New Record of Water Deer (*Hydropotes inermis*) from Iron Age Archeological Sites in Central Taiwan

Yen-Jean Chen[1], Ke-Hung Liu[2], and Whei-Lee Chu[2*]

[1] Department of Biology, National Museum of Natural Science, Taichung 404, Taiwan

[2] Department of Anthropology, National Museum of Natural Science, Taichung 404, Taiwan

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Abstract. A new record of the Chinese water deer (*Hydropotes inermis*), which is absent from the modern fauna, is reported from Iron Age archeological sites in Taichung, west-central Taiwan. Measurements and descriptions of the studied materials are provided, including a selection of less-fragmented upper canines and mandibles. The evidence shown from bone remains and records from early local historic documents indicate that *H. inermis* was once widespread and thrived on the island, and became extinct in very recent times, probably during the early 19th century. Its remains are expected to be found in archeological sites elsewhere in Taiwan. This study represents the first record of an isolated insular population of this monotypic species, as the distribution of *H. inermis* was previously confined to continental China and the adjacent Korean Peninsula.

Key words: *Hydropotes inermis*, water deer, new record, faunal remains, extinction, island population, archeological site, Taiwan.

INTRODUCTION

The Chinese water deer or water deer (*Hydropotes inermis*) is a small but unique deer species, with adults only reaching a height of 50~55 cm at the shoulder and a weight of 11~18 kg. This species is characterized by strong legs and long, dense hairs. Unlike most other deer species, it does not have antlers. Instead, the male develops large upper canines that protrude like fangs from the side of the mouth (Sheng, 1992; Cooke and Farrell, 1998). These unusual characters, also shared by members of the Tragulidae and Moschidae, have resulted in this species traditionally being considered the most primitive living cervid and classified in its own genus and subfamily (Hydropotinae). However, results of recent molecular studies placed it near roe deer (Capreolinae) (Randi *et al*., 1998), and suggested that the Chinese water deer may in fact be an advanced deer species that secondarily evolved primitive characters.

The water deer is endemic to China and Korea, and is classified into two subspecies: *H. i. inermis* of China and *H. i. argyropus* of Korea. According to Hu *et al*. (2006), the distribution of the Chinese population is now restricted to a few areas in the lower reaches of the Yangtze River, coastal Jiangsu, and islands of coastal Zhejiang, largely due to a reduction in its natural habitats. Historically it was more widely distributed from the northern provinces of Jilin and Liaoning, to the eastern Yangtze basin and islands at the mouth of the Yangtze River, and to the southeastern provinces of Hunan, Guangdong, and Guangxi (Sheng, 1992).

Water deer have never been reported from Taiwan, only 150 km east of the southeastern Chinese coast, except in the early local bibliography. Chen (2000) reviewed the many Chinese names for cervid species as well as their descriptions in early local Taiwanese historical

*Corresponding author. E-mail: wlchu@mail.nmns.edu.tw

documents, and suggested the possibility of the presence of a small deer species in ancient Taiwan, that once bore the Chinese name 獐,麞 (*zhang or chang*) , which has now disappeared. Chen also suggested that the animal remains from archeological sites are very likely to preserve evidence of recently extinct species including this deer species, as well as several other cervid and rodent species.

Large numbers of faunal bone remains were uncovered during excavations of several Iron Age (400~1400 BP) archeological sites in the Taichung area (west-central Taiwan) over the last decade, and these have been primarily sorted and indentified (Chen, 2006). In general, these bone remains are well preserved but highly fragmented, especially the skull parts and long bones of mammals. Most of the identifiable bone remains can be attributed to animals of extant species, with deer bones being the most common by far. An unexpected record of the Eurasian badger (*Meles meles*) was reported (Liu, 2010) which is a new record and is now absent from the modern fauna of Taiwan.

In our recent studies of bone remains from archeological sites in the Taichung area, a certain number of jaw and tooth remains of small-sized deer, which were previously identified as the extant and similarly sized Reeves' muntjac (*Muntiacus reevesi*), were rechecked. Distinctly large-sized upper canines and different types of craniomandibular features among the skull remains were noted. Herein, we report a new record of the water deer from Taiwan. Since most of the upper jaw remains are highly fragmented or isolated cheek teeth, the following descriptions are based on comparatively less-fragmented upper canines and mandibular remains.

MATERIALS AND METHODS

All bone remains examined in this study were unearthed from Iron Age middens of the following four archeological sites in the Taichung area between 1998 and 2011: the Huilai site (HLL, 1000~1300 BP), Nanshikeng site (NSK, 400~700 BP), Qingshui-Zhongshe Site (CS, 400~1400 BP), and Luliao site (LL, 400~1000 BP). The HLL site is situated in the western Taichung basin, near by the Fa-Tzu River, at an elevation of 70 m, with a straight-line distance of ca. 20 km to the coastline. The Nanshikeng and Luliao sites are close to each other, located on the western edge of the Tadu Tableland at an elevation of 50 m, and ca. 7 km to the coastline. The Qingshui-Zhongshe site is located on the coastal plain to the south of the Dajia River mouth, only 3 km from Taichung Port. Cultural phenomena and the paleo-environment of excavations analyzed from the four archaeological sites were reported by He *et al*. (1998, 2004), He and Liu (2005), He and Chu (2007, 2008), Chu *et al*. (2010), and Liu (2011).

A selection of less-fragmented bone materials, including 19 upper canines and 18 mandibles, was examined and measured, and they are listed below. The materials are incomplete fragments. The catalog number noted with an asterisk (*) indicates a complete or nearly complete sample: one canine (CSNB11) and three mandibles (CSNB33, CSNB38, and CSNB119) from the CS site; three canines (HLLNB5140, HLLNB5141, and HLLNB5142) and six mandibles (HLLNB317, HLLNB1136, HLLNB5143, HLLNB5144, HLLNB5145, and HLLNB5146) from the HLL site; 11 canines (LLNB1197*, LLNB1498, LLNB1543*, LLNB1754*, LLNB3361*, LLNB3362, LLNB3363*, LNB3364*, LLNB3365, LLNB3371, and LLNB3374) and four mandibles (LLNB3368, LLNB3369, LLNB3370, and LLNB3373) from the LL site; and four canines (NSKNB1184*, NSKNB1185, NSKNB1186, and NSKNB1187) and five mandibles (NSKNB1189, NSKNB1190*, NSKNB1191, NSKNB1192*, and NSKNB1193) from the NSK site. Mandible fragments are all from adults, in which the lower third molars were fully erupted. The bone remains examined are all deposited in the National Museum of Natural Science (Taichung, Taiwan).

Comparative specimens of modern water deer skulls and upper canines are from the collection of the Institute of Zoology, Chinese Academy of Science, Beijing (IOZ) which includes two crania numbered 1747 and 1318, five mandibles numbered 1199, 1206, 1759, 17911, and 17975, and two isolated upper canines numbered 17911 and 17976. The dental terminology used in tooth descriptions follows Bärmann and Rössner (2011). Measurement methods follow Kim *et al*. (2013) for the purpose of comparing measurements.

Family Cervidae

Subfamily Hydropotinae Trouessart, 1898

Hydropotes inermis Swinhoe, 1870
Hydropotes affinis Brooke, 1872
Hydropotes argyropus Heude, 1884
Hydropotes kreyenbergi Hilzheimer, 1905

DESCRIPTION

Upper canines: Seven of 19 upper canines are complete, and the others are at least 50% complete with a broken tip or root, or both (Fig. 1). The canine is long and saber-like, moderately curved downward (Fig. 1, D2, D4). It is laterally compressed (Fig. 1, D3), with a robust tooth root and tapers towards the tip end, resembling the blade of a scythe. The labial surface of the canine is more convex. The lingual surface is rather flat and smooth. The mesial border is convex and rounded. The distal border is concave and has a very sharp edge along the entire length of the erupted portion. The only two complete and unworn canines are from the LL site, and respectively measure 80.4 and 81.5 mm long. The canine can be heavily worn on the tip, leaving a long and narrow lens-shaped wear surface on the mesial-labial border surface, thus becoming much shorter in length (Fig. 1, C2, D1). The wear surface could be man-made, but the same tooth wear pattern was observed in the *H. inermis* collection (no. 1318, Fig. 3, B) from the IOZ. So the heavy tooth wear could also occur naturally. The mean length of four complete but worn canines from the LL site was only 56.4 mm, with a range of 51.1~65.3 mm. The averaged widths of the canines ranged 9.6~11.2 mm from the four archeological sites. Measurements are shown in Table 1.

Mandibles: Eighteen mandibles range from a fragmentary corpus to nearly complete. Measurements are shown in Table 2. The only two nearly complete mandibles, in which the incisor alveoli bones are missing, are from the NSK site. They respectively measure 117.5

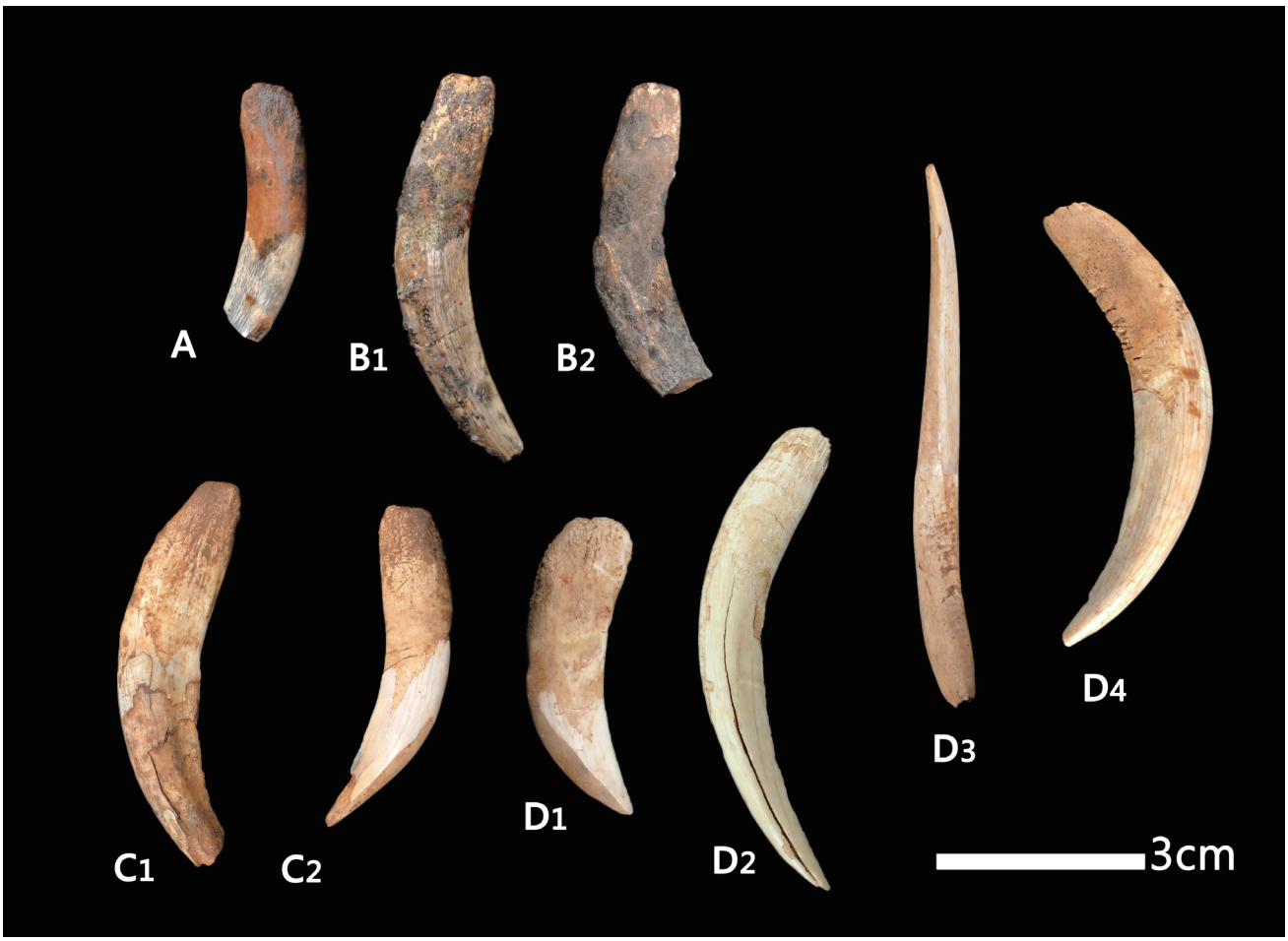

Fig. 1. Upper canines of *Hydropotes inermis*, labial view, unearthed from four archeological sites. CSNB11, broken (A); HLLNB5140, broken (B1); HLLNB5142, broken (B2); NSKNB1185, broken (C1); NSKNB1184, complete and worn (C2); LLNB1754, complete and worn (D1); LLNB1197, complete (D2); LLNB1543, complete, in distal view (D3) and labial view (D4).

Table 1. Upper canine measurements (mm) of the Chinese water deer from four archeological sites in Taichung, Taiwan. Mean values are shown when sample sizes were >1, with the range and sample sizes in parentheses.

Measurement	HLL site	CS site	NSK site	LL site
Canine length				81 (80.4~81.5, n=2)
Canine length (worn)			55.2	56.4 (51.1~65.3, n=4)
Canine length (broken)*	38.7~64.3, n=3	41.5	43.7~65.9, n=3	43.3~72.9, n=5
Canine width	11 (10.9~11.8, n=3)	9.6	11.2 (9.8~12.4, n=4)	10.8 (10.1~12.5, n=11)

* Tooth with broken root or tip, or both, only range and sample size are shown. HLL, Huilai; CS, Qingshui-Zhongshe; NSK, Nanshikeng; LL, Luliao.

Table 2. Mandible measurements (mm) and comparisons of *Hydropotes inermis* fragments examined in this study and modern specimen of adult *H. inermis* from Korea (Kim *et al.,* 2013). Mean values are shown when sample sizes were >1, with the range and sample sizes in parentheses.

Measurement	HLL	CS	NSK	LL	Modern *H. inermis*, Korea, mean values of males / females
ML			118.2 (117.5*~118.8*, *n*=2)		137.49 / 140.37
Gp2L		87.3 (86.2~88.4, *n*=2)	87 (85.1~89.2, *n*=3)		89.48 / 92.00
LPRL	20.4	19.4 (19.1~19.7, *n*=3)	22.6 (21.6~23.7, *n*=5)	21.7 (20.7~22.8, *n*=4)	23.89 / 23.34
LMRL	35.4 (33.9~36.6, *n*=4)	32.4 (32.2~32.7, *n*=3)	34.6 (33.7~35.7, *n*=5)	33.9	33.11 / 33.55
LCRL	56	52.7 (52~53.3, *n*=3)	58.2 (56.2~59.9, *n*=5)	57.8	56.62 / 56.52
Gm3L		36.5 (35.3~37.6, *n*=2)	33.1 (30.9~35, *n*=3)		34.03 / 36.42
AVRH			41.3 (39.5~43.9, *n*=3)		41.22 / 42.25
OVRH			65.2 (62.6~67.7, *n*=2)		63.74 / 65.34
CHPm2	13.8	13.3 (13~13.6, *n*=2)	12.8 (12.2~13.6, *n*=5)		
CHm1	14.8 (14.6~14.9, *n*=2)	14.6 (13.1~16.6, *n*=3)	14.1 (13~14.6, *n*=5)		
CHm2	17.5 (17.1~17.7, *n*=5)	18 (17.2~18.4, *n*=3)	17.5 (16.9~18.5, *n*=5)		
CHm3	19	19.8 (18.4~21.22, *n*=2)	19.7 (18.5~20.9, *n*=5)		
m2L	11 (10.7~11.7, *n*=6)	9.8 (9.2~10.3, *n*=3)	11.1 (10.2~11.9, *n*=5)	11.3	
m2W	7.4 (6.2~8.1, *n*=6)	7.2 (7~7.4, *n*=3)	7.3 (6.7~7.9, *n*=5)	7.3	

***** Incisor alveoli bone incomplete. ML, mandible length from the angle; Gp2L, length from oral border of pm2 to the angle; LPRL, lower premolar tooth row length; LMRL, lower molar tooth row length; LCRL, lower cheek teeth length; Gm3L, length from the aboral border of the alveolus of m3 to the angle; AVRH, length from the top of the condyle to the deepest point of the angle; OVRH, length from the top of the coronoid process to the ventral border of the angle; CHPm2, height of the corpus before pm1; CHm1, height of the corpus before m1; CHm2, height of the corpus behind m2; CHm3, height of the corpus behind m3; m2L, length of m2; m2W, width of m2.

and 118.8 mm long, and are estimated to have been approximately 5~10 mm longer if the mandibles were complete. The ventral border of the mandibles is slightly convex (Fig. 2). The height of the corpus increases from p2 to m3. The angular process is well developed, being rounded and posteriorly protruding. The lower posterior border of the ramus strongly inclines inwards, so that the angular process is more distally protruded then the condyle process. The mental foramen is large, varying in size and shape, and is located in the diastema. A laterally extended fossa is present in front of the mental foramen, and this fossa contains a second but rather small opening in its anterior end. A small posterior mental foramen may be present below

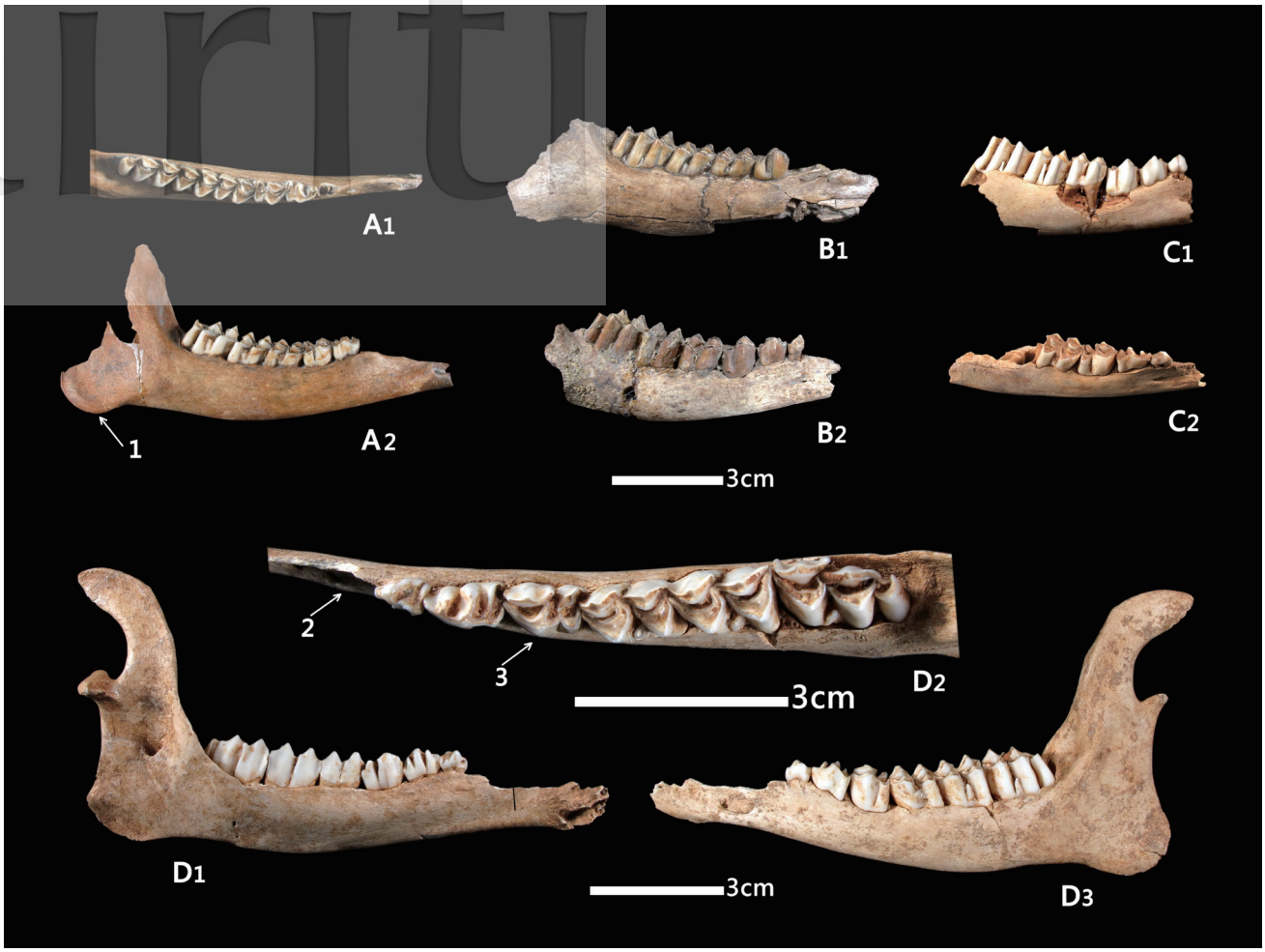

Fig. 2. Mandibles of *Hydropotes inermis*, labial view, unearthed from four archeological sites. CSNB119 with p3-m3, in occlusal view (A1) and labial view (A2); HLLNB5146 with p4-m3 (B1); HLLNB5143 with p2-m3 (B2); LLNB3368 with p2-m3 (C1); LLNB3369 with p2-m1 (C2); NSKNB1192 with p2-m3, in lingual view (D1), close-up of cheek teeth, occlusal view (D2) and labial view (D3). 1, Well-developed angular process; 2, Very narrow dorsal border of the diastema; 3, Bilobed p4.

and anterior to p2. The upper labial wall of the corpus is horizontally depressed between below p2 and the mental foramen, leaving a very narrow dorsal border (in occlusal view) to the diastema. The p2 is much smaller than p3. Both p2 and p3 are triangular in shape in occlusal view, with a well-developed mesolingual conid, mesolabial conid, posterolingual conid, posterior stylid, and posterolabial conid. The anterior stylid and anterior conid are fused and much reduced in p2. The anterior crest of p3 is bifurcated with a narrow but strong anterior stylid and anterior conid. The p4 is bilobed (molariform), with the anterior lobe much larger than the posterior lobe. In the lower molars, the stylids and ribs of conids on the lingual wall are weak. A well-developed ectostylid and weak anterior cingulid are present in all lower molars.

REMARKS

Previous studies on the craniomandibular traits of *H. inermis* are rare. The studied materials were compared to the modern cervid skull collection of the Institute of Zoology (IOZ), Chinese Academy of Science, Beijing, China, and were found to most closely resemble *H. inermis*. No major morphological differences were observed between the studied materials and modern specimens (Fig. 3). Two upper canine teeth specimens of *H. inermis* from the IOZ were measured at 66.69/11.72 and 58.69/9.92 mm (length/width), respectively, and the lengths of the lower cheek tooth row measured on five adult modern specimens ranged 51.8~55.7 mm with an average of 54.3 mm.

The length of the male upper canine was previously reported to be 75.3 mm (averaged

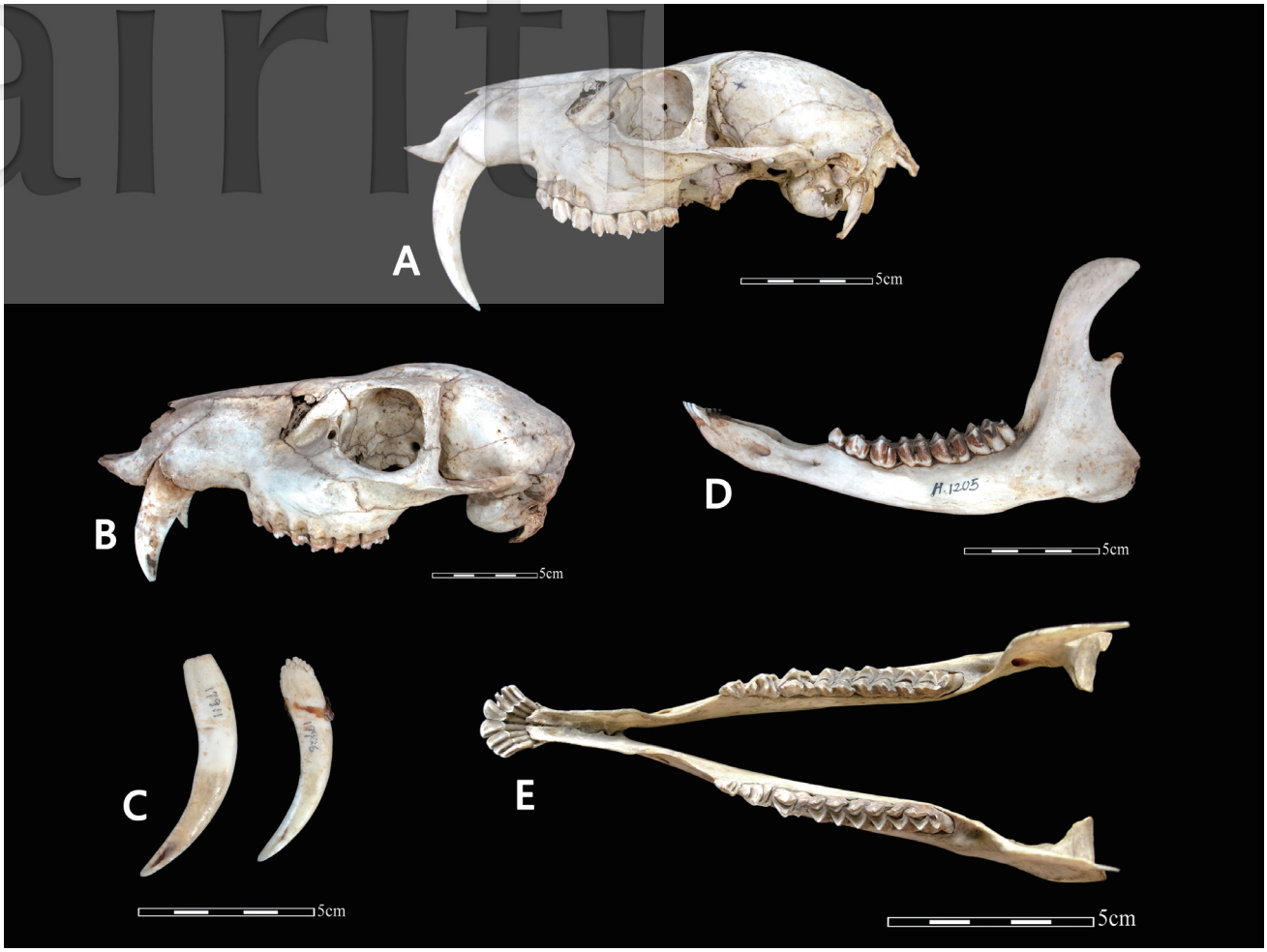

Fig. 3. Skulls and upper canines of modern *Hydropotes inermis* from the collection of the Institute of Zoology (IOZ), Chinese Academy of Science, Beijing, China. Specimen no. 1747, cranium with unworn upper canines (A); no. 1318, cranium with heavily worn upper canines (B); two isolated upper right canines (C) with no. 17911 (left) and no. 17976; no.1205, mandible in labial view (left side) (D) and occlusal view (E).

from Aitchison 1946), 53.10±4.42 mm (Sheng, 1992), and an average of 56 mm up to 72 mm (Cooke and Farrell, 1998). Females have much-smaller upper canines that are an average of 0.5 mm with a maximum length of up to 0.8 mm (Cooke and Farrell, 1998). There are few studies on the skull morphometrics of the Chinese subspecies. Thus we compared our measurements with mandibular measurements from the Korean subspecies (Kim *et al*., 2013) (Fig. 2). Most of the morphometrics of the studied materials at the four archaeological sites were close to those of modern specimens. The relatively high variance among the lengths of the lower cheek tooth row is probably due to the small sample size.

Bone fragments of *H. inermis* are very similar in size and appearance to those of Reeves' muntjac (*M. reevesi*). Reeves' muntjac also has protruding upper canines, but it is not difficult to distinguish these canines from those of *H. inermis*. The upper canine of *M. reevesi* is not compressed, but twisted, curving downward and outward, and is much smaller than that of *H. inermis*. The mandibles of the two species also differ in several characters. *M. reevesi* has a primitive form of p4 with a bifurcated anterior crest, p2 and p3 are oval shaped in occlusal view (not triangular), the dorsal border of diastema is more rounded, and the stylids and ribs of the lingual conids are more conspicuous.

DISCUSSION

Evidence from bone remains from the four Iron Age archeological sites in Taichung, central Taiwan, indicates that water deer were once a widespread and thriving species on the island, and it became extinct in very recent times. The latest date for the Qingshui-Zhongshe, Luliao,

and the Nanshikeng sites is only 400 years before the present, when water deer were clearly still abundant. As for the subsequent 350 years of the historical period, it was consistently listed as an endemic species in early local historical documents (Chen, 2000). The latest description that matched the water deer was found in local historic documents from Hengchun (Pingtung County) from 1894 (Tu, 1894), indicating that the local people were still familiar with this species at that time. So it seems possible that the Taiwanese water deer population survived into the early 19th century. It might have become very rare or perhaps had just gone extinct when the British biologist Robert Swinhoe made his first visit to Taiwan in 1856, since Swinhoe did not find this species during his 10-year investigation of the fauna of Taiwan. After 1866, he first found a specimen of water deer in Shanghai, China, and published it as a new species to the world in 1870 (Swinhoe, 1870). According to the dates of those records, we suspect that the total extirpation of the Taiwanese population of water deer occurred less than 200 years ago.

The water deer has a strong habitat preference for grass-covered floodplains and swamps such as lake banks, riversides, and alluvial deltas, as well as coastal wetlands and salt marshes, while avoiding dense bush and woodlands if possible (Zhang *et al*., 2006). It is a highly selective feeder, taking herbs and young sweet grasses, which are abundant in the dynamic ground of flooded areas, rather than the coarser and more-fibrous vegetation of mature grasses (MacDonald, 2013). As suggested by its name, the water deer can swim, and may swim for several kilometers when travelling between islets in water areas in search of food and shelter, but appears unlikely to colonize areas >20 km from a source population (Guo and Zhang, 2002). Because its remains are present in archeological sites, this species can be a good indicator of the ambient natural environment of ancient times. Recently, Chu *et al*. (2010) reported the prehistoric environment of the Taichung basin as a plain with wetlands braided among river channels, which periodically flooded. This type of environment perfectly matches the habitat preference of water deer.

Limited habitat and selective food habits may have led to the extirpation of this species in Taiwan, as the natural floodplain and the coastal wetland habitats were largely settled and converted to agriculture by the dramatically increasing immigrant population since the European times (began from 1624). Over-hunting may have been another important reason for its abrupt extinction. In addition to skin and meat, it is also well known that water deer were heavily hunted (very often with dogs) for colostrum, the semi-digested milk in the stomach of the fawn, as a traditional Chinese medicine (Sheng, 1992).

The known distribution of water deer was confined to eastern China and the adjacent Korean Peninsula. This report represents the first record of an insular population of this monotypic species, which had been isolated and evolved independently for at least 10,000 years before its extinction. We expect more remains of water deer to be found from archeological sites elsewhere in Taiwan. Further investigations are required in order to explore the geographic and morphological aspects of its prehistoric existence as well as its decline and extinction on this subtropical island. This record, together with another record of the recently extinct Eurasian badger *Meles meles* from prehistoric sites, not only increases the known diversity of the fauna but also raises our awareness and understanding of the magnitude of recent extinction events on the island of Taiwan.

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中台灣鐵器時代考古遺址鹿科新紀錄種：獐(*Hydropotes inermis*)

陳彥君[1]、劉克竑[2]、屈慧麗[2]

[1]國立自然科學博物館生物學組 臺中市40453館前路1號

[2]國立自然科學博物館人類學組 臺中市40453館前路1號

在中部鐵器時代考古遺址中灰坑發現已滅絕的台灣鹿科新紀錄種，獐（*Hydropotes inermis*）。本文根據較爲完整的出土遺留，對其獨特的大型上犬齒以及下顎骨與頰齒的特徵進行描述與測量。獐偏好水草豐美之氾濫平原與海岸溼地，是很好的棲地環境指標物種。從遺留數量、分佈與遺址年代，並參考歷史文獻紀錄，我們認爲台灣的獐族群曾經廣布於平原與海岸地帶，且推論可能直到十九世紀初期才告滅絕。已知獐的分佈向來僅限於中國大陸與鄰接的朝鮮半島，因此台灣獐族群的發現也是該鹿種具有島嶼族群的首次記錄。

關鍵詞：獐，鹿科，新紀錄種，動物相，滅絕，島嶼族群，考古遺址，台灣