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Food remains in *Confuciusornis sanctus* suggest a fish diet

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Abstract Despite hundreds of excellent fossils of *Confuciusornis*, the most abundant group of birds in the Early Cretaceous, ‘Jehol Biota’ in China, there is yet no indication of the food choice of these birds. Here, we describe fish remains preserved in the alimentary system of a specimen of *Confuciusornis sanctus* from the Jiufotang Formation. This find is about five million years younger than all previously published confuciusornithid birds from the Yixian Formation. Although it is unknown how common fish was in the diet of *Confuciusornis*, the find does not support previous hypotheses that it fed on plants or grain.

Introduction

The family Confuciusornithidae is the most abundant group of birds recovered in the Early Cretaceous ‘Jehol Biota’ in northeastern China (Chang et al. 2003). Several confuciusornithid species have been described (Hou 1997),

although some of these later have been questioned (Chiappe et al. 1999). The most common taxon, by far, is *Confuciusornis sanctus* (Chiappe et al. 1999; Hou et al. 1995, 1999; Hou 1997; Hou et al. 1999; Ji et al. 1999; Peters and Ji 1998, 1999). This species is represented by hundreds of specimens, most of them collected from a thin fossiliferous layer in the Yixian Formation at a locality near the village of Sihetun in Liaoning Province, northeast China. It is assumed that these birds were killed at about the same time, possibly a mass mortality event coupled to volcanic activity in the area. The large number of individuals also suggests that *Confuciusornis* may have had a colonial behavior (Hou et al. 1996; Martin et al. 1998). Despite hundreds of excellent fossils of confuciusornithids, there is yet no indication of the food choice of these birds, although their strong and toothless beak has led to suggestions that they were herbivorous or granivorous (Hou et al. 1999; Zhou and Zhang 2003a,b). Our report here on a specimen of *C. sanctus* with fish remains preserved in its alimentary system is, thus, rather unexpected.

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Materials and methods

The specimen (IVPP V13313, Fig. 1) was collected from the Jiufotang Formation at the Dapingfang locality near Chaoyang, Liaoning province. A $^{40}\text{Ar}/^{39}\text{Ar}$ date of 120.3 ± 0.7 on K-feldspar from tuffs interbedded within the fossil-bearing shales of the Jiufotang Formation in Chaoyang, Liaoning Province has recently been published (He et al. 2004). This indicates an Aptian age for the Jiufotang Formation, which is about five million years younger than the Yixian Formation from where all previous finds of *Confuciusornis* derive. The new find is, thus to date, the youngest find of a confuciusornithid bird.

Results

IVPP V13313 (Fig. 1) is a confuciusornithid bird that belongs to the genus *Confuciusornis* based on the

Fig. 1 a–c *Confuciusornis sanctus* (IVPP V13313). **a** The position of the small cluster of fish remains is indicated by the red rectangle; **b** Outline drawing of the specimen; **c** A close-up of the fish remains (cf. *Jinanichthys*, Kuyangichthyidae)



following derived characters: straight culmen and mandible, large round to oval foramen piercing the deltopectoral crest of the humerus, intermediate phalanx of manual digit II bowed (Chiappe et al. 1999), and digit II bears a very small claw compared to that of digits I and III. The specimen is well preserved; no major elements are missing and the skeleton is nearly articulated. Feather impressions are visible on the wings, head, and neck (Fig. 1). The morphology will be described in more detail elsewhere, but, we conclude that the specimen cannot be morphologically separated from *C. sanctus* and that it falls well in the size range and body proportions of this species. We, thus, refer IVPP V13313 to *C. sanctus*.

Partly underlying the ventral region of the seventh and eighth cervical vertebrae is a small cluster of fish bones of which approximately seven to nine vertebrae and a few ribs are visible (Fig. 1a,b). These are the only biotic remains other than *Confuciusornis* found in the slab IVPP V13313. The fish bones have tentatively been determined to derive from a primitive teleost fish, *Jinanichthys* (Kuyangichthyidae) (Zhang, J. personal communication). The fish bones are not in articulation but form a rather spherical cluster of circa 6 mm in diameter (Fig. 1c). The position of the congregation on the ventral side of the distal one-third of the neck of the bird suggests that the bones were processed in the alimentary system at the time of death of the bird.

Discussion

The cranial position of the fish remains in the alimentary system shows that they were not in the gizzard, and also, the proventriculus seems unlikely. Instead, their unarticulated and slightly fragmented status suggests they formed a pellet that was about to be regurgitated. Another option is that it was stored in the crop, a pouch-like enlargement of the lower part of the esophagus used for temporary food storage in birds. If this was the case, we may expect the fish remains to be more in articulation; however, no maceration takes place in the crop.

The finding has great significance for our understanding of the lifestyle of *C. sanctus* and of the general morphological evolution in early birds. This is the first observation of the diet of a confuciusornithid bird. Despite finds of several hundreds of individuals of *Confuciusornis*, no food remains or gastroliths have yet been reported (Zhonghe Zhou, personal observation; Luis M. Chiappe, personal communication). Given that most workers have speculated on granivorous or herbivorous habits of *Confuciusornis* (Hou et al. 1999; Zhou and Zhang 2003a,b), it is striking that gastroliths have not yet been reported in any specimen. Gastroliths are small stones swallowed by the bird to ease the digestion of plant fibers, and they have been reported from several early Cretaceous birds in the Jehol Biota, e.g.,

Sapeornis (Zhou and Zhang 2003a), and *Yanornis* (Zhou et al. 2004). One reason for assuming a granivorous diet of *Confuciusornis* has been the robust, toothless bill that seems to be capable of cracking seeds (Zhou and Zhang 2003a). Although we would not infer from the present find of a predominantly piscivorous diet of *Confuciusornis*, we, at least, are able to say that these birds were not obligate granivores or herbivores. On the contrary, the strong bill of *Confuciusornis* may very well allow the bird to have a wide, omnivorous diet, analogous with present-day crows and similar groups. Furthermore, teeth are not necessary for piscivory, as shown by many examples of extant birds. A partially piscivorous diet has also been inferred for the ornithurine bird, *Yanornis*, in which fish remains were preserved in the abdominal region (Zhou et al. 2002, 2004; Zhou 2004). Our findings are also in agreement with the conclusion by Elzanowski (2002) that *Confuciusornis* "...foraged on the wing by seizing prey from the surface of the water or ground."

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