchu, direct descendants of the Jurchens who ruled China during the twelfth century, eventually established the Qing Dynasty. The Manchu tradition of frog consumption may therefore have deeper historical roots, possibly tracing them back to their Jurchen ancestors.

Although numerous Chinese historical documents mention frogs and toads as popular delicacies and important ingredients in traditional medicine (also see [Table 2](#) in the [Supplementary Material](#)), archaeological discoveries of substantial quantities of anurans remain are exceedingly rare. Many zooarchaeological reports merely note the presence of anuran remains without providing quantitative data ([Dai and Zhang, 2021; Zhang, 2021](#)). In the few cases where counts are available, anuran bones appear in extremely low numbers. For example, [Hou et al. \(2022\)](#) identified a single left radio-ulna of a *Rana* individual

from a house feature at the Xichuangou site, dated to 6500–6000 BP. Similarly, at the Neolithic Huanggang site in Jiangsu (7300–6200 BP), researchers reported two right humeri, also identified as belonging to *Rana* individuals ([Pei, 2020](#)).

In contrast to the rich textual record, archaeological research has thus far demonstrated a marked deficiency in the recovery and analysis of anurans remains. This study aims to address that gap by presenting zooarchaeological evidence from a large assemblage of anuran bones recovered at the Changshan site in Northeast China, thereby shedding new light on the role of anurans in ancient Chinese subsistence practices.

2. Changshan site

The Changshan site is located on the western bank of the East Liao River in Jilin Province, Northeast China (43°49'26" N, 125°15'54" E). It was initially discovered in 1983 during a regional heritage survey. In 2016, a joint archaeological excavation was undertaken by the Research Center for Chinese Frontier Archaeology at Jilin University, the Institute of Cultural Relics and Archaeology of Jilin Province, and the Cultural Relics Management Committees of both the city of Siping and the county of Lishu ([Fig. 2](#)). The excavation covered a total area of approximately 855 m² and uncovered cultural features and artifacts spanning the Neolithic and Bronze Ages, as well as the Liao and Jin Dynasties ([RCCFA, 2020](#)). On the basis of stratigraphic data and pottery typology, the faunal remains analyzed in this study are primarily associated with the Liao and Jin Dynasty occupation of the site.

3. Materials and methods

3.1. Materials

During the 2016 excavation season, approximately 2388 faunal specimens from Liao and Jin Dynasty contexts—including features and stratigraphic layers—were taxonomically identified. To facilitate the recovery of small skeletal elements, we sieved the infill from the ditches and layers with a 10 mm mesh and the sediments from the pits and burials through a finer 5 mm mesh. Preliminary analysis of the faunal assemblage revealed that anuran bones constituted the majority of all the identified specimens from the site ([Table 1](#)).

3.2. Methods

All anurans discussed in this study originate from features dated back to the Liao and Jin Dynasties. The animal bones were recovered through sieving with 5- or 10-mm mesh screens. Taxonomic identification of anurans remains particularly challenging because of the limited availability of modern comparative specimens. To address this, we utilized comparative collections housed in the Zooarchaeology Laboratory at Jilin University and published osteological studies illustrating the skeletal morphology of anuran species native to the region ([Othman et al., 2022; Ratnikov, 2001; Prikryl et al., 2009; Thomas, 1996; Yan et al., 2023; Zhang et al., 2020](#)). In addition, we consulted publicly accessible digital resources, including MorphoSource ([morphosource.org](#)), to supplement our comparative dataset.

The taxonomic classification that is employed in this study follows [Frost \(2024\)](#) and [AmphibiaChina \(2024\)](#). The ilium and humerus are the most frequently used skeletal elements in species identification, as they are the most diagnostically informative for frog taxa ([Holman, 1989, 2003; Matthews et al., 2015; Matthews et al., 2019](#)). At the Changshan site, the majority of humeri and ilia are well preserved, with only 23.2% (N = 77) exhibiting breakage. Consequently, species identification is primarily based on these two elements. Anatomical terminology for the ilium and humerus follows the conventions of [Holman \(2003\)](#) and [Gómez and Turazzini \(2016\)](#).

The presence or absence of a dorsal crest on the ilial bones serves as a key trait distinguishing different anuran families ([Matthews et al.,](#)

2019). A long and broad dorsal crest is commonly recognized as a characteristic of the family Ranidae (Holman and Schloeder, 1991; Meylan, 2005). The Ranidae ilia (Fig. 3A) from Changshan are comparable to the genus *Pelophylax* (formerly included in *Rana* until Frost et al., 2006), on the basis of the wide, pyriform shape of the dorsal tubercle, a high dorsal crest anterior to the dorsal tubercle, and a small preacetabular zone (Ratnikov, 2001). The ventral acetabular wall is wide, which is a characteristic of *Pelophylax*. In the posterior view, the ilioischiatic juncture thicker than that of brown frogs of the genus *Rana* (Bailon, 1999; Gleed-Owen, 2000; Blain and Arribas, 2017). The acetabular diameter-to-thickness (d/t) ratio ranged from 2.16 to 2.85 (n = 94) (Fig. 4). Excluding six specimens whose ratios exceeded 2.75, most of the specimens fell within the range of 2.12–2.88 observed for *Pelophylax* and were well outside the range of 2.75–4.00 measured for *Rana* (Gleed-Owen, 2000). Today, the genus *Pelophylax*—represented by *Pelophylax nigromaculatus*—is widely distributed across eastern and northeastern China.

One of the taxa from Changshan is represented by ilia that lack a dorsal crest (Fig. 3Q). In northeastern China, anuran families without dorsal ilial crests include Bufonidae, Microhylidae, Bombinatoridae, and Hylidae (AmphibiaChina, 2024). However, the dorsal tubercle is more robust than those of Bombinatoridae and Hylidae (Bailon, 1999; Blain and Arribas, 2017; Prikryl et al., 2009). Moreover, the presence of a paraventral crest on the humerus (Fig. 3R) excludes *Kaloula borealis*, the only species of Microhylidae found in northeastern China (Keeffe and Blackburn, 2020). Although species-level identification of Bufonidae can be facilitated by a combination of morphological features of the ilium and humerus, the ilial anatomy of this family is highly homogeneous. Owing to the limited availability of comparative specimens from species within Bufonidae, identifying the Changshan Bufonidae beyond the family level remains difficult. Consequently, all toad bones have been classified as Bufonidae indet. (Fig. 3L-T).

Additional skeletal elements, such as angular, pterygoid, shoulder girdle, radio-ulna, vertebrae, urostyle, femur, tibiofibula, and tarsalia, were also examined for anuran identification. For example, although tibiofibula have no obvious trait by which Ranidae and Bufonidae can be distinguished, the tibiofibular of Ranidae is longer and more gracile than that of Bufonidae. This characteristic can also be observed in the humerus and femur (Fig. 5). Within Ranidae, however, owing to the overlapping morphological characteristics of these elements, it is still difficult to distinguish *Pelophylax* from *Rana*. Consequently, these

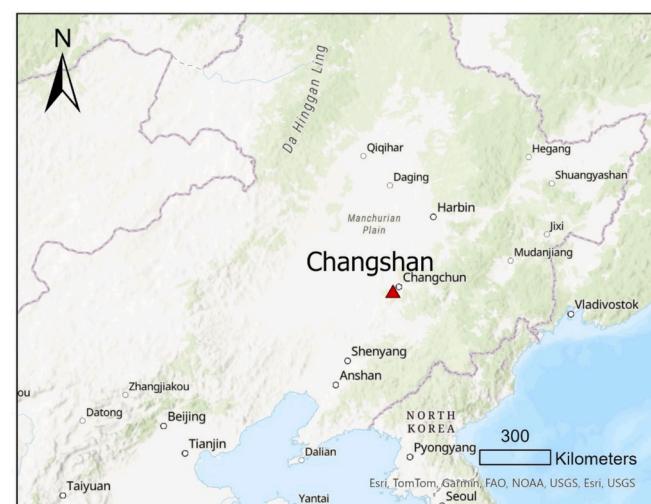


Fig. 2. The Location of the Changshan site.

elements have been identified as Ranidae indet. (Fig. 3C-K). Other skeletal remains that can only be assigned to the order level have been classified as Anura indet. (Table 2).

The number of identified specimens (NISP) and the minimum number of individuals (MNI) were used to quantify the anuran remains at Changshan (Lyman, 2008). To assess the relative abundance of different skeletal elements, the minimum animal unit (MAU) and its standardized value (MAU%) were calculated (Binford, 1981; Lyman, 1994). Bone measurements (Fig. 4), including those of the ilium, humerus, femur, and tibiofibula, were taken following the standards established by Bailon (1997).

4. Results

4.1. Anuran list and distribution

A total of 1,350 skeletal remains were osteologically identified and assigned to anurans. These remains represent the two families of Ranidae and Bufonidae. The predominant taxon is Ranidae, with 1,085 remaining corresponding to a minimum of 255 individuals. This

Table 2

Anuran taxonomic attribution, number of identified specimens (NISP), and minimum number of individuals (MNI) in different contexts from Changshan. G: trench; H: pit; M: tomb; T: unit; indet.: indetermined.

Feature	Ranidae				Bufonidae indet.		Anuran indet.		% of total anuran assemblage	
	<i>P.nigromaculatus</i>		Ranidae indet.		NISP	MNI	NISP	MNI	NISP%	MNI%
G002	0	0	8	3	2	1	0	0	0.74	1.33
G003	4	2	31	6	17	4	2	1	4.00	4.32
G004	4	1	14	3	2	1	0	0	1.48	1.66
G005	2	1	8	3	8	2	0	0	1.33	1.99
G006	214	68	707	137	152	20	14	3	80.52	75.75
G007	8	3	30	5	24	4	1	1	4.67	4.32
G008	0	0	1	1	0	0	0	0	0.07	0.33
H004	0	0	3	2	0	0	0	0	0.22	0.66
H033	1	1	4	1	0	0	0	0	0.37	0.66
H034	0	0	4	2	0	0	0	0	0.30	0.66
H042	0	0	1	1	0	0	0	0	0.07	0.33
H044	0	0	1	1	4	1	1	1	0.44	1.00
H064	2	1	18	5	3	1	0	0	1.70	2.33
H084	0	0	8	1	17	2	12	1	2.74	1.33
H094	0	0	1	1	3	1	0	0	0.30	0.66
M003	0	0	2	1	0	0	0	0	0.15	0.33
M007	2	1	2	1	0	0	0	0	0.30	0.66
M008	1	1	3	1	1	1	0	0	0.37	1.00
T0901	0	0	1	1	2	1	0	0	0.22	0.66
Total	238	79	847	176	235	39	30	7	100	100

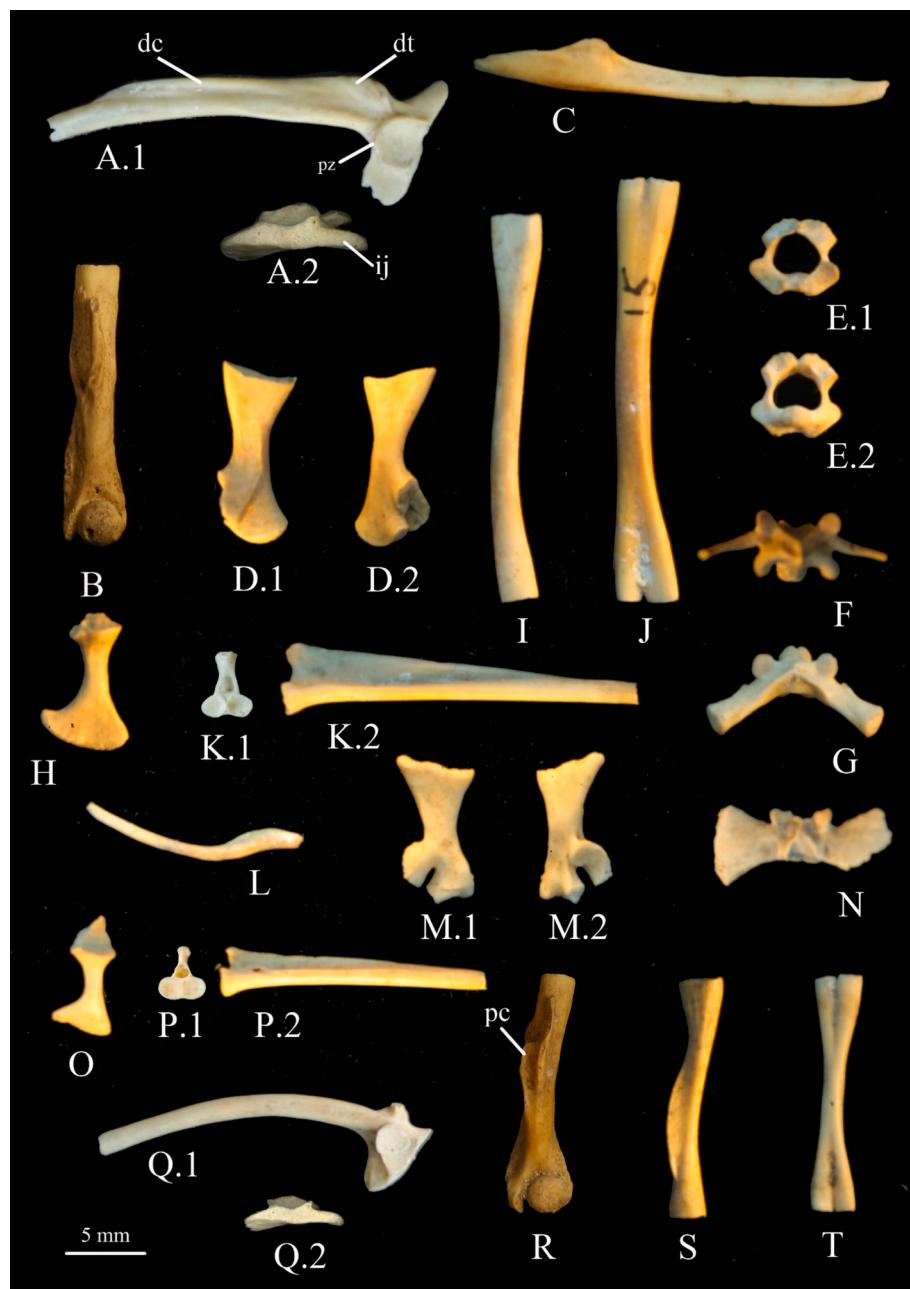


Fig. 3. Anuran remains from Changshan. A-B: *Pelophylax nigromaculatus*, A: left ilium, lateral (A.1; dc, dorsal crest; dt, dorsal tubercle; pz, preacetabular zone) and posterior views (A.2; ij, ilioschiatic juncture); B: male left humerus, ventral view; C-K: Ranidae indet., C: right angular, dorsolateral view; D: left scapula, ventral (D.1) and dorsal (D.2) views; E: atlas, anterior (E.1) and posterior (E.2) views; F: trunk vertebrae, dorsal view; G: sacrum, dorsal view; H: right coracoid, dorsal view; I: femur, lateral view; J: tibiofibula, ventral view; K: urostyle, anterior (K.1) and left lateral view (K.2); L-T: Bufonidae indet., L: left angular, dorsolateral view; M: left scapula, ventral (D.1) and dorsal (D.2) views; N: sacrum, dorsal view; O: right coracoid, dorsal view; P: urostyle, anterior (P.1) and left lateral view (P.2); Q: left ilium, lateral (Q.1) and posterior (Q.2) view; R: left humerus, ventral view (pc, paraventral crest); S: femur, lateral view; T: tibiofibula, ventral view.

accounts for 80.4 % of the identified NISP and 84.7 % of the total MNI ([Table 2](#)).

Within Ranidae, 238 remains were identified as *P. nigromaculatus*, based on diagnostic features of the ilium and humerus. Fewer diagnostic elements were classified as Ranidae indet., although they likely also belong to *P. nigromaculatus*, as all identifiable ilia and humeri were from a single species ([Driver, 2011](#)).

With the exception of three anuran bones recovered from the first layer of unit T0901, all anuran remains were found in various pits, ditches, and burials. Among these features, 80 % of the anuran bones were recovered from Feature G006 ([Table 2](#)). Feature G006 is a ditch, which the excavator proposed functioned as a defensive moat. Only a

portion of the ditch was exposed during excavation; the revealed section measured 9.40 m by 4.40 m in area and is 3.62 m deep.

The ditch was excavated in three layers on the basis of soil color. The middle layer served as an interlayer between the upper and lower layers. Unlike the upper and lower layers, which extend across the entire ditch, the middle layer is restricted to the center and is thinner than the other two layers. It may represent the remnants of a small puddle, although its exact formation process remains unclear. Owing to its limited thickness and distribution, only a small number of bones were recovered from this layer (see [Table 3](#) in the [Supplementary Material](#)), and anuran remains were found only in the upper and lower layers. The discussion that follows focuses exclusively on these two layers. Although Feature G006

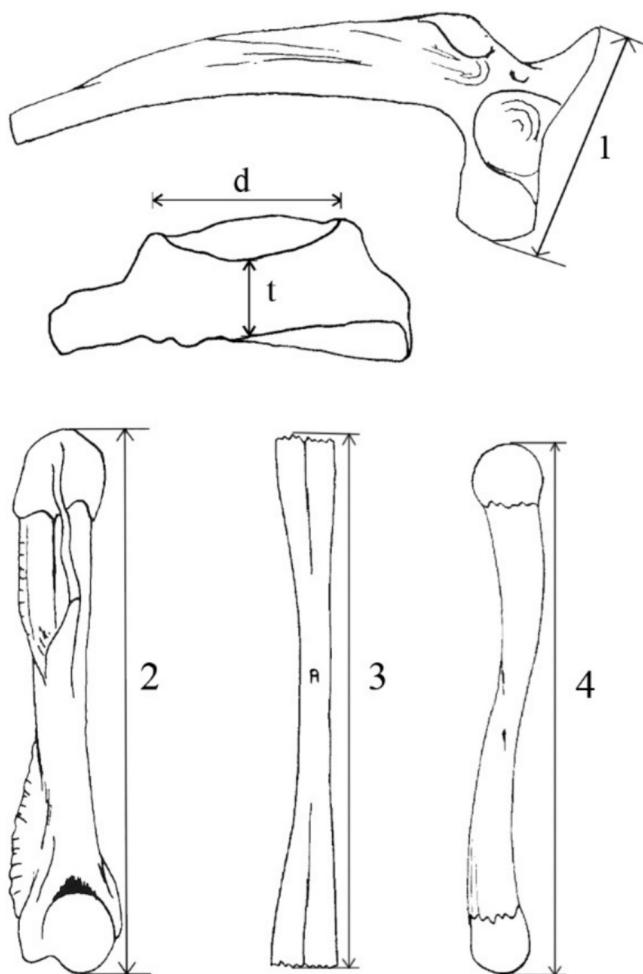


Fig. 4. Definition of measured measurements (after Bailon 1997; Gleed-Owen 2000; Blain et al., 2015, modified from Gleed-Owen 2000; Ratnikov 2001). 1, maximum width of the ilioischiatric juncture; 2, length of humerus; 3, length of tibiofibula; 4, length of femur; d, acetabular diameter; t, corpus thickness at centre of the acetabulum.

was stratigraphically divided into three layers, all the layers were dated to the Liao and Jin Dynasties on the basis of ceramic topology and decoration.

4.2. Skeletal element representation in feature G006

Among the taxa accumulated in Feature G006, the remains of *P. nigromaculatus* can be studied in the greatest detail. Diagnostic features for identifying this species are limited to the humerus and ilium. Other elements, such as the scapula, vertebrae, urostyle, femur, and tibiofibula, can be distinguished at the family level (Ranidae or Bufonidae) but are difficult to attribute more specifically to *Pelophylax* or *Rana*. These have therefore been classified as Ranidae indet. (Table 2).

However, since all the identifiable humeri and ilia were assigned to *P. nigromaculatus*, it is reasonable to infer that the elements were classified as Ranidae indet. (Table 3) also belong to this species. On the basis of this inference, we further assumed that the anuran elements that could be assigned to the Ranidae family likewise belong to *P. nigromaculatus*, allowing us to compare the frequency of skeletal elements across the sample.

The representation of *P. nigromaculatus* skeletal elements is shown in Table 4. With the exception of the humerus and urostyle, the skeletal representation follows a similar pattern in both layers. The most frequently represented elements ($MAU\% \geq 50\%$) are the hindlimb bones

(femur and tibiofibula) in both layers, along with the urostyle in the upper layer. A second group of well-represented elements ($MAU\% \text{ between } 25\% \text{ and } 49\%$) includes the ilium and tarsalia in the upper layer, and the humerus and ilium in the lower layer. With the exception of the humerus, all the elements in this group are closely associated with the hindlimb, which is the most abundant anatomical region.

The least represented elements ($MAU\% \leq 10\%$) included the scapula, trunk vertebrae, and humerus in the upper layer, and the angular, shoulder girdle (scapula and coracoid), and vertebral column (atlas, trunk vertebrae, sacral vertebrae, and urostyle) in the lower layer. This underrepresented group is notable, as most of the bones belong to the head and axial skeleton, except for the humerus in the upper layer, which is the only limb bone in this category. The absence of cranial and spinal elements could suggest that these parts were discarded elsewhere after the “thighs”—the most meat-bearing portions—were processed (Bailon, 1993; Kysely, 2008). However, since these underrepresented bones are small compared with the larger, better preserved limb elements, an alternative explanation is differential preservation caused by recovery bias. Although the Changshan site employed a more refined screening process than the other sites, the use of 5 mm and 10 mm mesh screens may still have been insufficient for effectively recovering microfauna remains (Whyte and Compton, 2020).

4.3. Sex-ratio

Sexual dimorphism is often associated with differences in the intensity of sexual selection between sexes. Yan et al., (2023) reported morphological features of the humerus that can distinguish male and female *Bufo gargarizans*, a species widely distributed across China, Russia, and the Korean Peninsula. In this species, the deltoid crest and medial crest of male humeri are more pronounced than those of female humeri (Yan et al., 2023). In archaeological research, Bailon (1999) described stronger medial and lateral crests in males, suggesting that these features serve to facilitate amplexus by helping males grasp females during copulation. He proposed that the presence or absence of crests on the humerus can be used to distinguish between sexes. This pattern has also been observed in *P. ridibundus*, *P. lessonae* and *P. esculentus* (Sanchiz et al., 1993; Blain et al., 2015).

Sexual dimorphism in body size and limb musculature has been confirmed in *P. nigromaculatus* as well (Zheng et al., 2002; Mao et al., 2014). Compared with males, females exhibit significantly greater snout-urostyle lengths and body masses, whereas males possess heavier forelimb muscles, specifically the flexor carpi radialis, flexor carpi ulnaris, and abductor indicis longus, which are involved in the axillary amplexus (Mao et al., 2014). Ratnikov (2001) reported that male *P. nigromaculatus* developed pronounced humeral crests, which were morphologically comparable to those of the specimens from Changshan. Although factors other than sex may also influence crest development, humeral morphology can nevertheless be used to distinguish sex in the *P. nigromaculatus* assemblage from Changshan (Bailon 1993, 1997; Gehasse 2001; Kysely 2008).

On the basis of these criteria, the sample includes a minimum number of individuals (MNI) of 54 males and 20 females, indicating a male-to-female ratio of 2.7:1 (Table 5). Males are thus significantly more prevalent than females in the assemblage.

4.4. Surface alteration

Most of the anuran specimens are well preserved, with some long bones retaining their cartilage capsules, indicating favorable preservation conditions at the site. The surfaces of the anuran bone assemblage were examined under a digital microscope (AM3111). Overall, the materials exhibit minimal weathering, and 39 specimens (2 % of the NISP) show traces of root etching (Pokines and Baker 2021). No signs of breakage or surface alteration caused by predator digestion were observed, suggesting that the anuran assemblage at Changshan is

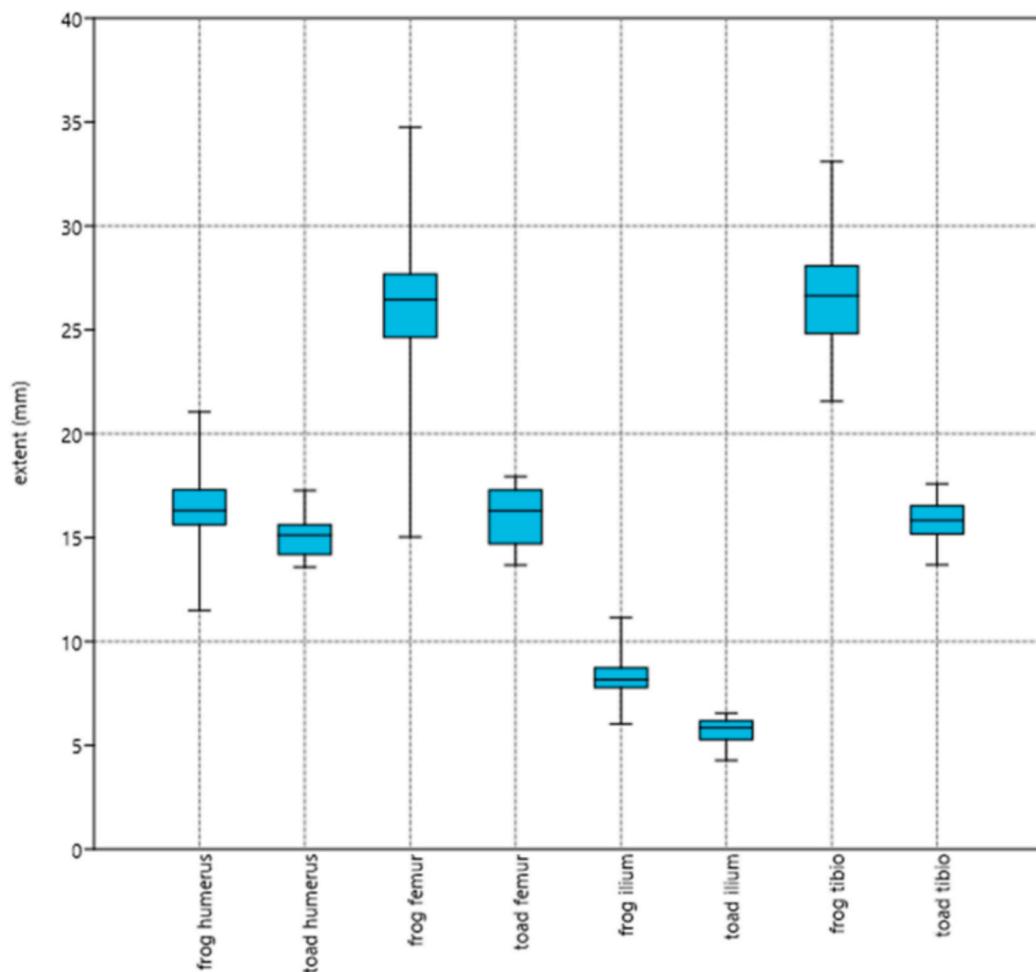


Fig. 5. The boxplot represents the measurements of Ranidae and Bufonidae bones from Changshan. Basic statistical characteristics of osteometric variability in four measurements: the length of the humerus, femur, and tibialia, and the maximum diameter of the ilium at the level of the acetabulum (for measurement definitions, see also Fig. 3).

unlikely to result from predator accumulation (Pinto-Llona and Andrews, 1999). Only one charred specimen, blackened by heat and recovered from Feature H004, displays evidence of burning (Fig. 6). Several potential explanations exist for burning marks on faunal remains (Bosch et al., 2012). Such charring could result from cooking activities or from accidental exposure to fire—possibly through contact with fuel materials. Therefore, it is not possible to definitively attribute the burning to cooking based on a single specimen.

5. Discussion and summary

An unusually large quantity of anuran bones was recovered at Changshan, where Ranidae dominated the faunal assemblage. Notably, more than 80 % of the anuran remains were concentrated in a single context, trench G006. Understanding the presence and origin of these Ranidae remains essential (Bailon 1993; Kyselý 2008; Bisbal-Chinesta et al., 2020).

Skeletal representation is among the most commonly used approaches for interpreting anuran remains at archaeological sites. For comparative purposes, the MAU% for each skeletal element or anatomical group of *Rana temporaria* from Chalain-3 Level VI Zone B (Bailon 1993) and Kutná Hora-Denemark site Feature 36 (Kyselý 2008), *Hyla gr. arborea* from El Mirador (Bisbal-Chinesta et al., 2020), were analyzed (Fig. 7). The skeletal profile of Ranidae (including *P. nigromaculatus* and Ranidae indet.) from the lower layer of Feature G006 at Changshan exhibits a pattern comparable to that of Chalain-3

and Kutná Hora-Denemark, particularly in the high representation of posterior skeletal elements such as hindlimbs and, to a lesser extent, the ilia. Similarly, lower representation values at Changshan reflect those at Chalain-3 and Kutná Hora-Denemark, with consistently low MAU% for the head, vertebrae, shoulder girdle, and forelimbs. Such an accumulation pattern, where hindlimbs dominate, is often interpreted as evidence of human consumption, as these parts are the most meat-bearing in the frog's body.

In contrast, compared with the Changshan Ranidae assemblage, the El Mirador assemblage, which was identified as a pellet deposit produced by a medium to large owl, has a much greater proportion of skulls, vertebrae, scapula, and forelimbs (Fig. 7). Similar anatomical distributions are also found in other naturally accumulated deposits. For instance, the Queens Hotel site in York (Piper and O'Connor 2001) and the WS Ranch site in New Mexico (Shaffer and Neely 1992) present nearly complete skeletal representations.

Unlike the Ranidae remains, the Bufonidae assemblage from Feature G006 at Changshan shows a markedly higher representation of forelimbs, particularly the humerus, with MAU% values approaching 90–100 % (Fig. 7). This high representation stands in contrast to the underrepresentation of forelimbs in the Ranidae assemblage from the same context. Although recovery methods may partially account for the lower MAU% values in head, vertebrae, and shoulder girdle in both Ranidae and Bufonidae, the contrasting preservation rates in forelimb bones suggest that taphonomic conditions and recovery techniques alone do not fully explain the difference in preservation between the two

Table 3

Representation of anuran assemblage from Feature G006.

	NISP			
	<i>P. nigromaculatus</i>	Ranidae indet.	Bufoinae indet.	Anuran indet.
Feature G006				
(1)				
skull fragment				1
trunk		4		
vertebrae				
humerus	2		1	
radio-ulna		1		
ilium	4		1	
urostyle		3		
femur	8		1	
tibiofibula		12	1	
tarsalia		5	2	
Total	6	33	6	1
Feature G006				
(3)				
skull fragment				4
maxilla				3
angular		14	1	
pterygoid		10		
atlas		2		
trunk		76		
vertebrae				
sacrum		11		
scapula		23	5	
coracoid		11	2	
humerus	110		36	
radio-ulna		29	3	
ilium	98		24	5
urostyle		29	3	
femur		145	21	
tibiofibula		256	38	
metapodial				1
tarsalia		68	13	
Total	208	674	146	13

Table 4Quantification of the minimum number of elements (MNE) and the standardized values of the minimum animal unit (MAU%) at the level of each bone in Ranidae (including *P. nigromaculatus* and Ranidae indet.) of Feature G006 from Changshan. G006 (1): upper layer; G006 (3): lower layer.

Element	G006(1)		G006(3)	
	MNE	MAU%	MNE	MAU%
Skull bones				
angular	0	0	14	5.5
pterygoid	0	0	10	3.9
Shoulder girdle				
coracoid	0	0	11	5.1
scapula	1	8.3	23	10.9
Vertebrae				
atlas	0	0	2	1.6
trunk vertebrae	4	9.5	76	7.4
sacral vertebrae	0	0	11	7.8
Forelimb				
humerus	2	16.7	110	43.0
radio-ulna	1	8.3	29	11.3
Urostyle				
ilium	4	33.3	98	38.3
Hindlimb				
femur	8	66.7	145	56.6
tibiofibula	12	100	256	100
Tarsalia	3	25.0	68	14.5

families.

Bone surface modification provides another important line of evidence for identifying the origins of anuran assemblages. For example, at Chalain-3, at least 350 bone elements exhibited traces of burning, with approximately 200 bones fully charred—affecting 4.7 % of the entire

Table 5NISP and MNI of male and female *P. nigromaculatus* among different features.

Features	NISP		MNI	
	male	female	male	female
G006	87	25	51	17
G003	1	0	1	0
G004	1	1	1	1
G007	1	2	1	1
M007	0	1	0	1

**Fig. 6.** Burned Ranidae tibiofibula from feature H004 at Changshan.

assemblage (Bailon 1993). At other sites, such as Kutná Hora-Denemark (Kyselý 2008) and Baume d’Ogens (Chiquet 2005), the proportion of burnt bones is notably higher, reaching 10.2 % and 59 %, respectively. Among these sites, burning is associated with human consumption.

However, burning is not always indicative of human processing. Piper and O’Connor (2001) suggest that the charring observed on some skeletal elements may result from unintentional burning, likely caused by the accidental inclusion of bones, possibly with fuel, into ovens or fires. Similar evidence has been reported at the El Harhoura 2 cave, where up to 9 % of the bone elements in an ashen layer showed signs of burning, likely due to post-depositional effects rather than deliberate cooking (Stoetzel et al., 2011; 2012). Moreover, the El Mirador assemblage shows digestion marks and breakage, which is consistent with the accumulation of pellets. At Changshan, although one Ranidae element from Feature H004 exhibited signs of burning, this isolated case more likely reflects accidental exposure to fire. Furthermore, the absence of digestion traces and the relatively good preservation of bones suggest that avian predators or carnivores were unlikely to have been responsible for the accumulation of anuran remains at the site.

Further evidence supporting the anthropogenic origin of anuran accumulation includes the presence of a uniform death assemblage predominantly composed of a single species and displaying a biased sex ratio. For instance, male frogs constituted approximately 70 % of the individuals at Chalain-3 (Bailon 1993). At Kutná Hora-Denemark, the sex ratio of *R. temporaria* in Feature 36 was 16:1 in favor of males (Kyselý 2008). Bailon (1993) and Kyselý (2008) suggested that such a skewed ratio may result from the selective collection of adult males, which are more easily captured during the breeding season when they congregate in shallow puddles and pools to call for mates (Schwartz 1993; Vallejos et al., 2017; Wang et al. 2008). A similar pattern was observed at

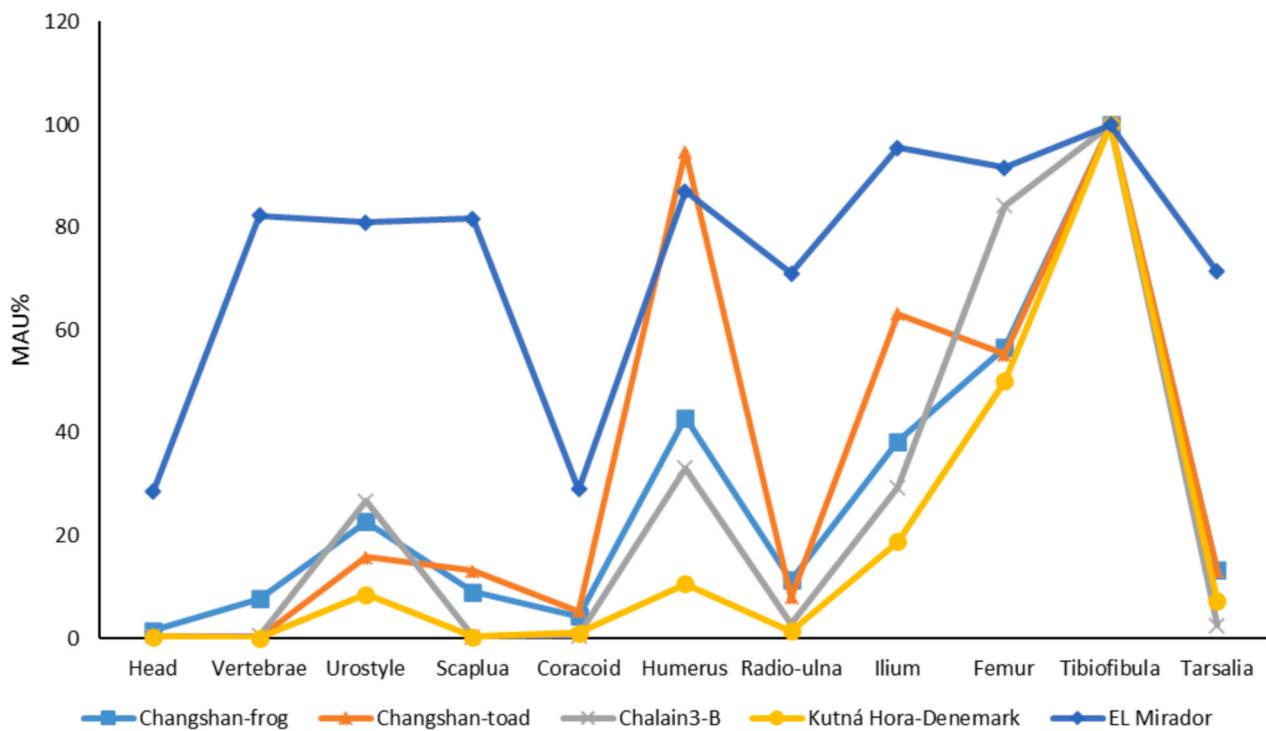


Fig. 7. The MAU% of each bone element and anatomic region among the Ranidae (*P. nigromaculatus* and Ranidae indet.) and the Bufonidae of Feature G006(3) from Changshan, *R. temporaria* from Chalain-3 Level VI Zone B (Chalain3-B, [Bailon 1993](#)), *R. temporaria* of Feature 36 from Kutná Hora-Denemark (Kutná Hora-Denemark, [Kysely 2008](#)), the *Hyla gr. arborea* of MIR5-P21-n4 taphocenosis from El Mirador cave (El Mirador, [Bisbal-Chinesta et al., 2020](#)).

Changshan, where *P. nigromaculatus* remains from Feature G006 revealed a male-to-female ratio of 3.0:1, exceeding the contemporary sex ratio of 2.17:1 typically recorded during the breeding season ([Wang et al., 2008](#)). This elevated male representation may likewise reflect targeted harvesting during seasonal aggregations.

In summary, the Changshan site yielded a total of 1350 anuran bones, representing a minimum of 255 individuals of Ranidae and 39 of Bufonidae. The majority of these remains were recovered from Feature G006. The analyzed Ranidae assemblage is characterized by the selective representation of certain anatomical parts, primarily hindlimbs, and a uniform death population with a high proportion of male individuals, both of which may indicate human selection. Only one specimen showed evidence of burning, which is more likely the result of accidental contact with fire.

Given the limited role of anurans in traditional human diets, definitively determining whether these frogs are consumed by humans remains difficult. However, the analysis of anuran remains from Changshan provides potential evidence that the accumulation of Ranidae may be linked to human hunting and consumption. These findings contribute to a broader understanding of anuran exploitation and offer insight for further zooarchaeological research in China.

Anuran accumulations are components of the archaeological record. Unlike previous studies that often dismissed frogs and toads as intrusive species or accidentally trapped animals, largely because of their small size and analytical difficulty, we propose that they can significantly enhance our understanding of ancient human diets, or even contribute to the reconstruction of the social and ritual lives of the people in China. Further research is needed, including the implementation of more intensive sieving strategies and the development of a comprehensive comparative modern anuran collection, to clarify the origins of anuran accumulations and their potential roles in past human subsistence practices. It is therefore essential to reconsider the significance of anuran

remains in zooarchaeological analyses. After all, every bone counts!

CRediT authorship contribution statement

Zhe Zhang: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Xiaohong Lv:** Visualization, Investigation, Data curation. **Zhongwei Jing:** Resources, Data curation. **Sen Lin:** Resources, Data curation. **Chunxue Wang:** Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We thank the Institute of Cultural Relics and Archaeology of Jilin Province, the Siping Antique Administration Committee Office, and the Lishu Cultural Heritage Administration for their field work at the Changshan site. We thank all the anonymous reviewers for their valuable comments and suggestions.

Funding

This work was funded by Major Project of the Key Research Base for Philosophy and Social Sciences of the Ministry of Education (22JJD780009, 16JJD780007), Fundamental Research Funds for the Central Universities, China (No.2022CXTD17).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jasrep.2025.105421>.

Data availability

Data will be made available on request.

References

- AmphibiaChina, 2024. The database of Chinese amphibians. Electronic Database accessible at <http://www.amphibiachina.org/>. Kunming Institute of Zoology (CAS), Kunming, Yunnan, China.
- Bailon, S., 1993. Quelques exemples de la consommation d'amphibiens à travers le temps, in Desse, J., Audoin-Rouzeau, F., Exploitation des animaux sauvages à travers le temps. Editions APDCA, pp. 320–326.
- Bailon, S., 1997. La grenouille rousse (*Rana temporaria*): une source de nourriture pour les habitants de Chalain 3, in Petrequin, P. (Eds.), Les Sites Littoraux Néolithiques de Clairvaux-les-Lacs et de Chalain (Jura), pp. 711–16.
- Bailon, S., 1999. Differenciation ostéologique des anoures (Amphibia, Anura) de France. In: Série, C. (Ed.), Fiches D'ostéologie Animale Pour L'archéologie. Varia, pp. 3–41.
- Binford, L.R., 1981. Bones: Ancient man and Modern Myths. Academic Press.
- Bisbal-Chinesta, J.F., Bañuls-Cardona, S., Fernández-García, M., Cáceres, I., Blain, H.-A., Vergès, J.M., 2020. Elucidating anuran accumulations: massive taphocenosis of tree frog *Hyla* from the Chalcolithic of El Mirador cave (Sierra de Atapuerca, Spain). *J. Archaeol. Sci. Rep.* 30, 1–14.
- Blain, H.-A., Arribas, O.J., 2017. A description of the skeletal morphology of *Rana pyrenaica* (Anura: Ranidae), with comments on functional morphology, ecological adaptation and relationships with other Iberian ranids. *Zootaxa* 4319 (3), 510–530.
- Blain, H.-A., Lozano-Fernández, I., Böhme, G., 2015. Variation in the ilium of central European water frogs *Pelophylax* (Amphibia, Ranidae) and its implications for species-level identification of fragmentary anuran fossils. *Zool. Stud.* 54, 1–9.
- Bosch, M.D., Nigst, P.R., Fladerer, F.A., Antl-Weiser, W., 2012. Humans, bones and fire: Zooarchaeological, taphonomic, and spatial analyses of a Gravettian mammoth bone accumulation at Grub-Kranawetberg (Austria). *Quat. Int.* 252, 109–121.
- Chiquet, P.A., 2005. Des Mésolithiques Amateurs de Grenouilles? Une étonnante Découverte sur le Site de la Baume d'Ogens (Vaud, Suisse). *Revue De Paléobiol.* 10, 59–67.
- Dai, L.L., Zhang, Y.Z., 2021. The preliminary analysis of faunal remains at Beiqugou site, Anhui. *Res. China's Front. Archaeol.* 30, 267–282.
- Driver, J.C., 2011. Identification, classification and zoarchaeology. *Ethnobiol. Lett.* 2, 19–39.
- Frost, D.R., 2024. Amphibian Species of the World: an Online Reference. Version 6.2 (accessed 24 October 2024). Electronic Database accessible at <https://amphibiансoftheworld.mnhn.org/index.php>. American Museum of Natural History, New York, USA. doi.org/10.5531/db.vz.0001.
- Frost, D.R., Grant, T., Faivovich, J., Bain, R.H., Haas, A., Haddad, C.F., DeSa, R.O., Channing, A., Wilkinson, M., Donnellan, S.C., Raxworthy, C.J., Campbell, J.A., Blotto, B.L., Moler, P., Drewes, R.C., Nussbaum, R.A., Lynch, J.D., Green, D.M., Wheeler, W.C., 2006. The amphibian tree of life. *Bull. Am. Mus. Nat. Hist.* 297, 1–291.
- Gehasse, E., 2001. Archaeoherpetological remains from the Noordoostpolder in the Netherlands, in: Buitenhuis, H., Prummel, W. (Eds.), Animals and Man in the Past. ARC-Publicatie 41, Groningen, pp. 227–235.
- Gleed-Owen, C.P., 2000. Subfossil records of *Rana* cf. *lessonae*, *Rana arvalis* and *Rana* cf. *dalmatina* from Middle Saxon (c. 600–950 AD) deposits in eastern England: evidence for native status. *Amphibia-Reptilia* 21 (1), 57–65.
- Gómez, R.O., Turazzini, G.F., 2016. An overview of the ilium of anurans (Lissamphibia, Salientia), with a critical appraisal of the terminology and primary homology of main ilial features. *J. Vertebr. Paleontol.* 36, 103–123.
- Holman, J.A., 1989. Identification of *Bufo calamita* and *Bufo bufo* on the basis of skeletal elements. *British Herpetol. Soc. Bull.* 29, 54–55.
- Holman, J.A., 2003. Fossil frogs and toads of North America. Indiana University Press.
- Holman, J.A., Schroeder, M.E., 1991. Fossil herpetofauna of the Lisco C quarries (Pliocene: early Blancan) of Nebraska. *Transactions of the Nebraska Academy of Sciences*, XVIII, pp. 19–29.
- Hou, Y.F., Zhang, J., Cao, Y.P., Jin, S.A., 2022. Faunal remains of the Yangshao period from the Gouwan site, Xinchuan county, Henan Province. *Acta Anthropol. Sinica* 41 (5), 914–926.
- Keeffe, R., Blackburn, D.C., 2020. Comparative morphology of the humerus in forward-burrowing frogs. *Biol. J. Linn. Soc.* 131 (2), 291–303.
- Kyselý, R., 2008. Frogs as a part of the Eneolithic diet. Archaeozoological records from the Czech Republic (Kutná Hora-Denemark site Rívnáč Culture). *J. Archaeol. Sci.* 35 (1), 143–157.
- Lakomska, B., 2021. Images of animals in Neolithic Chinese Ceramic. *Athens J. Humanit. Arts* 8, 63–79.
- Li, J.Y., 2012. The research of toad and frog ritual practice based on the archaeological discoveries in Neolithic. *Liaoning Provincial Museum J.* No.00, 213–223.
- Lyman, R.L., 1994. Vertebrate Taphonomy. Cambridge University Press.
- Lyman, R.L., 2008. Quantitative Paleozoology. Cambridge University Press.
- Mao, M., Mi, Z.P., Yang, Z.S., Zhou, C.Q., 2014. Sexual dimorphism in the limb muscles of the dark-spotted frog, *Pelophylax nigromaculata*. *Herpetol. J.* 24, 147–153.
- Matthews, T., Van Dijk, E., Roberts, D.L., Smith, R.M., 2015. An early Pliocene (5.1 Ma) fossil frog community from Langebaanweg, south-western Cape, South Africa. *Afr. J. Herpetol.* 64, 39–53.
- Matthews, T., Keeffe, R., Blackburn, D.C., 2019. An identification guide to fossil frog assemblages of southern Africa based on ilia of extant taxa. *Zool. Anz.* 283, 46–57.
- Meylan, P.A., 2005. Late Pliocene anurans from Inglis 1A, Citrus County, Florida. *Bull. Florida Museum Nat. History* 45, 171–1118.
- Othman, S.N., Litvinchuk, S.N., Maslova, I., Dahn, H., Messenger, K.R., Andersen, D., Jowers, M.J., Kojima, Y., Skorinov, D.V., Yasumiba, K., 2022. From Gondwana to the Yellow Sea, evolutionary diversifications of true toads *Bufo* sp. in the Eastern Palearctic and a revisit of species boundaries for asian lineages. *Elife* 11, 70–94.
- Pei, Q., 2020. Study on Faunal Remains of Neolithic of Huanggang site in Huai'an, Jiangsu province. Shandong University. Master thesis.
- Pinto-Llona, A.C., Andrews, P.J., 1999. Amphibian taphonomy and its application to the fossil record of Dolina (middle Pleistocene, Atapuerca, Spain). *Palaeogeogr. Palaeoclimatol. Palaeoecol.* 149 (1–4), 411–429.
- Piper, P.J., O'Connor, T.P., 2001. Urban small vertebrate taphonomy: a case study from Anglo-Scandinavian York. *Int. J. Osteoarchaeol.* 11, 336–344.
- Pokines, J.T., Baker, J.E., 2021. Effects of burial environment on osseous remains. In: Pokines, J.T., L'Abbe, E.N., Symes, S.A. (Eds.), Manual of Forensic Taphonomy. CRC Press, pp. 103–162.
- Přikryl, T., Aerts, P., Havelková, P., Herrel, A., Roček, Z., 2009. Pelvic and thigh musculature in frogs (Anura) and origin of anuran jumping locomotion. *J. Anat.* 214 (1), 100–139.
- Qin, Y.S., 1999. The research of Zhuang's Maguai Festival in Donglan, Guangxi. *Guangxi Ethnics Stud.* 2, 69–78.
- Ratnikov, V.Y., 2001. Osteology of Russian toads and frogs for paleontological researches. *Acta Zool. Cracov.* 44 (1), 1–23.
- RCCFA (Research Center for Chinese Frontier Archaeology of Jilin University), Administration Committee Office & the Lishu Cultural Heritage Administration, 2020. The report of archaeological excavation in 2016 at Changshang site, Lishu county, Jilin Province. *Res. China's Frontier Archaeol.* 23, 43–84.
- Sanchiz, B., Schleich, H.H., Esteban, M., 1993. Water frogs (Ranidae) from the Oligocene of Germany. *J. Herpetol.* 27, 486–1449.
- Schwartz, J.J., 1993. Male calling behavior, female discrimination and acoustic interference in the Neotropical treefrog *Hyla microcephala* under realistic acoustic conditions. *Behav. Ecol. Sociobiol.* 32, 401–414.
- Shaffer, B.S., Neely, J.A., 1992. Intrusive anuran remains in pit house features: a test of methods. *Kiva* 57 (4), 343–351.
- Siska, V., Jones, E.R., Jeon, S., Bhak, Y., Kim, H., Cho, Y.S., Kim, H., Lee, K., Veselovskaya, E., Balueva, T., Gallego-Llorente, M., Hofreiter, M., Bradley, D.G., Eriksson, A., Pinhasi, R., Bhak, J., Manica, A., 2017. Genome-wide data from two early Neolithic East Asian individuals dating to 7700 years ago. *Sci. Adv.* 3 (2), e1601877.
- Stoetzel, E., Marion, L., Nespollet, R., El Hajraoui, M.A., Denys, C., 2011. Taphonomy and palaeoecology of the late pleistocene to middle holocene small mammal succession of El Harhoura 2 cave (Rabat-Témara, Morocco). *J. Human Evol.* 60, 1–33.
- Stoetzel, E., Denys, C., Bailon, S., El Hajraoui, M.A., Nespollet, R., 2012. Taphonomic analysis of amphibian and squamate remains from El Harhoura 2 (Rabat-Témara, Morocco): contributions to palaeoecological and archaeological interpretations. *Int. J. Osteoarchaeol.* 22, 616–635.
- Thomas, S.C., 1996. Differentiation of selected frog (*Rana*) and toad (*Bufo*) bones using morphological and osteometric traits. *Canadian Zooarchaeol./zooarchéologie Canadienne* 10, 2–8.
- Vallejos, J.G., Grafe, T.U., Ahmad Sah, H.H., Wells, K.D., 2017. Calling behavior of males and females of a Bornean frog with male parental care and possible sex-role reversal. *Behav. Ecol. Sociobiol.* 71, 1–12.
- Wang, N., 2022. A study of the cultural meaning of Zhuang's Frog Festival in Guangxi, China. *Gonnexion: J. Humanities Soc. Sci.* 11 (2). <https://doi.org/10.14456/gonnexion.2022.12>.
- Wang, Y., Wu, Z., Lu, P., Zhang, F., Li, Y., 2008. Breeding ecology and oviposition site selection of black-spotted pond frogs (*Rana nigromaculata*) in Ningbo, China. *Front. Biol. China* 3, 530–535.
- Whyte, T.R., Compton, J.M., 2020. Explaining toad bones in southern Appalachian archaeological deposits. *Am. Antq.* 85 (2), 305–330.
- Xi'an Banpo Museum, Shaanxi Provincial Institute of Archaeology, Lintong Museum, 1988. Jiangzhai: Excavation report of the Neolithic site, Cultural Relics Press.
- Yan, C., Ma, H., Yang, Y., Mi, Z., 2023. Sexual dimorphism in the limb bones of Asiatic toad (*Bufo gargarizans*) in relation to sexual selection. *Animals* 13 (16), 26–38.
- Yang, T.G., 1968. Shengu <沈故>. Kwangwen Book Company, Shanghai.
- Zhang, K., 2010. The Study of Decorations of Fish, Frogs on the Painted Pottery in Neolithic. Chongqing Normal University. MA thesis.
- Zhang, B.J., 2018. Analysis and Research on Frog and Human Patterns of Painted pottery in the Majiayao Culture. Northwest Normal University. MA thesis.
- Zhang, X.X., 2021. The Study on Faunal Remains during 2018 Excavation at Qingqiu Mound Site in Heze, Shandong. Shandong University. Master thesis.
- Zhang, M., Chen, X., Ye, C., Fei, L., Li, P., Jiang, J., Wang, B., 2020. Osteology of the asian narrow-mouth toad *Kaloula borealis* (Amphibia, Anura, Microhylidae) with comments on its osteological adaptation to fossorial life. *Acta Zool.* 101 (4), 366–383.
- Zheng, R.Q., Du, W.G., Shou, L., 2002. Sexual dimorphism and female reproductive characteristics in the Black-spotted Pond frog, *Pelophylax nigromaculata*. *Chinese J. Zool.* 37 (4), 14–18.