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# Diet of Two Endangered Box Turtles (*Cuora* spp.) on Hainan Island, China

FANRONG XIAO, JICHAO WANG*, ZAIZHONG LONG, AND HAITAO SHI*

*College of Life Sciences, Hainan Normal University, Haikou 571158, China*
*[xiao71815@163.com; jichao-wang@263.net; 631438917@qq.com; haitao-shi@263.net]*
**Co-corresponding authors*

ABSTRACT. — **The present study is the first to report the diet of 2 sympatric turtle species, *Cuora mouhotii* and *Cuora galbinifrons*. In Diaoluoshan Natural Reserve in Hainan Province, China, both species were observed to have an omnivorous diet; however, the composition of the diets was different between the species. The diet of *C. mouhotii* consisted of fungi, plants, earthworms, land snails, and insects, whereas the diet of *C. galbinifrons* included fungi, plants, earthworms, and lepidopterous larvae.**

Basic ecological studies of Asian box turtles (Geoemydidae, *Cuora*) are scarce, especially on diet (Lue and Chen 1999; Cheung 2007; Wang et al. 2011a, 2011b). Zhou and Li (2013) reported that many species of this genus, including *Cuora mouhotii* and *Cuora galbinifrons*, feed on fruits (e.g., banana) and pork liver in captivity. However, little is known about their feeding habits in the wild (Das et al. 2016) because it is difficult to observe feeding events and collect fecal samples in the wild. Moreover, the diet of endangered species cannot be studied by sampling stomach contents because individuals may incur injuries in the process (Wang et al. 2013).

*Cuora mouhotii* and *C. galbinifrons* are classified as endangered and critically endangered, respectively, by the International Union for Conservation of Nature Red List (IUCN 2016a, 2016b). Understanding a species' basic ecology is critical in establishing effective conservation strategies for endangered turtle species (Servis et al. 2015); therefore, we conducted a study on the diet of *C. mouhotii* and *C. galbinifrons* with the aim of providing important ecological data and offering some suggestions for their conservation. To the best of our knowledge, this study is the first to report the diet of box turtles in the wild from China.

*Methods*. — We studied the diet of adult *C. mouhotii* and *C. galbinifrons* at the Diaoluoshan Natural Reserve in Hainan Province, China (lat 18°43′53″N, long 109°52′10″E; elevation 914 m) from April 2015 to February 2016. Turtles were captured in traps baited with salty fish or rancid pork skin; thereafter, a radio-tracking transmitter (RI-2B, 216.000–216.999 MHz; 6g; Holohil Systems, Ltd, Caro, ON, Canada) was fitted to the last costal scute of each turtle, using curing agents of epoxy. The frequencies of transmitters were different from one another. Seven adult *C. mouhotii* individuals (3 females and 4 males) and 5 adult *C. galbinifrons* individuals (4 females and 1 male) were tracked daily at 0900 and 1600 hrs by using radiotelemetry. For each individual, we determined the diet by directly observing their feeding during the process of tracking and calculated the frequency of occurrence of food items that they consumed as follows (Paralikidis et al. 2010):

$$\mathrm{FO\%} = \frac{n}{N} \times 100$$

where FO%, $n$, and $N$ are the frequency of occurrence, number of specific food items, and total number of dietary samples for each turtle, respectively. Multiple food items were not observed for single turtles during single observations. We calculated an average of FO% for each specific food item from all *C. mouhotii* individuals or *C. galbinifrons* individuals. Whether the diets of the 2 species differed was examined using a Pearson $\chi^2$ test.

Bite force was measured using a bite force transducer (type S1-100NHL-001, range ± 100 N; Nanjing Bio-inspired Intelligent Technology Co, Ltd, Nanjing, China) that was connected to a charge amplifier (NBIT-DSU-2404A; Nanjing Bio-inspired Intelligent Technology Co, Ltd) and a portable computer. All turtles that were used to measure bite force were individuals tracked during the study. Although *C. mouhotii* (3 females and 1 male) often attempt to bite their handlers, the less responsive *C. galbinifrons* (2 females) were coerced with gentle taps at their jaws when their heads were outstretched. The bite force of each turtle was measured 3 times with an interval of 15 min, and the highest value was used as each individual's maximum bite force. These performance experiments were conducted in a laboratory at 23°C, which has been reported as an optimal performance temperature (Wang 2010). The Welch approximate $t$-test was used to test whether the 2 species differed in maximum bite force.

*Results*. — We observed 44 and 40 total prey consumed for *C. mouhotii* and *C. galbinifrons*, respectively. Both species exhibited an omnivorous diet, but their dietary composition differed significantly ($\chi^2 = 18.55$, $p = 0.001$). The majority of the diet of *C. galbiniforns* consisted of fungi (Table 1; Fig. 1), whereas *C. mouhotii* consumed mostly fungi and lepidopterous larvae. *Cuora galbinifrons* consumed lepidopterous larvae less frequently than did *C. mouhotii* (Table 1). Both species consumed earthworms and plants at similar but lower frequencies (Table 1). *Cuora mouhotii* consumed land snails (Fig. 1) and an adult orthopteran, while *C. galbinifrons* consumed neither item. The mean maximum bite force of 4 *C. mouhotii* (31.11 N, SE = 3.09, range = 25.6–37.3 N) was 3

**Table 1.** Constituents of the diets of the 2 *Cuora* spp. FO% = mean frequency of occurrence, *n* = number of specific food items consumed.

| | *C. mouhotii* (7 turtles, 44 observations) | | *C. galbinifrons* (5 turtles, 40 observations) | |
|---|---|---|---|---|
| Food item | *n* | FO% | *n* | FO% |
| Agaricomycetes (fungi) | | | | |
| *Auricularia polytricha* | 1 | 25 | | |
| *Russula amoena* | 3 | 17 | 4 | 23 |
| *Collybia albuminosa* | | | 2 | 12 |
| *Boletus speciosus* | 3 | 16 | | |
| *Boletus ornatipes* | | | 3 | 11 |
| *Amanita hemibapha* | | | 2 | 25 |
| Unknown order | 9 | 23 | 15 | 36 |
| Plants | | | | |
| Deciduous leaves | 1 | 13 | | |
| Fallen fruits | | | 1 | 13 |
| Fleshy roots | | | 1 | 11 |
| Gastropoda | | | | |
| *Bradybaena tourannensis* | 4 | 31 | | |
| Oligochaeta (earthworms) | | | | |
| *Pheretima magna* | 6 | 25 | 6 | 21 |
| Insecta | | | | |
| Orthoptera | | | | |
| *Sinochlora hainanensis* | 1 | 17 | | |
| Lepidoptera (larvae) | 16 | 36 | 6 | 17 |

times greater than that of 2 *C. galbinifrons* (10.35 N, SE = 0.55, range = 9.8–10.9 N; $t_{3.2} = 6.62$, $p = 0.006$).

*Discussion*. — Because the 2 *Cuora* species are closely related (Stuart and Parham 2004), it is not surprising that their diets were similar. Both species displayed an omnivorous diet, which included fungi, plants, earthworms, and lepidopterous larvae. While both species are omnivores, their overall dietary composition was significantly different. The diet of *C. mouhotii* included mainly fungi and insect items, which is contrary to earlier reports that the species is exclusively herbivorous (Sachsse 1973; Ernst and Barbour 1989; Shi et al. 2011). The diet of *C. galbinifrons* consisted mostly of fungal fruiting bodies.

Another dietary difference between the species was that *C. mouhotii* consumed land snails (durophagy), while *C. galinifrons* did not. The diet of a turtle is a vital factor in determining the morphology of its head (Herrel et al. 2002; Claude et al. 2004). Herrel et al. (2002), for example, suggested that turtles with durophagous diets are able to bite harder than the species consuming other diets, such as those with omnivorous diets. They also suggested that only variation in head height is related to variation in bite force. Such a pattern is in accordance with the hypothesis that an evolved increase in bite force has adapted certain turtle species to feed on larger or harder prey. Therefore, we suggest that the bigger and higher head of *C. mouhotii* (Xiao 2017) is suitable for feeding on land snails, whereas the smaller head of *C. galbinifrons* (Xiao 2017) is restricted to preying on fungi and soft lepidopterous larvae because the bite force of *C. mouhotii* was much greater than that of *C. galbinifrons*. However, unless further dietary studies prove otherwise in the future, the durophagous diet of *C. mouhotii* must be interpreted cautiously because of the low percentage of land snails.

Dietary nutrition greatly influences female turtle reproductive output (Liu et al. 2013). As the diets of *C. mouhotii* and *C. galbinifrons* in the wild were unknown prior to the present study, the 2 species were always fed in captivity according to the diet composition used by Zhou and Li (2013). For example, Zhou and Li (2013) considered that both species feed on pork, beef, pork liver, banana, and tomato, but our findings showed that *C. galbinifrons* consumed mostly fungi, whereas *C. mouhotii* consumed mostly fungi and insect larvae. These 2 species are difficult to breed in captivity, especially *C. galbinifrons* (Anonymous 2016). Therefore, the detailed dietary information obtained in the present study can provide a


**Figure 1.** The diet of the 2 *Cuora* spp.: (A) a *Cuora mouhotii* feeding on a land snail; (B) a *C. galbinifrons* feeding on a fungal fruiting body. Both photographs by F. Xiao.

useful reference for artificial breeding programs for manipulative dietary studies to investigate reproductive success in the future.

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