

Sexual dimorphism in *Heosemys spinosa* (Testudines: Geoemydidae) in Sarawak, Borneo

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Sexual dimorphism in turtles, comprising secondary sexual characteristics of morphology, has previously been reviewed by Berry and Shine (1980) and Gibbons and Lovich (1990). Colour differences (sexual dichromatism) have been discussed less often (but see Moll et al., 1981; Ennen et al., 2015), perhaps because of challenges associated with colour standardisation and loss of pigmentation details upon preservation (Coon, 1949).

Heosemys spinosa (Gray, 1831) is a mid-sized (maximum straight carapace length 275 mm; Goetz, 2007) tropical terrestrial turtle, currently listed as ‘Endangered’ in the IUCN Red List. The known distribution of the species extends from southern Myanmar, south into the Malay Peninsula, in addition to the islands of Sumatra, Borneo, and the southern Philippines (Bonin et al., 2006; Platt et al., 2014). The unusual morphology of the juvenile carapace gave rise to its common name of “walking pin-cushion” (Mardiastuti, 2008), and ontogenetic changes in its shell, particularly the relative flattening of the posterior marginal, that are lost with age appear in the taxonomic literature (e.g., Boulenger, 1889; de Rooij, 1915; Smith, 1931; Lim and Das, 1999). The strongly keeled spine present in juveniles is assumed to serve as a means to prevent being swallowed by predators. However, little has been published on sexual dimorphism and dichromatism in the species. Zug and Mulcahy (2019) were the first to report on the topic, describing carapace shape as “elongate, oblong, moderately domed and dorsally flattened in males” and “broad oblong and moderately domed in females.” Further, a report by Spinks et al. (2012) indicated the presence of cryptic variation in *H. spinosa* based on the distinct genetic and phenotypic variation observed in large, confiscated specimens in Hong Kong and China. This included variation in size, iris colour, and shell colouration among the observed

specimens. However, a lack of reliable geographic provenance limited further systematic evaluation.

Materials and Methods

The following observations were made as part of a larger study on a population of *H. spinosa* at Kubah National Park, Sarawak, Borneo, East Malaysia (Park Headquarters at 01.6124°N, 110.1966°E; WGS 84; elevation 141 m; Fig. 1), that emphasised the spatial, trophic, and thermal biology of the species (Baizurah, 2021). This note addresses variation between sexes in colouration observed in 11 wild individuals and of morphology in six tagged specimens (two males, four females) fitted with radiotransmitters and iButtons. These six individuals remained tagged from April 2017–January 2019, and their straight carapace length (SCL) and straight carapace width (SCW) were measured periodically over the 22-month period. Sexual size dimorphism was assessed by comparing the allometric relationship of SCL and SCW between sexes. All measurements were log-transformed to achieve linearity in regression analyses. X-rays were taken using a Model E7239X Sedecal Apr-Vet radiographic unit with settings of 78 kVp / 25 mAs / 320 mA / 0.08 s. The Xscan radiology application (Version 2.10) was used to edit the images obtained. Measurements were taken with Mitutoyo CD-CSX vernier callipers. Photographic images were obtained using a Nikon D600 camera and a 105 mm MicroNikkor lens in a Lastolyte lightbox. A total of 11 individuals were examined for colouration, which was described using the standard colour swatches in Smithe (1975).

Results and Discussion

Size. The six individuals used in this study ranged in size from 125.2–240.3 mm, with males the larger of the sexes (mean SCL in males 210.8 ± 7.5 mm, in females 167.0 ± 25.3 mm). A significant difference (Pearson correlation, $P < 0.05$) was found between measurements ($SCW = 1.204 \pm 0.4266$ SCL in males, $SCW = 1.434 \pm 0.3209$ SCL in females), demonstrating that shell proportions in adult *H. spinosa* are sexually dimorphic (Fig. 2).

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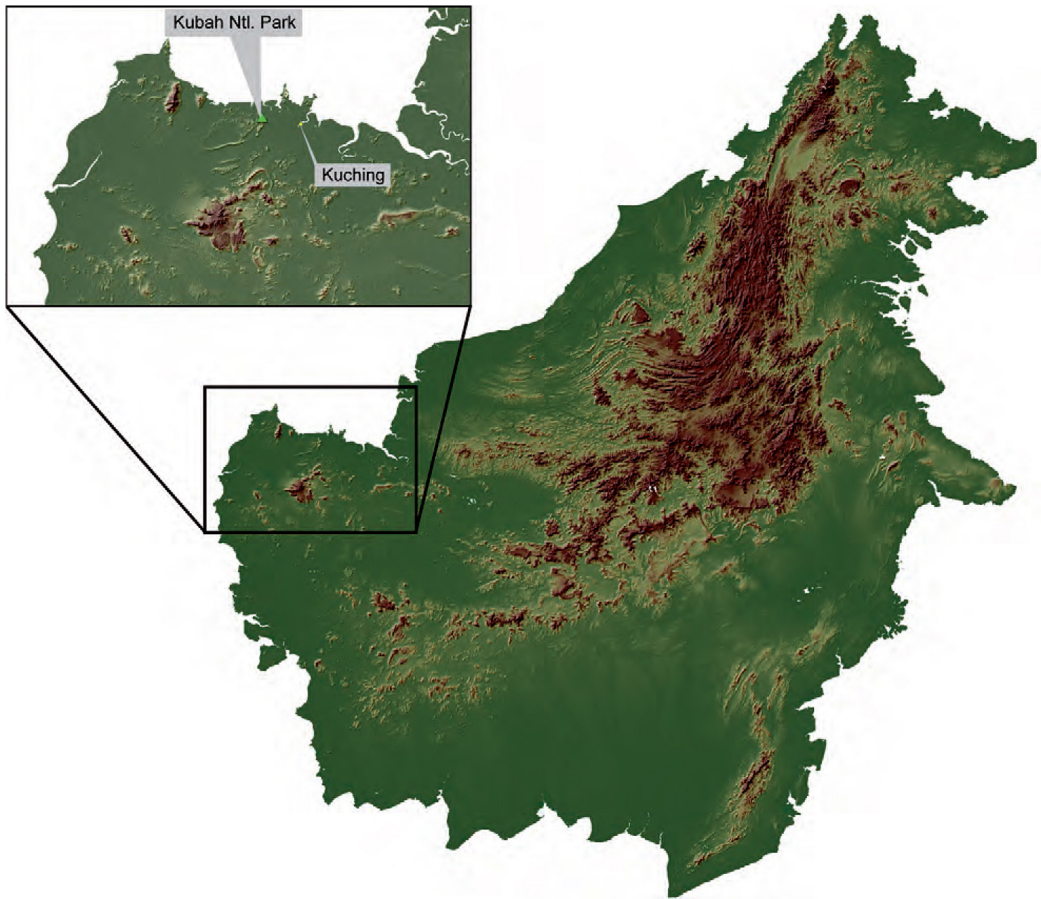


Figure 1. Relief map of the island of Borneo, showing the location of Kubah National Park in Sarawak State, East Malaysia.

Shape. As reported earlier by Waagen (1984) and Moll (1985), adult females seasonally develop areas of deossification on plastral bones that was interpreted as a partially kinetic plastron. In radiographs (Fig. 3), these are seen as distinct sulci, presumably comprising connective tissue across the midbody, specifically the transverse hyoplastral-hyoplastral and hyoplastral-xiphiplastral junctures under the abdominal and femoral scute regions, respectively. Of the six individuals examined, males showed distinctly flattened shells whereas those in females were domed (Fig. 4A–D). In addition, the two adult males also showed a distinctly concave plastron (Fig. 4E–F). Finally, the two males had relatively longer tails, with more swollen bases. However, our sample size precluded informative statistical comparisons.

Colour in females. Head plumbeous (#78) on forehead and sides with a warm sepia (#221A) postocular stripe and another stripe of the same colour running from the angle of the jaw to the tympanum. Tympanum walnut

brown (#221B), tympanic ring light russet vinaceous (#221D). Nape vinaceous pink (#221C) with jet black (#89) dots forming a distinct linear pattern.

Carapace with a mahogany red (#132B) ground colour and radiating jet black (#89) lines along the costal and marginal scutes; patterning more prominent in the bridge area. Sutures along scutes darker compared to overall ground colour, vertebral keel flesh colour (#5) with a more distinct tone in females. Plastron ground colour ferruginous (#41) with concentrated radiating black lines on each scute that are broader than those on the carapace. Eyes with jet black (#89) pupils, inner iris smoke grey (#45), outer iris chestnut (#32).

Colour in males. Head blackish neutral grey (#82) on the forehead and sides without stripes. Tympanum indistinct from ground colour, tympanic ring faintly paler. Nape tawny (#38) with concentrated jet black (#89) dots. Carapace with chestnut (#32) ground colour, appearing darker than in females due to the presence of blackish

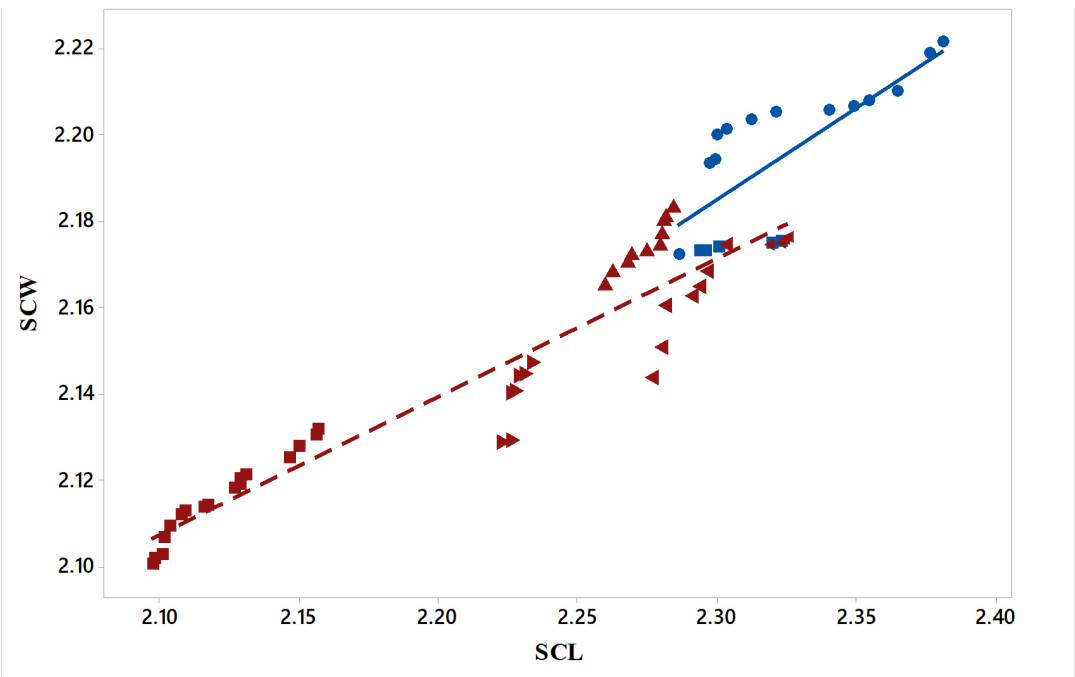


Figure 2. Allometric relationship between log straight carapace length (SCL) and log straight carapace width (SCW), recorded during a 22-month growth study of a wild *Heosemys spinosa* population in Kubah National Park, Sarawak State, East Malaysia. The sample consisted of tagged individuals, including four females represented by red triangles (apex facing left = SNB 638; apex facing up = SNB 643; apex facing right = SNB 642) and red squares (SNB 641), and two males represented by blue circles (SNB 637) and blue squares (SNB 644).

neutral grey (#82) areolae extending outward on the vertebral scutes, sutures and keel lighter than the rest of the carapace. Plastron with flesh ochre (#132D) ground colour and less distinct black radiating stripes on the scutes than in females. Eyes with jet black (#89) pupils, iris sky blue (#168D) with a warm sepia (#221A) ring.

Facial colour patterns in the two sexes are shown in Fig. 4G–H. In general, the relatively dark carapace, distinctly pale iris, and dark pigmentation around the radiating pattern of the plastral scutes represent one of the colour phenotypes reported by Spinks et al. (2012).

Although based on a small sample size, the Kubah population of *H. spinosa* shows distinct morphological and colour differences between adult males and females, here interpreted as sexual dimorphism. The largest individual was a male (240.3 mm), which was well outside the size range encountered in females (143.4–211.4 mm) in this study. Males showed relatively flat-topped carapaces and a deep plastral concavity, as well as relatively longer tails, with swollen bases. In addition, males were distinctly darker than females, while females showed a pink-edged, dark postocular band that reached the tympanum, as well

as more distinct radiating pattern on plastral scutes. Our study provides the first assessment of the morphological variation in this species at a specific geographic locality and lends further support to the hypothesis of cryptic variation in populations of *H. spinosa* (Vetter and Van Dijk, 2006; Spinks et al, 2012).

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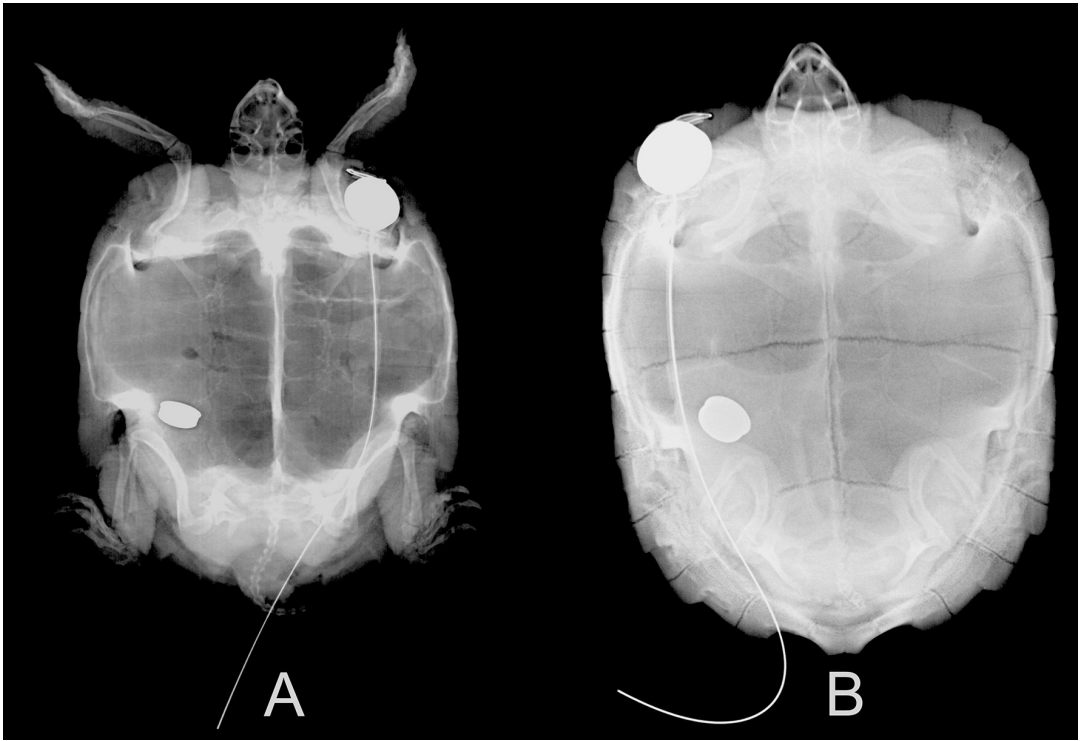


Figure 3. Radiographs of the plastron of female (A) and male (B) of *Heosemys spinosa* from Kubah National Park, Sarawak State, East Malaysia, showing the sulci transversely crossing the hyoplastral-hyoplastral and hypoplastral-xiphiplastral junctions of the female. The opaque implanted radio-transmitters and iButtons are visible in the animals.

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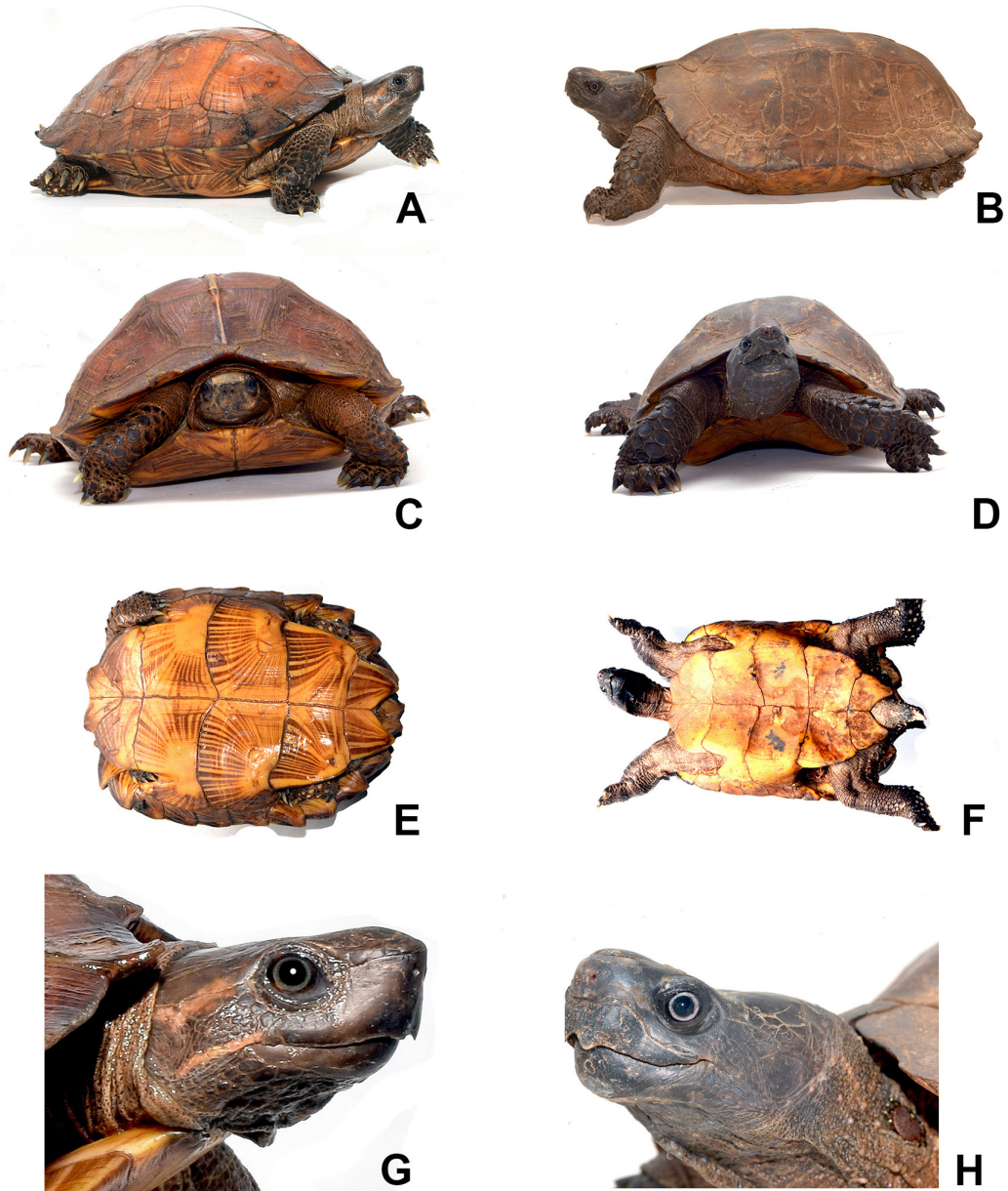


Figure 4. Adult *Heosemys spinosa* from Kubah National Park, Sarawak State, East Malaysia. Images on the left are of a female, those on the right of a male. Included are lateral views (A, B), frontal views (C, D), plastral views (E, F), and head profiles (G, H).

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