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Mycophagous behaviour by a Spiny Turtle, *Heosemys spinosa* (Gray, 1831), on a Bridal-veil Stinkhorn Mushroom (*Phallus indusiatus*)

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The Spiny Turtle (*Heosemys spinosa*) is an unmistakable species, whose juvenile and subadult individuals sport a dramatically spiky, radiating carapace that softens with age. It inhabits the rainforest floors, peat swamps, and streams of Southeast Asia (from Myanmar and Thailand through Peninsular Malaysia to Sumatra and Borneo), where it faces mounting pressure from overexploitation and habitat loss. The IUCN has categorised *H. spinosa* as Endangered, with the population experiencing a decline of 50–80%. Despite this decline and the urgency to learn more about such an iconic reptile, there is limited knowledge about its natural history and ecology (Cota et al., 2021). The feeding behaviour and diet of *H. spinosa* remain among the least understood aspects. In captivity, individuals are commonly fed vegetables, fruits, and herbaceous plants, supplemented with meat (Goetz, 2007; Schilde, 2018; Karyadi et al., 2023), but in its natural habitat the species mainly consumes fruits and plant materials (Lim and Das, 1999; Iskandar, 2000). It has also been reported consuming arthropods, mammal carrion, and fungi (Jensen and Das, 2006; Baizurah and Das, 2020).

By occasionally consuming fungi, *H. spinosa* may benefit from their rich amino acid profile – particularly important for growth – while also potentially aiding spore dispersal in its forest floor habitat. Elliot et al. (2019) reported that 32 turtle species, including *H. spinosa*, have been observed consuming fungi as part of their diet. Most of these turtles are facultatively mycophagous, except for the tortoise *Manouria impressa* (Günther, 1882), which prefers to feed on mushroom (Elliot et al., 2019; Pham et al., 2023). Detecting fungi in a reptile's diet can be challenging due to the ease with which they are digested and the difficulty in finding macroscopic remnants in faecal samples (Elliot et al., 2019). Therefore, natural history observations are valuable for recording fungus intake by turtles. Baizurah and Das (2020) observed *H. spinosa* consuming *Russula* and *Boletus* mushrooms, which both have a role as ectomycorrhizal fungi that serve important roles as tree root symbionts in forest ecosystems (Trappe, 1962). We here describe an additional instance of mycophagous behaviour of *H. spinosa*.

The behaviour was observed on 28 April 2020 at 12:00 h in a mixed peat swamp forest in the Kemapit watershed system, a tributary of the Mentaya River on a sunny day with variable cloud cover. The location is part of the Katingan-Mentaya Restoration Project managed by Rimba Makmur Utama corporation and is located in Kotawaringin Timur, Central Kalimantan, Indonesia (2.5339°S, 113.1252°E, elevation 20 m). The feeding process lasted about 6 min. The adult turtle (18 cm straight carapace length) approached the mushroom (Fig. 1A) and started by feeding on the lace-like indusium (Fig. 1B), then moved on to the cap and the stalk (Fig. 1C), and lastly it consumed the remaining indusium (Fig. 1D).

Every component of the mushroom's basidiocarp (fruiting body), including the indusium, cap, and stalk, were seen being consumed by the turtle. The indusium and cap of the mushrooms were fully formed, suggesting that this particular mushroom was mature and had already produced viable spores. The fungus being eaten by the turtle most closely resembles *Phallus indusiatus*, based on the brown cap and the presence of the indusium (Putra, 2020; Putra and Astuti, 2021).

Mature *Phallus* mushrooms produce a putrid-smelling fruiting body and release sticky slime, which attracts

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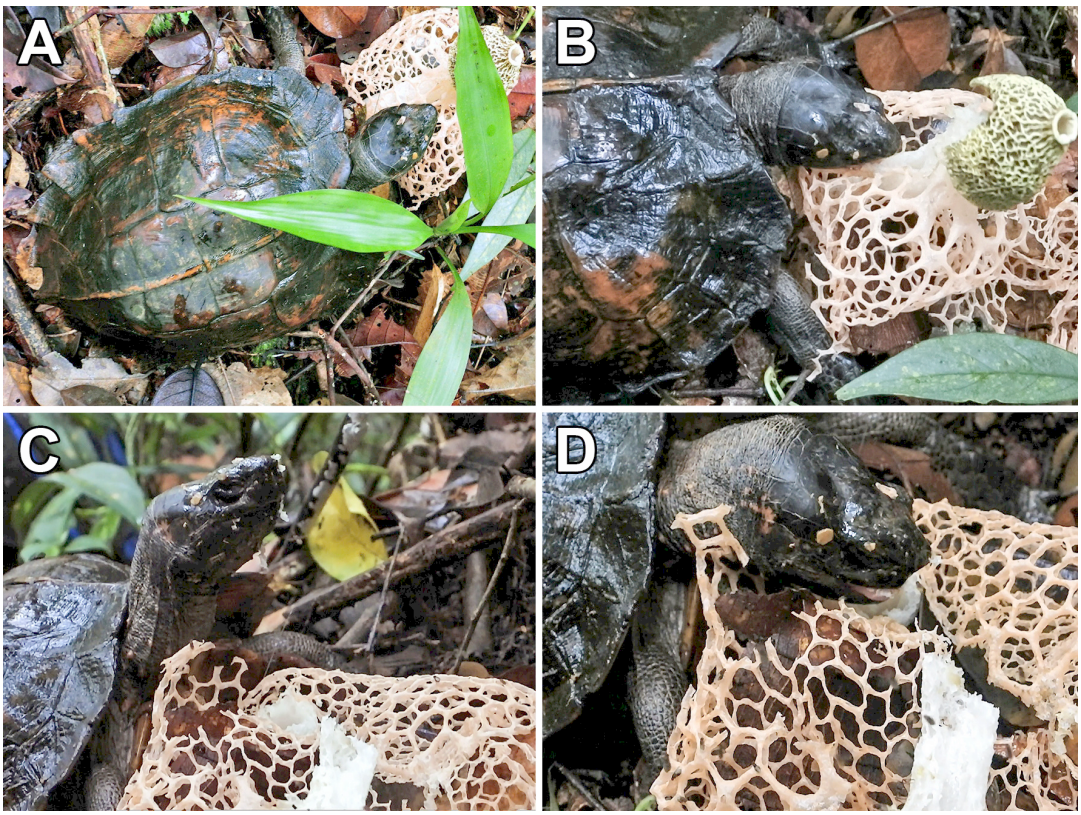

Figure 1. A Spiny Turtle (*Heosemys spinosa*) feeding on *Phallus indusiatus* in the Kemapit watershed system, central Kalimantan, Indonesia. (A) The turtle is approaching the mushroom. (B) It begins to feed on the indusium (veil). The edge of the mushroom's cap also shows bite damage. (C) The turtle has eaten the stalk of the mushroom and (D) continues to feed on the remaining indusium, its face covered by mushroom debris. Photos by Ahmad K. Anwar.

insects to feed on the mucilaginous internal spore-bearing mass (gleba) to consume the spores. The fungal spores are then dispersed to new locations by way of the insect's excrement (Oliveira and Morato, 2000; Tuno, 1998). Insects like fruit flies (Diptera: Drosophilidae) and stingless bees (Hymenoptera: Meliponini) can be observed around these fungi, possibly drawn by the odour.

Turtles have good olfaction (Ibáñez et al., 2021) and the odour of mushrooms could potentially attract *H. spinosa*, which is known for its opportunistic and scavenging diet (Baizurah and Das, 2020). Som et al. (2006) and Pham et al. (2023) noted incidental consumption of insects during mushroom feeding by *Manouria impressa*. Although some insects could be seen around the mushroom, we did not observe any incidental insect feeding by *H. spinosa*.

Turtle species can play crucial roles in the dispersal of plant seeds and fungal spores. The extended spore retention time during digestion in a turtle would likely enhance spore dispersal success in forest ecosystems (Elliot et al., 2019). Research on *Manouria impressa* has shown that their consumption of mushrooms contributes to the dispersion of ectomycorrhizal fungi in rainforests of Vietnam (Chan-ard et al., 1996; Som et al., 2006; Wanchai et al., 2012; Elliot et al., 2019; Pham et al., 2023). Within peat swamp forests various species of fungi could also possibly form ectomycorrhizae associations with the roots of higher plants, fostering the growth of various native plants and enhance natural regeneration of peat swamp forests (Turjaman et al., 2008, 2011; Graham et al., 2013, 2016; Helbert et al., 2019; Maulana et al., 2021). This observation confirms mycophagy as part of the *H. spinosa* diet, confirming the potential ecological benefit conveyed by turtles in maintaining peat swamp forest ecosystems, particularly in regard to the dispersal of saprobic and ectomycorrhizal fungi. However, there is no published literature documenting spore dispersal

by *H. spinosa* or other peat swamp-associated turtles. Further research is required to elucidate the spore dispersal potential of these species.

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