CONSERVATION BIOLOGY OF FRESHWATER TURTLES AND TORTOISES

A Compilation Project of the IUCN SSC Tortoise and Freshwater Turtle Specialist Group

Edited by

Anders G.J. Rhodin, John B. Iverson, Peter Paul van Dijk, Craig B. Stanford, Eric V. Goode, Kurt A. Buhlmann, and Russell A. Mittermeier

Orlitia borneensis Gray 1873 – Malaysian Giant Turtle, Bornean River Turtle, Kura-Kura Byuku, Kura-Kura Raksasa

Daniel F. Hughes, Mark Auliya, Pelf-Nyok Chen, Andreas B. Hardian, Veryl Hasan, Herdhanu Jayanto, Cisca Nurfi'aini, Irhamna P. Rahmawati, Nathan Rusli, Jalma G. Sukmawati, Josephine V. Tirtayani, and Edward O. Moll

Chelonian Research Monographs
Number 5 (Installment 20) 2026: Account 140

**Published by
Chelonian Research Foundation and Turtle Conservancy**

in association with
IUCN SSC Tortoise and Freshwater Turtle Specialist Group, Re:wild,
Turtle Conservation Fund, and International Union for Conservation of Nature / Species Survival Commission

Chelonian Research Monographs
Contributions in Turtle and Tortoise Research

CHELONIAN RESEARCH MONOGRAPHS (CRM) (ISSN 1088-7105) is an international peer-reviewed scientific publication series for monograph-length manuscripts, collected proceedings of symposia, edited compilations, and other longer research documents focused on turtles and tortoises. The series accepts contributions dealing with any aspects of chelonian research, with a preference for conservation or biology of freshwater and terrestrial turtles and tortoises. Bibliographic and other reference materials are also of potential interest. Submit manuscripts directly to Anders Rhodin at the e-mail address above. The series is published on an occasional basis, from 1996–2016 by Chelonian Research Foundation, and from 2017 and on by Chelonian Research Foundation and Turtle Conservancy.

Published CRM Issues

CRM 1. The Galápagos Tortoises: Nomenclatural and Survival Status. 1996. By Peter C.H. Pritchard. 85 pp. Open-access pdf available here.

CRM 2. Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. 2000. Edited by Peter Paul van Dijk, Bryan L. Stuart, and Anders G.J. Rhodin. 164 pp. Open-access pdf available here.

CRM 3. Biology and Conservation of Florida Turtles. 2006. Edited by Peter A. Meylan. 376 pp. Open-access pdf available here.

CRM 4. Defining Turtle Diversity: Proceedings of a Workshop on Genetics, Ethics, and Taxonomy of Freshwater Turtles and Tortoises. 2007. Edited by H. Bradley Shaffer, Nancy N. FitzSimmons, Arthur Georges, and Anders G.J. Rhodin. 200 pp. Open-access pdf available here.

CRM 5 (Installments 1–20, 140 species accounts to date). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN SSC Tortoise and Freshwater Turtle Specialist Group. 2008–2026. Edited variously by Anders G.J. Rhodin, John B. Iverson, Peter Paul van Dijk, Kurt A. Buhlmann, Peter C.H. Pritchard, Craig B. Stanford, Eric V. Goode, Raymond A. Saumure, and Russell A. Mittermeier. 1,580 pp. to date. All accounts available as open-access pdf downloads: follow links here.

CRM 6. Turtles on the Brink in Madagascar: Proceedings of Two Workshops on the Status, Conservation, and Biology of Malagasy Tortoises and Freshwater Turtles. 2013. Edited by Christina M. Castellano, Anders G.J. Rhodin, Michael Ogle, Russell A. Mittermeier, Herilala Randriamahazo, Rick Hudson, and Richard E. Lewis. 184 pp. Open-access pdf available here.

CRM 5 (Installment 8). Turtles and Tortoises of the World During the Rise and Global Spread of Humanity: First Checklist and Review of Extinct Pleistocene and Holocene Chelonians. 2015. TEWG [Turtle Extinctions Working Group: Anders G.J. Rhodin, Scott Thomson, Georgios L. Georgalis, Hans-Volker Karl, Igor G. Danilov, Akio Takahashi, Marcelo S. de la Fuente, Jason R. Bourque, Massimo Delfino, Roger Bour, John B. Iverson, H. Bradley Shaffer, and Peter Paul van Dijk]. 66 pp. Open-access pdf available here.

CRM 7. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (8th Ed.). 2017. TTWG [Turtle Taxonomy Working Group: Anders G.J. Rhodin, John B. Iverson, Roger Bour, Uwe Fritz, Arthur Georges, H. Bradley Shaffer, and Peter Paul van Dijk]. 292 pp. Open-access pdf available here.

CRM 8. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (9th Ed.). 2021. TTWG [Turtle Taxonomy Working Group: Anders G.J. Rhodin, John B. Iverson, Roger Bour, Uwe Fritz, Arthur Georges, H. Bradley Shaffer, and Peter Paul van Dijk]. 472 pp. Open-access pdf available here.

CRM 9. Range-Wide Demographic Collapse and Extinction Dynamics of the Endemic Burmese Roofed Turtle, *Batagur trivittata*, in Myanmar. 2024. Steven G. Platt, Win Ko Ko, Kalyar Platt, Tint Lwin, Swann Htet Naing Aung, Khin Myo Myo, Me Me Soe, Myo Min Win, Kyaw Thu Zaw Wint, Htun Thu, Shine Hsu Hsu Naing, Brian D. Horne, and Thomas R. Rainwater. 26 pp. Open-access pdf available here.

CRM 10. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (10th Ed.). 2025. TTWG [Turtle Taxonomy Working Group: Anders G.J. Rhodin, John B. Iverson, Uwe Fritz, Natalia Gallego-García, Arthur Georges, H. Bradley Shaffer, and Peter Paul van Dijk]. 575 pp. Open-access pdf available here.

Other Chelonian Research Foundation & Turtle Conservancy Publications

Turtles in Trouble: The World's Most Endangered Tortoises and Freshwater Turtles – 2025. TCC [Turtle Conservation Coalition: Craig B. Stanford, Anders G.J. Rhodin, Peter Paul van Dijk, Torsten Blanck, Eric V. Goode, Rick Hudson, Andrew D. Walde, Jordan Gray, Russell A. Mittermeier, and Vivian P. Páez. (Eds.)]. 2025. 77 pp. Open-access pdf available here.

Tortoises in the Mist: Turtle Poetry for Conservationists. Anders G.J. Rhodin and Eric V. Goode (Eds.)]. 2021. 106 pp. Open-access pdf available here.

CHELONIAN RESEARCH MONOGRAPHS (CRM) issues are variously available for purchase from Chelonian Research Foundation and Turtle Conservancy. Contact either Turtle Conservancy (www.turtleconservancy.org) or Chelonian Research Foundation (www.chelonian.org/crm; 564 Chittenden Dr., Arlington, VT 05250 USA; 978-807-2902; RhodinCRF@aol.com) for prices, titles, and to place orders for available print copies. Chelonian Research Foundation (founded in 1992) and Turtle Conservancy (founded in 2005 as Chelonian Conservation Center, renamed in 2010) are nonprofit tax-exempt organizations under section 501(c)(3) of the Internal Revenue Code.

Conservation Biology of Freshwater Turtles and Tortoises:
A Compilation Project of the IUCN SSC Tortoise and Freshwater Turtle Specialist Group
A.G.J. Rhodin, J.B. Iverson, P.P. van Dijk, C.B. Stanford, E.V. Goode, K.A. Buhlmann, and R.A. Mittermeier (Eds.)
Chelonian Research Monographs (ISSN 1088-7105) No. 5 (Installment 20), doi:10.3854/crm.5.140.borneensis.v1.2026

Orlitia borneensis Gray 1873 – Malaysian Giant Turtle, Bornean River Turtle, Kura-Kura Byuku, Kura-Kura Raksasa

Daniel F. Hughes[1], **Mark Auliya**[2], **Pelf-Nyok Chen**[3], **Andreas B. Hardian**[4,5], **Veryl Hasan**[6], **Herdhanu Jayanto**[7], **Cisca Nurfi'aini**[4], **Irhamna P. Rahmawati**[4], **Nathan Rusli**[8], **Jalma G. Sukmawati**[9], **Josephine V. Tirtayani**[10], **and Edward O. Moll**[11†]

[1]*Department of Biological Sciences, Tarleton State University, Stephenville, Texas 76402, USA [dhughes1@tarleton.edu];*
[2]*The Leibniz Institute for the Analysis of Biodiversity Change, Adenauerallee 160, 53113 Bonn, Germany [m.auliya@leibniz-lib.de];*
[3]*Turtle Conservation Society of Malaysia, 13538, Lorong Solehah 3A,Taman Desa Solehah, 24000 Kemaman, Terengganu, Malaysia [pelf@turtleconservationsociety.org.my];*
[4]*Yogyakarta Nature Conservation Foundation–Wildlife Rescue Centre Jogja, Yogyakarta, Indonesia [andreasbandangh@ub.ac.id; andreasbandang@wrcjogja.org];*
[5]*Laboratory of Veterinary Anatomic Pathology, Faculty of Veterinary Medicine, Universitas Brawijaya, Malang, Indonesia;*
[6]*Department of Fisheries and Marine Sciences, Universitas Airlangga University, Surabaya, East Java, Indonesia [veryl.hasan@fpk.unair.ac.id];*
[7]*KONKLUSI (Kolaborasi Inklusi Konservasi - Yayasan), Sleman, DI Yogyakarta, 55284, Indonesia [herdhanu@konklusi.org];*
[8]*Indonesia Herpetofauna Foundation, Jl. H.Wahid No.44, Kp. Gelonggong, Ds. Kedung Waringin, Bojong Gede, Bogor, Indonesia [nathan@herpetofaunaindonesia.org];*
[9]*Ecology Research Center, National Research and Innovation Agency (BRIN), Dr. (H.C.) Ir. H. Soekarno Science and Technology Area, Cibinong, Bogor, West Java, Indonesia [jalmagiring@gmail.com];*
[10]*Gembira Loka Zoo, Jalan Kebun Raya No. 2, Yogyakarta, Indonesia [vanda@gembiralokazoo.com];*
[11]*Department of Biological Sciences, Eastern Illinois University, Charleston, Illinois 61920 USA; †Deceased*

Summary. – The Malaysian Giant Turtle, *Orlitia borneensis* (family Geoemydidae), is a large freshwater species native to Southeast Asia and listed on the IUCN Red List as Critically Endangered. The species is very poorly known with almost no studies on wild populations. In general, *O. borneensis* is a relatively nondescript aquatic species that inhabits large rivers and streams in swamp-forest habitats across lowland, coastal regions. *Orlitia borneensis* typically has a patternless, dark-colored carapace and dorsal skin (with some variation), and a tan plastron and pale ventral skin. It is one of the largest freshwater turtle species in tropical Southeast Asia, with a wide range of reported maximum straight-line carapace lengths (SCL) from an estimated 76.3 cm to 117 cm, but most individuals are about 40–60 cm SCL, with males usually larger than females. It has been reported to lay at least one clutch of 6–12 brittle, elongate eggs annually in April–June, which average about 80 x 40 mm in size. *Orlitia borneensis* seems to consume mainly vegetation in the wild, especially fallen forest fruits and aquatic plants, but may also opportunistically feed on fish and aquatic invertebrates. The species is heavily exploited for human consumption throughout most of its range. Enforcement of existing laws and status surveys of this species in the wild are urgently needed.

Distribution. – Indonesia (Kalimantan, Sumatra), Malaysia (West Malaysia, Sabah, Sarawak), Singapore. *Orlitia borneensis* occurs in lowland river systems throughout the Sundaland region of Southeast Asia, including West Malaysia, Singapore, and on the major islands of Borneo and Sumatra. On Borneo, it is found in southwestern Sarawak, the lowlands of Kalimantan, and in Sabah. Many of the smaller islands between these larger land masses also harbor populations, such as Belitung and Bangka, where the species has recently been reported.

Synonymy. – *Cistudo borneensis* Bleeker 1857 (*nomen nudum*), *Orlitia borneensis* Gray 1873, *Bellia borneensis, Clemmys (Heteroclemmys) gibbera* Peters 1874, *Clemmys gibbera, Heteroclemmys gibbera, Hardella baileyi* Bartlett 1895, *Brookeia baileyi, Adelochelys crassa* Baur 1896, *Liemys inornata* Boulenger 1897, *Batagur signatus* † Jaekel 1911.

Subspecies. – None recognized.

Status. – IUCN 2026 Red List: Critically Endangered (CR A2acd; assessed 2020). CITES: Appendix II (2003), a zero quota for commercial purposes of wild specimens (2013).

Figure 1. Adult male Malaysian Giant Turtle (*Orlitia borneensis*) from Geosite Tebat Rasau, East Belitung, Indonesia. This individual measured straight-line carapace length (SCL) of 40.7 cm, curved carapace length (CCL) of 46.1 cm and straight-line plastron length of 37.9 cm. Photo by Daniel F. Hughes.

Taxonomy. — The Malaysian Giant Turtle or Bornean River Turtle (*Orlitia borneensis*) is a large, monotypic freshwater turtle species in the family Geoemydidae and the subfamily Batagurinae (Figs. 1–4). It was first named *Cistudo borneensis* as a *nomen nudum* by Bleeker (1857), based on a hatchling from Sintang, Kapuas River, Borneo (West Kalimantan, Indonesia). It was subsequently formally described by Gray (1873) as a new genus and species, *Orlitia borneensis* (holotype: BMNH 1947.3.4.9; Iverson 2022).

Over the next few decades, several subsequently synonymized species were described, including *Clemmys (Heteroclemmys) gibbera Peters* 1874 (holotype: ZMB 5022), *Hardella baileyi* Bartlett 1895 (holotype: not located), *Adelochelys crassa* Baur 1896 (holotype: ZSM 3049/0), *Liemys inornata* Boulenger 1897 (syntypes: BMNH 1947.3.4.28-29), and *Batagur signatus* † Jaekel 1911 (lectotype: ZMB (MB R5); Karl 1987) (Iverson

Figure 2. Adult *Orlitia borneensis* showing mushroom-like second vertebral scute (yellow dashed line polygon). Photos by Andreas B. Hardian.

Figure 3. Adult *Orlitia borneensis* close-up head portraits. Photos by Andreas B. Hardian (*top*) and Sabine Schoppe (*bottom*).

Figure 4. Lateral view of *Orlitia borneensis* showing bridge and distinct color demarcation between carapace and plastron. Photo by Cisca Nurfi'aini.

2022; TTWG 2025). However, by the very early twentieth century, the name *O. borneensis* was in consistent use, with all the other described species synonymized, and no subspecies have been described or recognized.

Orlitia and *Siebenrockiella* have historically been considered to be closely related based on morphological similarities (McDowell 1964; Hirayama 1984; Sites et al. 1984) and were even long regarded as congeneric within the genus *Bellia*, despite their extreme divergence in adult body size. Historical support for this relationship comes from their similar appearance, especially the shared unique shape of vertebral scutes, as well as studies of biochemical characters (Sites et al. 1984) and karyotypes (Carr and Bickham 1986).

The latter is particularly noteworthy because *Orlitia* and *Siebenrockiella* are among three batagurine genera and species to have 50 rather than 52 chromosomes (Carr and Bickham 1986). A third genus, *Malayemys*, differs in the location of the nucleolus organizer region and was historically considered to be more distantly related (Sites et al. 1984). Nevertheless, recent molecular phylogenetic studies indicate that *Malayemys* and *Orlitia* are sister taxa (e.g., Spinks et al. 2004), with the genus *Siebenrockiella* closely related to them (Le et al. 2007; Reid et al. 2011; Thomson et al. 2021). *Siebenrockiella* diverged from the *Malayemys* + *Orlitia* clade in the Eocene, while *Orlitia* diverged from *Malayemys* in the Miocene (Thomson et al. 2021).

Additional close relatives of *Orlitia* are embedded in the Asian river turtle subclade (the subfamily Batagurinae), including the genera *Geoclemys, Morenia*, *Pangshura, Hardella,* and *Batagur* (Thomson et al. 2021).

This subclade within the Geoemydidae comprises many monotypic genera that exhibit widely variable traits, including some taxa that have temperature-dependent sex determination system, one species (*S. crassicollis*) that has XX/XY sex determination, and another species (*P. smithii*) that has ZZ/ZW sex determination (Badenhorst et al. 2013). A Pleistocene fossil from Solo River in Sambungmacan, eastern Central Java, Indonesia, confirms that the genus *Orlitia* has existed since at least the Late Quaternary (Setiyabudi et al. 2016; Karl et al. 2019) and previously had a wider distribution.

Figure 5. Hatchlings of *Orlitia borneensis* showing prominent vertebral keel, serrated posterior marginals, and orange-red colored plastron. Photos by Cisca Nurfi'aini.

Figure 6. Juvenile *Orlitia borneensis* showing retention of weak posterior vertebral keel and less prominently serrated posterior marginals. Photo by Sabine Schoppe.

From several confiscated *O. borneensis* now in European zoos, Palupčíková et al. (2012) sequenced 1,119 base pairs of the mitochondrial cytochrome b gene and 1,084 base pairs of the RNA fingerprint protein 35, which revealed three main haplogroups. Salleh et al. (2023) sequenced 658 base pairs of the mitochondrial control region (MCR) for a male *Orlitia* from Malaysia. Salleh and Esa (2024) reported a complete mitochondrial DNA genome of *O. borneensis* also from Malaysia. Ongoing phylogenetic work based on partial sequences of several mitochondrial genes (ATP86, CytB, CO1, and ND4) has suggested that there is some structuring among populations in West Malaysia, Sumatra, and Borneo, with possible geographic divisions between West Malaysia and Indonesia, including evidence of divergence in the Belitung Islands, but broader sampling is needed (Hardian et al. 2026a).

Description. — The Malaysian Giant Turtle is one of the largest freshwater turtles in Southeast Asia (Lim and Das 1999; Iskandar 2000; Auliya and Chen 2024; TTWG 2025). The adult carapace is highly domed, smooth, and oval in shape. The head is large with powerful jaws and a slightly protruding snout. The digits are fully webbed with long, thick claws. There are no recognized geographic variants of *O. borneensis* based on morphology, and its large size and dark dorsal coloration make it unlikely to be confused with sympatric turtle species.

General accounts of the size of *O. borneensis* report a maximum size of over 80 cm curved carapace length (CCL) and a weight around 50 kg body mass (BM) in the largest individuals (Ernst and Barbour 1989; Lim and Das 1999). Exceptionally, Iskandar (2000) claimed he had measured a specimen with carapace length of 117 cm, but the measurement may have been curved carapace length and specimen documentation remains unverified (i.e., Auliya and Chen 2024). From measurements we took on a single adult male *Orlitia,* we found that CCL is about 1.13 times larger than SCL (or SCL is ca. 0.88 of CCL), and using this ratio on the largest individual measured by Auliya and Chen (2024: CCL = 86.4 cm), we calculate a maximal estimated SCL of ca. 76.0 cm.

The head of *O. borneensis* is conspicuously large and broad. The skin on the posterior dorsal surface is divided into irregularly shaped scale-like structures, as is that over the tympanum and a narrow strip between the tympanum and the eye, a trait which is shared with other geoemydids (McDowell 1964). Adult individuals possess pebble-like granular scales around the eyes.

The triturating surface of the jaw is moderately broad posteriorly, narrows anteriorly, and has a single low non-denticulated ridge on each side. The upper jaw is notched and slightly bicuspid anteriorly. The lower jaw has a single sharp anterior cusp. Otherwise, the jaw margins are smooth.

The species has esophageal papillae lining the inside of the throat, which are small, blunted, and coated in a thin layer of mucus down the entire esophagus (Pressler et al. 2003).

The skull has a complete zygomatic arch formed from the jugal, quadrojugal, and postorbital bones. The frontal bone does not enter the orbital rim, nor do its anterior processes extend beyond the leading edge of the orbit. The orbito-nasale foramen is small and approximates the size of the posterior palatine foramen.

Each forefoot has five claws and each hindfoot has four. The digits are broadly webbed, the webs extending to the base of the claws. The array of large scales covering the forelimbs become more elongated and band-like near the feet. Large scales also strengthen the flap of skin along the lateral border of each limb. The hind legs and the feet, other than the lower surfaces of the toes, are covered with tiny, granular scales.

The shell is long, relatively narrow to oval-shaped, sometimes egg-like. The posterior marginal scutes are sometimes flared, which can be more common in large individuals. The carapace has a natural dome shape, sometimes flattened, which can be prominent in captive individuals. There is a fairly distinct ontogenetic shape change from rounded, higher-domed juveniles to lower-shelled, flatter-topped large adults.

The second through fourth vertebral scutes are hexagonal ("mushroom shaped"), with the short sides anteriorly and posteriorly (Fig. 2). The plastron is truncated anteriorly, deeply notched posteriorly, and somewhat shorter than the carapace. The abdominal midline suture is the longest and the anal suture the shortest of the plastral scutes. The humero-pectoral seam falls just posterior to the entoplastral bone. The broad bridge exceeds the length of either the anterior or posterior lobe of the plastron.

Shell bones are thinner and the buttresses narrower compared to the shells of *Batagur*, although large males have very heavy shells, with full ankylosis of the discrete bony elements. The anterior buttresses fuse to the first costal bone just above the pleuro-peripheral scute junction, while the posterior buttresses fuse on costal six near the junction with costal five, at or just above the pleuro-peripheral suture.

In general, *O. borneensis* has dark green or dark grey coloration on the dorsal parts of the carapace, extremities, head, and tail, with no ornamental coloration. The ventral parts of the body, including the plastron, bridge, axillary, inguinal, and ventral surfaces of the marginal scutes as well as ventral parts of the extremities, head, and tail have distinct ivory-to-pale yellow coloration. The ventral side of the marginals is suffused with dark pigment around their periphery.

Some individuals have exceptional red-to-orange coloration transitioning to dorsal dark green to ventral ivory coloration on the head (Figs. 1, 3). Head, neck, and limbs are black in the young but become brown or olive in older turtles. Young turtles also have light yellowish to orange vermiculations on the posterior portions of the head. The skin in less exposed regions tends to be white to light gray.

Orlitia can be distinguished from all similar species with overlapping geographic ranges, except the Black Marsh Turtle (*Siebenrockiella crassicollis*), by the mushroom-shaped second vertebral scute, with the posterior half being about half the width of the anterior half (Fig. 2). It differs from *Siebenrockiella* in lacking large cream-colored spots on the head, having a plastron that is predominantly light in color, an interhumeral suture seam that equals or exceeds the intergular seam in length, and a relatively straight femoro-anal seam. *Orlitia* further differs from the other large, riverine batagurines of Asia (genus *Batagur*) by having the posterior edge of the first pleural scute contact the fifth marginal (rather than the fourth), by having smooth (rather than serrate) jaw margins, and having black, long, and slightly curved claws, somewhat resembling those of a bear (Jayanto and L. McCaskill, pers. obs.).

Sexual Dimorphism. — Sexual size dimorphism in *O. borneensis* has not been reported in the literature. In fact, Palupčíková et al. (2012) found no sex-based differences in the shape of the carapace or plastron using geometric

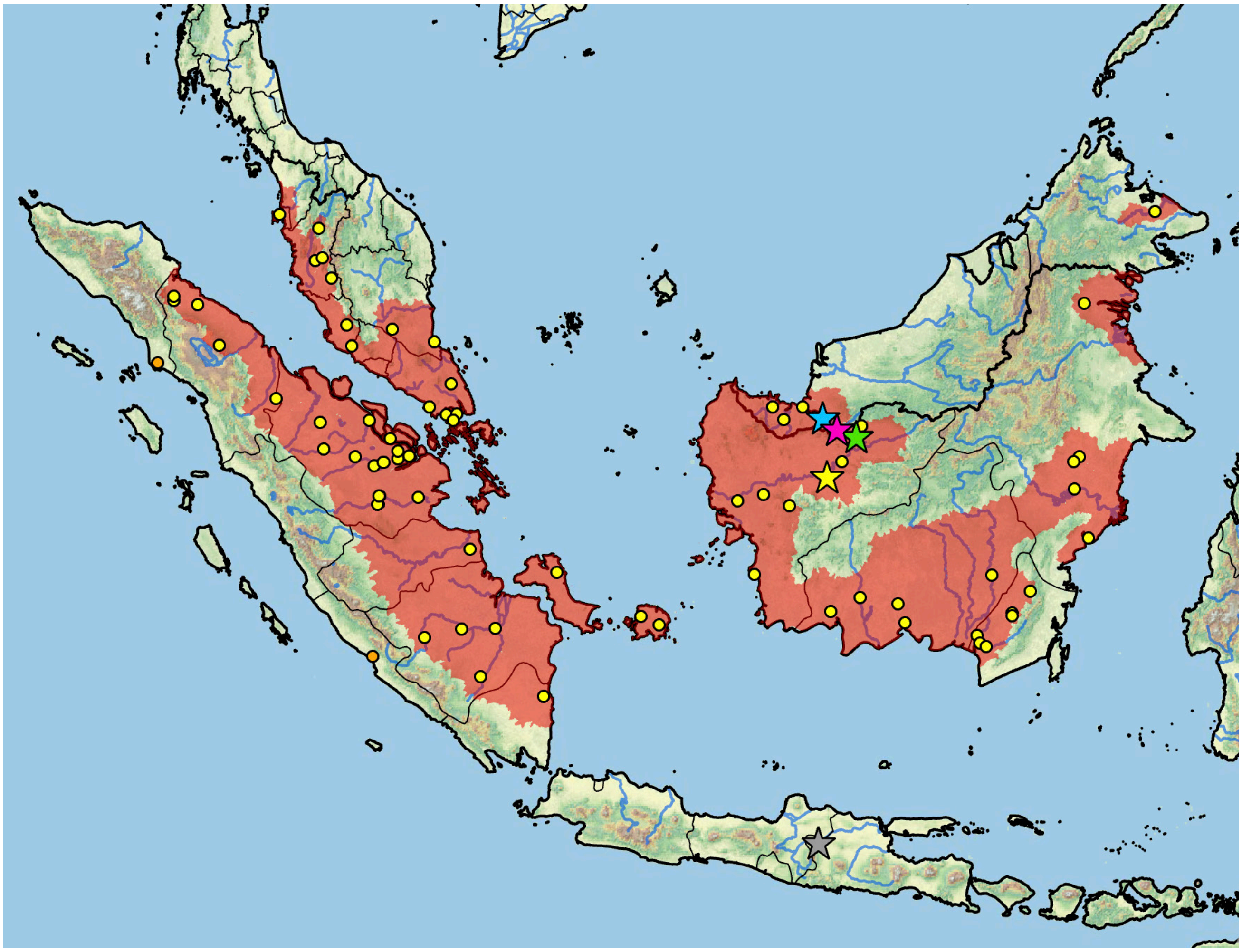

Figure 7. Estimated historical indigenous distribution of *Orlitia borneensis* in Indonesia and Malaysia. Yellow dots = museum and current and historical occurrence records of presumed native populations based on literature and online records (TTWG 2025; in prep.); orange dots = presumed trade-related or other translocated or introduced non-native records; yellow star = type locality for *Cistudo borneensis* Bleeker 1857 (*nomen nudum*) and restricted type locality for *Orlitia borneensis* Gray 1873; green star = type locality for *Clemmys (Heteroclemmys) gibbera* Peters 1874; blue star = type locality for *Hardella baileyi* Bartlett 1895; pink star = type locality for *Liemys inornata* Boulenger 1897; gray star = type locality for *Batagur signatus* † Jaekel 1911 (TTWG 2025). Colored shading = estimated historical indigenous range. Distribution is based on fine-scaled GIS-defined level 12 HUCs (hydrologic unit compartments) constructed around localities and then adding HUCs that connect point localities in the same watershed or physiographic region, and similar habitats and elevations as verified HUCs, based on TTWG (2025) and adjusted based on subsequent data (TTWG, in prep.) and from the authors. Map by Chelonian Research Foundation.

morphometrics for 24 males and 20 females from European zoos. In general, however, males tend to be larger and more robust than females, commonly exceeding 70 cm SCL and maturing at a larger size (Moll, pers. obs.). Other than a noticeable body size difference, males are somewhat distinguishable from females by their tail which is much thicker at the base than in females, and longer, as the cloaca extends further past the marginal scutes than in females. The preanal length of the male tail approximates 60% of the total tail length, whereas in females it is about 50% (Moll, unpubl. data).

Males also exhibit a slightly concave plastron whereas females tend to have a flat or slightly convex plastron, but this is not a very reliable trait. Brockmann et al. (2013) noted that males also tend to have a larger head with more robust mandibles than females of similar body sizes, and the posterior marginal scutes in males flare outwards, while they are mostly unflared in females. Brockmann et al. (2013:f.1–2) provided dorsal and ventral views of a verified mature male and female mating pair.

Given the lack of quantifiable sexual dimorphism in this species (e.g., Palupčíková et al. 2012), otherwise standard sex-determining methods used for freshwater turtles are difficult to apply to *O. borneensis*. Sex identification in this species is best determined by complementary approaches, some based on observation of differences listed above, as well as more intrusive methods such as finger probing in the cloaca to detect the presence of a penis in males. Another technique, which works best in juveniles, is cloacal popping, where pressure is applied at the base of the tail to evert the penis in males. In some cases, pelvic morphology can be examined using X-ray imaging, where a U-shaped pelvic opening indicates a female, while a V-shaped configuration indicates a male (Hardian, unpubl. data).

Hatchlings. — Hatchlings have a rounded carapace with a steeply domed shell, a median dorsal keel that is most prominent along the last three vertebral scutes, and a highly serrated posterior shell margin (Ernst and Barbour 1989). Five hatchlings measured by Moll (unpubl. data) averaged 62 mm SCL, 50 mm straight-line carapace width (SCW), and 44 g BM. At Gembira Loka Zoo, Java, eight hatchlings had pale red plastrons (Fig. 5) with no distinct patterning and measured an average of 62.3 mm SCL, 51 mm SCW, and 43.3 g BM.

In addition to the distinct shell shape in juveniles, they also have a different color pattern than adults. Juveniles tend to have some mottling or lighter markings on their skin; notably, young individuals have a pale stripe running from the corner of their mouth toward the back of the head, which contrasts with the mostly uniform head coloration of adults. As the turtles grow, the shell elongates and the keel fades, resulting in the lower, smooth oval adult shell profile and more uniform colors (Fig. 6).

Distribution. — *Orlitia borneensis* is endemic to the Sundaland region of Southeast Asia. Its range spans West Malaysia (primarily the southern half of the Malay Peninsula) and the major Sunda Islands of Borneo and eastern Sumatra, especially wetlands connected with the Malacca Strait and South China Sea, but not the Indian Ocean drainages (Fig. 7). Furthermore, it is known from Sumatra's satellite islands of Bangka, Belitung, and presumably also occurred in the northern Riau Islands, Indonesia. For example, Hasan et al. (2025) recently reported it in the Lenggang River on the island of Belitung, although its presence there had been known by locals for a long time. Also, an adult female was found in 2023 near Penyamun Village on the island of Bangka, west of Belitung, presumably caught incidentally by a fisherman.

Historically, the species was recorded in river drainages such as the Perak and Klang in West Malaysia and in lowland rivers of Sarawak (Malaysian Borneo) and Kalimantan (Indonesian Borneo) (CITES 2002). In Sumatra, it occurs in eastern lowland rivers and associated wetlands. It has apparently not been formally recorded in extreme southern peninsular Thailand or in the wild in Singapore, but there are several observations of this species on iNaturalist from Singapore (https://www.inaturalist.org/observations?subview=map&taxon_id=39947); although these probably represent introduced or translocated specimens, as the native population seems to have been extirpated (P.P. van Dijk, pers. comm.).

A recent field guide suggests that the species also occurs in Sabah, Malaysia (Das 2026), and a specimen has been reported from the Kinabatangan River (Global Biodiversity Information Facility; www.GBIF.org). In West Malaysia, the northernmost record is from Penang Island (Boulenger 1912). However, this must be viewed cautiously as Penang records were frequently based upon market specimens brought from elsewhere. Today the species can be regularly encountered at least as far north as Ipoh, Perak. Several encounters have also been reported in Johor and Negeri Sembilan.

Reliable reports of *O. borneensis* provided to us (Jayanto, Rahmawati, and Hardian, pers. comm.) include observations from Langsa (Aceh), Pangkalan Bun (Central Kalimantan), Palembang (South Sumatra), Teluk Binjai, Gambut Mutiara, and Serapung (Riau). Additional records generated by us (Jayanto, Rahmawati, and Hardian, unpubl. data) come from South Sumatra (Musi Banyuasin, Penukal Abab Lematang Ilir), North Sumatra (Langkat, Parapat), Central Sumatra (Jambi, Kumpeh), Lampung (Batanghari, Way Kambas, Way Kanan, Way Kiri River), Central Kalimantan (Seruyan, Buntok, Tamiyang Layang, Babai, Sebabi, Sungai Mentaya, Kumai, Sampit, Nyaru Menteng), East Kalimantan (Tenggarong, Long Mesangat), North Kalimantan (Malinau Barat), South Kalimantan (Kandangan, Banjarmasin, Sungai Miai, Angkinang, Padang Batung, Halong, Cindai Alus), West Kalimantan (Singkawang, Sintang, Sejiram Village of Sambas District, and Batang Lupar Village of Kapuas Hulu District).

We note there are at least two reports of *O. borneensis* from Indian Ocean drainages in western Sumatra, including Singkil (J. Guntoro, pers. comm.) and Bengkulu (A. Ruyani, pers. comm.); however, these occurrences should be viewed cautiously, as they are likely the result of traded or inadvertently translocated animals, some of which may now be in captivity at the Turtle Learning Center at Universitas Bengkulu (Wahyuni and Ruyani 2026).

Biogeographically, it is plausible that *O. borneensis* could have dispersed across the Sunda Shelf through ancient river networks, which limited their range to lowland, coastal areas with large rivers. As major paleorivers drained to the ancient basin among the Sunda Shelf's islands, these very large river systems would have facilitated the dispersal of *O. borneensis* across the wider region, particularly into lowland areas (Solihuddin 2014). The distribution of *Orlitia* largely parallels that of the Painted Terrapin, *Batagur borneoensis,* and the Sunda Gharial, *Tomistoma schlegelii*, except it does not extend as far north into Thailand (P.P. van Dijk, pers. comm.). Fossils of *O. borneensis*, understood to date from the Middle Pleistocene (0.78–0.13 Ma), have been found in the Solo River, Sambung Macan, East Java, and Madura Strait (Setiyabudi et al. 2016; Karl et al. 2019; Berghuis et al. 2025), indicating a previously wider distribution across the Sunda Shelf.

Habitat and Ecology. — Few specific data exist on most aspects of the ecology of *O. borneensis*, especially from wild individuals (Wahyuni and Ruyani 2026). For example, there are no published estimates of home range sizes, movement rates, microhabitat selection, site fidelity,

Figure 8. Habitat diversity in East Belitung, Indonesia, where Malaysian Giant Turtle (*Orlitia borneensis*) individuals were documented. *Top left*: The riparian landscape and vegetation in the tributary of Lenggang River with minimum anthropogenic activity provides a safe area for *O. borneensis*. *Top right*: Pengkalan Pakre is a fishing port functioning as a local docking platform for traditional fishing boats and is part of Lenggang River where more semi-permanent fishing equipment (e.g., basket bamboo trap or wire fish trap) are installed and where increasing by-catch events were reported. *Bottom left*: Arongan Panjang, a bank on the Lenggang River within Lintang Forest where locals frequently encountered large terrapins, illustrating a suitable nesting area for *O. borneensis*. *Bottom right*: A hallmark of Pice Dam where bycatch events of *O. borneensis* were also frequently reported and skeletonized large-sized terrapins were frequently found along the riverbanks during the low tide period. Photos by Andreas B. Hardian and Cisca Nurfi'aini.

seasonal movements, survivorship, growth, sex ratios, or population dynamics. Furthermore, there is no published information on predators, competitors, or other major ecological interactions in general. Nor are there any telemetry, mark-recapture, or observational data available that address aspects of its population ecology in the wild. Consequently, most of the information about this species is derived from anecdotes, studies with small sample sizes, short-term field observations, and captive individuals. The most robust data available for the ecology of this species are for its body size and diet, which are detailed below.

Habitat Associations. — *Orlitia borneensis* is a primarily aquatic turtle of freshwater habitats where it apparently rarely leaves the water except for nesting, movements, and possible basking (Gonzalez 2026). It is primarily associated with large, lowland river systems in forested areas, including slow-flowing rivers, lakes, and swamps (Ernst and Barbour 1989), and appears to be more common in lentic than in lotic systems (Moll, pers. obs.) and in peat-swamp habitats (Fig. 8). Nyckel (1984) observed several aquatic turtle genera from tropical Asia and classified *O. borneensis* as a bottom-walker rather than an active swimmer.

Available records consistently describe the species as occurring in major river channels and adjacent low-energy aquatic habitats, but provide little detail on microhabitat use or water characteristics such as depth, turbidity, or flow velocity (Horne et al. 2020). However, it is known to occur in peat-swamp habitat with high acidity (pH = 3–5), such as in Muaro Jambi (Jambi), Kampar (Riau), Mentaya river (Central Kalimantan), and Mesangat swamp (East Kalimantan) (Jayanto, unpubl. data). Habitat descriptions are largely qualitative and derived from occurrence records rather than systematic habitat surveys (Kimmel

1980; Ng and Lim 2010; Auliya and Chen 2024; Hasan et al. 2025).

Orlitia borneensis has been commonly found in slow-moving rivers of riparian landscapes that possess dense canopy cover and aquatic plants emerging from 1–2 m depth in the water column. The bottom and riverbanks generally consist of muddy and sandy soils. Observations in Geosite Tebat Rasau, East Belitung, at less than 25 m altitude, recorded several main types of vegetation populating the riparian landscape, including palms, bamboo, screw pines (e.g., *Pandanus* spp.), water lilies (e.g., *Nymphaea* spp.), mixed bushes, and other trees (Jayanto, unpubl. data). Many *O. borneensis* habitats in Sumatra and Kalimantan are associated with Rasau Palm (*Pandanus helicopus*) and Bakung (*Hanguana malayana*) (Jayanto, pers. obs.).

The population in our study area on Belitung Island is sympatric with several turtle species, including the Black Marsh Turtle (*Siebenrockiella crassicollis*), Asiatic Softshell Turtle (*Amyda cartilaginea*), Southeast Asian Box Turtle (*Cuora couro*), and Asian Leaf Turtle (*Cyclemys dentata*). A rapid semiquantitative water quality test into the deep core zone of Geosite Tebat Rasau, East Belitung, where *Orlitia* is encountered, recorded zero levels of ammonia (NH3, NH4), chlorine (Cl2), nitrite (NO2), and nitrate (NO3), with pH at 6.4 (Hardian, unpubl. data). Several localities with moderate anthropogenic activity had low ammonia levels, ranging from 0.25–0.5 ppm, and chlorine recorded at 0.8 ppm.

Preliminary species distribution modeling (SDM) based on 27 occurrences of *O. borneensis* in the wild found that soil type and elevation were the major determining factors of habitat suitability, followed by land cover and water flow accumulation (Hardian, unpubl. data). Soils predominantly composed of albic podzol (spodosol) and brunic arenosols with more than 80% sand (wet weight) were the most suitable habitat for this species, which indicates that it is generally found in large water systems at less than 100 m altitude. A preliminary map based on this modeling revealed several areas of high habitat suitability outside the species' known distribution, including rivers in West Java, Sabah (Das 2026), Sarawak, and several small islands off the south coast of Singapore.

Activity Patterns. — The species is generally considered to be diurnal, and basks in captivity, suggesting that basking may occur in the wild as well (Mo 2020). Nocturnal overland movements have been observed under semi-natural captive conditions, perhaps related to nesting behavior or nocturnal basking (e.g., McKnight et al. 2023), although the ecological significance remains unclear (Gonzalez 2026). Field-based information on activity patterns for *O. borneensis* is not available, although an individual released at Tebat Rasau, Belitung Island, was recaptured again just a day later 1 km away in a traditional fish trap (P. Nasidi, pers. comm.). No published studies have documented diel activity, seasonal shifts in activity, or even simple behavioral patterns in natural habitats.

It appears that this species is mostly solitary, with the largest individuals usually staying away from others in captivity (Jayanto, pers. obs.). Thus, individuals may only interact with conspecifics for breeding or at artificially high densities in captivity. Limited captive observations indicate that individuals may engage in basking behavior and display behavioral interactions with other large chelonian species, though such observations cannot be assumed to reflect natural conditions (Mo 2020).

Body Size. — The species was described from the unmeasured juvenile holotype by Gray (1873), who stated that "it is evidently the young of a very large and solid species; for even this young specimen is well solidified, though there is an oblong groove (the remains of the opening of the yelk-bag [sic]) in the central suture of the abdominal and preanal plates." According to Siebenrock (1904), the holotype in the British Museum had a shell length of 80 mm, while a specimen from the Natural History Museum in Vienna with a shell length of 82 mm also still had an umbilical scar; thus, he assumed that *Orlitia* must grow much larger. Boulenger (1897) described the synonymized species, *Liemys inornata*, based on two female specimens, one of which had a shell length of 39 cm, which is presumably within the subadult size class. Siebenrock (1902) examined a skull of *Adelochelys crassa* (another synonymized name) and found its length (premaxilla to the occipital condyle) to be 132 mm, which he compared to a complete skeleton of *Liemys inornata* that had a skull length of 76 mm and SCL of 46 cm. He concluded, "if a skull measuring 76 mm corresponds to a carapace measuring 460 mm in length, then logically a skull measuring 132 mm in length of the same species must correspond to a carapace measuring 798 mm." This extrapolation could provisionally establish the maximum CL for the species, which has been oft repeated in secondary sources as approximately 80 cm (e.g., Ernst and Barbour 1989; Manthey and Grossmann 1997; Das 1999; Figueroa et al. 2023), but also reported as 70 cm (Das 1995) and 75 cm (Muslim 2016). However, these sources rarely specified whether measurements referred to SCL or CCL.

Recent verified measurements from West Malaysia have documented larger individuals than previously confirmed. An adult observed in Perak in 2008 measured 85.0 cm CCL and 70.0 cm CCW, while a rescued individual from Pahang currently maintained at Kuala Berang measured 86.4 cm CCL and 73.6 cm CCW (Auliya and Chen 2024). These represent the largest reliably measured individuals to date. Additional adult individuals in captivity measured 81.2 cm CCL (Bota Kanan), 69 and 60 cm CCL (Zoo Melaka), and between 29.6 and 65.2 cm CCL at A'Famosa Water Theme Park (Auliya and Chen 2024). A male and female held in a German zoo measured 51 cm and 41 cm SCL, respectively (Brockmann et al. 2013). From two Malaysian individuals, Moll and Moll (1990) reported a mean body size of 47.5 cm SCL and mean mass of 13.5 kg. At the Xing Ping market, China, in May 2000, seven of the largest *Orlitia* for sale were measured by putting the front of the animal against a wall and over a steel measuring tape, which revealed a mean SCL of 67.4 cm (± 6.7 cm; range, 55–77 cm) (P.P. van Dijk, unpubl. data). Recent measurements from a captive individual in Taman Hewan Pematang Siantar were 81.5 cm CCL, 62 cm CCW, and ca. 50 kg BM (Jayanto, Rahmawati, and Hardian, unpubl. data).

All recent records were based on CCL taken using flexible measuring tape, rather than standardized SCL using calipers. Because most data were derived from isolated observations rather than systematic morphometric surveys, size variation, sexual dimorphism, and maximum verified SCL remain insufficiently documented. Nevertheless, available evidence confirms that mature individuals can exceed 85 cm CCL, supporting the characterization of *O. borneensis* as the largest hardshell freshwater turtle in the region (Auliya and Chen 2024). A single male *Orlitia* was recently measured with both large tree calipers and a flexible measuring tape (see Fig. 1; SCL 40.7 cm, CCL 46.1 cm), which indicated that SCL is about 0.88 of CCL. Using this rough ratio, then the largest turtles measured as CCL by Auliya and Chen (2024) (i.e., 85.0 cm and 86.4 cm CCL) would have SCLs of approximately 74.8 cm and 76.0 cm.

Longevity. — Published records of longevity are limited, with the longest for a captive individual of eight years, six months, which was presumably received as an adult (Flower 1937), but a captive specimen in Indonesia has been inferred to be at least 21 years old based on historical anecdotes from the zookeeper (Jayanto, Rahmawati, and Hardian, unpubl. data). Three captive individuals that live at the Columbus Zoo and Aquarium in Ohio were hatched at the Bronx Zoo in 1991, thus they are currently 35 years old. Given the species' large size, presumed slow growth, and inferred late sexual maturity, these records are likely a significant underestimation of its true lifespan.

Growth Patterns and Size at Sexual Maturity. — Immature males have been observed as large as 55 cm SCL, whereas all apparently mature males had SCL of at least 60 cm (Moll, pers. obs.). Females are thought to be mature at around 47 cm SCL and can attain at least 55 cm SCL (Moll, unpubl. data), but a captive 41 cm SCL female successfully reproduced with a 51 cm SCL male (Brockmann et al. 2013).

At Gembira Loka Zoo, we analyzed morphometric data from 49 individuals confiscated from illegal trade for one year from 2023 to 2024 (Hardian et al., in review). Among the 20 adults, 19 were male and one was female, which collectively had an average CCL of 55.34 cm (± 5.88 cm; range, 39.8–61.0 cm) and average BM of 19.45 kg (± 5.72 kg; range, 8.6–31.45 kg) (Hardian, unpubl. data). We found variation in carapace growth during ontogeny. The smaller individuals (ca. 18–43 cm CCL) showed measurable growth over the year of monitoring (~8.7 cm CCL annually on average) with body mass gain of ~1.2 kg annually on average). The larger individuals (55–60 cm CCL) exhibited such slow growth during a year of morphometric monitoring that no difference was detected between the first and last measurements, though they constantly gained body weight (~5.3 kg annually on average). We also monitored the first hatchlings in 2023 ($n = 8$) which showed growth of ~2.6 mm SCL per month on average in the first 10 months of monitoring.

Considering that several turtle species gain sexual maturity at an average carapace length (CL) of about 70% (range, 58–83%) of maximum CL (Shine and Iverson 1995), we estimate that sexual maturity of *O. borneensis* in our captive population was reached at a range of ca. 40–50 cm CCL. This estimate is supported by our observation of oviposition by the only female in the population at 43.3 cm CCL in 2023 (Hardian, unpubl. data).

Mating Behavior. — Based on observations of captive individuals at Gembira Loka Zoo, mating in *O. borneensis* occurs underwater. Courtship typically involves the male actively pursuing the female before copulation, and the breeding season likely occurs between February and May. The onset of this period is often indicated by increased visibility and activity of females, which are observed swimming more frequently near the surface, basking more often, and showing increased appetite. When a female is housed with more than one male, mating behavior by one individual may stimulate similar behavior in others. In some cases, males may also display mating behavior toward other males. For this reason, controlled mating is recommended.

Reproduction and Nesting. — Published information on reproduction is extremely limited. For example, there

Figure 9. Eggs of the Malaysian Giant Turtle (*Orlitia borneensis*) found laid in the pond at the Gembira Loka Zoo, Yogyakarta, Indonesia. Photo by Gembira Loka Zoo.

are no published data on reproductive ecology in natural settings, including nesting habitat, nesting seasonality, incubation period, or hatchling emergence. According to Lim and Das (1999), the species nests on riverbanks and islands. Females apparently nest by excavating a hole in mud or sand along riverbanks, or swamp edges where they deposit their eggs. Local villagers have indicated that *Orlitia* nests in piles of debris (Moll, pers. comm., *in* Ernst and Barbour 1989), as well as noting that the species tends to excavate shallow nests, particularly when compared to soft-shelled turtles such as *Amyda cartilaginea*, which typically excavates deeper nests.

In captive conditions at Wildlife Rescue Centre Jogja (WRC Jogja) and Gembira Loka Zoo, and based on our own observations, females select terrestrial nesting sites close to the water's edge, typically in concealed areas with muddy or loose soil and nearby vegetation. In many cases, the species appears to dig only minimally and may leave eggs partially exposed on the substrate (Fig. 9). At WRC Jogja and Gembira Loka Zoo, egg laying has been recorded around June each year. To date, eggs have only been observed to be laid once during this period, suggesting that the species may produce a single clutch annually under the current management conditions.

Brockmann et al. (2013) mated a female with a male under captive conditions on 10 January and again on 15 February, with copulation lasting 1–2 minutes. On 2 April, the female started nesting on land, which she attempted for several days, and finished on 6 April, with the depth to the bottom of the final nest at 15–20 cm. The eggs were incubated at 29°C, and the hatchlings emerged between 127–154 days.

At Gembira Loka Zoo, artificially incubated eggs hatched within a range of 120–165 days, with most hatchlings having emerged after approximately 150 days (Hardian, unpubl. data). Eggs that had been buried in the ground in more natural conditions of the enclosure showed no visible signs of hatching even after 150 days (i.e., no egg cracking was observed). As a precaution, these eggs were transferred to an artificial incubator on day 150, after which they successfully hatched on days 158 and 165.

In addition, Moll (pers. obs.) recorded that 22 eggs from two captive females were incubated at ambient room temperatures ranging from 22–33°C, and five hatchlings emerged after a period of 144–147 days.

Clutch and Egg Size. — This species produces relatively small clutches for its body size, but large, brittle-shelled eggs overall (Ernst and Barbour 1989; Moll and Moll 1990, 2004). It is not known if it lays multiple clutches annually. According to a general account, Lim and Das (1999) indicated that the species lays 12–15 eggs per clutch, but empirical data from actual clutches suggest a lower range.

Based on the seven documented clutches described below, the average clutch size for *O. borneensis* is 9 eggs (±1.83; range, 6–12). Siebenrock (1904) reported six mature eggs, which measured 79 mm in egg length (EL) and 41 mm in egg width (EW), removed from the oviduct of an animal that died in Vienna. Two females purchased from an animal dealer in Perak, Malaysia, produced clutches of 10 and 12 brittle-shelled eggs averaging 79.15 mm EL x 42.78 mm EW and 93.90 g in mass (Moll, *in* Iverson et al. 2024). The mean BM of these two females was 13.53 kg with a mean clutch mass of 1.132 kg, which produced a relative clutch mass (clutch mass / gravid body mass) of 8.37% (Moll and Moll 1990; Iverson et al. 2025). Van der Meer Mohr (1934) reported nine eggs from Sumatra that averaged 65.67 mm x 39.39 mm and 57.32 g (Iverson et al. 2024). For the 31 total eggs, reported by van der Meer Mohr and Moll, the following equation established the relationship between egg dimensions and mass: egg mass = 1.454EL + 4.336EW – 207.4 (Iverson et al. 2024). Schilde (2004) reported on eggs that measured approximately 79 x 41 mm.

In semi-captive conditions, one female produced eight eggs in a clutch but none of them hatched (R. Gonzalez, pers. comm.). In captivity, Brockmann et al. (2013) found nine eggs in one clutch (average egg mass, 76.6 g; range, 68–81 g), and another clutch of nine eggs has been noted from a female at Gembira Loka Zoo (Hardian, unpubl. data).

Parasites. — A survey of helminths in confiscated Malaysian freshwater turtles, including *O. borneensis*, discovered trematodes (*Telorchis* spp.) and nematodes (*Orientatractis* spp.), which frequently use intermediate aquatic hosts such as mollusks and fishes (Neely et al. 2017). *Falcaustra greineri* is a species-specific nematode which was isolated from the large intestine of an *O. borneensis* confiscated from an illegal trade seizure (Bursey and Kinsella 2003). *Placobdelloides tridens* is a glossiphoniid leech that was recently described from a captive *O. borneensis* in Thailand (Chiangkul et al. 2021).

Diet. — The species seems to have an opportunistic omnivorous diet composed primarily of vegetation, as it will frequently take fallen fruits and aquatic plants, but also fish and aquatic invertebrates. However, empirical dietary information for *O. borneensis* in the wild is limited; thus, its trophic ecology is poorly understood. General accounts, such as Lim and Das (1999), typically report that this species is omnivorous with a preference for fish, while others, such as Iskandar (2000), emphasized the consumption of leaves, fruits, and large seeds. However, Kimmel (1980) examined two fecal samples of one wild individual, which revealed an herbivorous diet with fruit, identified as Berembang (*Sonneratia caseolaris*), comprising 85.8% of the total volume of food matter, with leaves and stems comprising 6.2%, and unidentified plant matter the remaining 10.3%. Furthermore, Moll (unpubl. data) collected fecal samples from three adults captured in the wild, which were composed mainly of plant matter, especially fruits from tree species in the genera *Sonneratia* and *Pandanus*, with one fecal specimen containing a few snail shells.

Based on villagers near the Lenggang River, East Belitung, this species frequently feeds on the seeds of Rasau fruit (*Pandanus helicopus*), which are generally not consumed by humans due to their bitter taste (P. Nasidi, pers. comm.). In addition, individuals have been reported to consume aquatic vegetation, including the aquatic bamboo plant (*Blyxa aubertii*) (P. Nasidi, pers. comm.). Animal prey apparently includes small fish, with a particular preference for the locally known *cempedik* or *bantak* (*Osteochilus spilurus*), a member of the fish family Cyprinidae (P. Nasidi, pers. comm.).

In Jambi and East Kalimantan, this species fed on wild silurid catfish such as *Clarias nieuhofii* and small *Wallagonia leeri* when they were used as bait in a passive traditional fishing method using hooks and small bamboo poles (Jayanto, pers. obs.). Anecdotal information from fishers in East Kalimantan suggested that they also consume local figs known as *ara* (*Ficus* sp.) (P. Kasno and I. Shinyo, pers. comm.).

Using DNA metabarcoding of cloacal swabs from 104 individual *O. borneensis*, 18S mitochondrial gene profiles were generated, providing a conservative, presence-only representation of the possible diet and generally confirming the direct dietary observations (Hardian, unpubl. data). Preliminary detections from this ongoing molecular work include freshwater fish in the families Cyprinidae and Mugilidae, obligatory fish parasites in the class Myxozoa, freshwater gastropods in the families Physidae and Planorbidae, aquatic insects in the families Dytiscidae and Belostomatidae, freshwater jellyfish (genus Craspedacusta), and plants, likely consumed as fruits, in the genera *Ficus* and *Musa*. No more quantitative data from wild individuals are available on prey composition, feeding frequency, or ontogenetic shifts in diet.

In captivity, *Orlitia* regularly consumed packaged turtle pellets and various vegetables and fruits, such as sweet potatoes, watermelon, and cantaloupe (Gonzalez 2026). Mehrtens (1970) reported feeding observations of a single immature female which ate a variety of meats, while the only plant food eaten was over-ripe bananas that it consumed equally well in or out of the water.

It seems that this species may consume a more carnivorous diet when young and becomes more herbivorous as it matures (but also see Diet in Captive Husbandry below). For example, Moll (pers. obs.) found that captive juveniles readily ate meat and fruit. Furthermore, a captive juvenile kept for ten years in Malaysia and at the Eastern Illinois University Vivarium readily ate plant and animal food, such as dried dog food, bananas, and leafy vegetables, but it was also observed eating kangkung (*Ipomoea aquatica*, water spinach), dried shrimp, and fish. Brockmann et al. (2013) fed captive-bred hatchlings (just after yolk absorption) molted mealworms, fish fillets, pieces of grapes, and dandelion greens. Later, Brockmann et al. (2013) fed the hatchlings daily meals of turtle pellets with homemade jelly made from fish, poultry bones, freshwater shrimp, dandelion greens, carrots, apples, mineral supplement, and gelatin.

Hematology and Blood Chemistry. — A hematologic study of captive *O. borneensis* at WRC Jogja (Hardian et al. 2026b) found that the cellular morphology of blood cells was very similar to other chelonian species (Hernández et al. 2017). Basophils were the rarest leukocytes found and three mononuclear-like cells were also detected (monocytes, putative azurophils, and immature erythrocytes). Azurophils were indistinctly discriminated from monocytes due to their almost identical morphology and size, though there was more basophilic cytoplasm coloration in azurophils; thus, several studies suggested these cells merely as monocytes (Nieto-Claudín et al. 2024). Thrombocyte clumps were not observed in a Giemsa-stained blood smear.

Erythrocytes (average cell length 17.45 ± 1.43 µm; cell width 11.71 ± 1.12 µm) were comparatively smaller than those of the Bolson Tortoise (*Gopherus flavomarginatus*) (average cell length = 22.4 ± 1.5 µm; cell width 12.5 ± 1.0 µm), which may reflect the demands of oxygen intake between aquatic and terrestrial species (García-De la Peña et al. 2020; Hardian et al. 2026b). Several abnormal erythrocyte morphologies were also noted, including dacrocyte, pleomorphic bipolar erythrocytes, and erythrocytes with significant central pallor, and these erythrocyte variations may indicate clinical concern, especially in anemic conditions (Hardian et al. 2026b).

Population Status. — Little is known concerning the population status of *O. borneensis*. It is likely that the current area of occupancy is highly fragmented due to habitat loss and overharvesting. Thus, many former localities may no longer support viable populations. While conducting surveys of river turtles in southern Malaysia in 1990, Moll (pers. obs.) regularly encountered indigenous people as well as ethnic Chinese with specimens of this turtle that were being kept for food. The species was believed to be relatively common in the Tasik Bera, a wetland in swamp forest, and Dampar area of Pahang and in the state of Johor, but it was less frequently seen in northern Malaysia (Moll, pers. obs.). A sample of 393 turtles collected on Malaysia's lower Perak River, contained only one specimen of *O. borneensis* (Moll and Moll 1990). None were encountered in a survey of stocks being maintained by five animal dealers and two market vendors (Moll and Moll 1990).

Lim and Das (1999) stated that the species was formerly abundant in the Klang River in West Malaysia, but by then it was seen only occasionally. The Klang River was significantly polluted by tin mining in its headwaters starting around 1900, and the species was not observed near the middle Klang River in 1999 (P.P. van Dijk, pers. obs.). Sharma and Tisen (2000) reported that ample habitat remained in the southern part of West Malaysia, but there was little information on the size of the *Orlitia* populations there at that time.

Samedi and Iskandar (2000) listed *Orlitia* as "uncommon" in Indonesia, and based on anecdotal information from traders and hunters, reported that populations had declined considerably. However, a survey coordinated by Iskandar in southern Sumatra encountered *Orlitia* more commonly than either *Batagur affinis* or *B. borneoensis* (Moll and Moll 1990). Surveys of fishermen in Sumatra, focusing on 133 residents of the Pasir Darat, Sekampung, and Indragiri watersheds, noted that *O. borneensis* (23%) was the second most commonly observed species, just behind *Cuora amboinensis* (25%) (= *C. couro*) (Tiara et al. 2025).

Orlitia borneensis was most recently assessed as Critically Endangered on the IUCN Red List (Horne et al. 2020), which was a change from earlier assessments: Endangered in 2000 (ATTWG 2000) and Near Threatened in 1996 (TFTSG *in* Baillie and Groombridge 1996). Presumed declines led to its uplisting to Critically Endangered after an estimated >80% population decline over the past three generations (Horne et al. 2020), but we note that no studies on wild populations have ever been conducted to support such inferences, nor have studies been conducted to dispute them. We note that the existence of remnant populations does not disprove a range-wide collapse as the perception of persistence is prevalent in long-lived turtles, but data is urgently needed to determine their status in the wild.

In the mid-20th century, the species was never considered abundant, but it was regularly found in local markets and rivers. By the 1990s, exploitation had increased drastically. For instance, in just a ten-month period of 1999, over 21,000 individuals were exported from West Malaysia (CITES 2002). Traders, hunters, and experts noted a rapid decline in supply by the late 1990s, attributable to over-collection rather than habitat loss (Samedi and Iskandar 2000; Shepherd 2000; van Dijk et al. 2000). Overall, the current wild population is believed to be a fraction of its historical size (Horne et al. 2020). Precise numbers are unknown since we have no data from wild populations on sizes, age-class distribution, sex ratios, survival, density, or biomass. Nevertheless, we have found that for some local communities, especially among fishermen, the species can still be observed year-round in its natural habitat.

Threats to Survival. — Adult *Orlitia* likely have few natural predators due to their large size, but eggs and juveniles would be vulnerable to predation. In Berbak National Park, the remains of broken shells, beaks, and skins of large *O. borneensis* were observed on four separate occasions in traditional fish traps (i.e., *tembilar*), which bore marks of predation from Sunda Gharials (*Tomistoma schlegelii*) (Jayanto and L. McCaskill, pers. obs.). However, as a large, presumably late-maturing species with a relatively low reproductive output for its large size, *O. borneensis* is intrinsically vulnerable to over-exploitation.

The species' limited geographic distribution in Sundaland suggests that habitat degradation and loss, together with associated exploitation, are among the species' most significant threats (Salleh et al. 2022). Freshwater systems that support the species—including rivers, floodplains, and peat-swamp forests—are increasingly affected by land conversion and resource extraction. Across its range, mining activities together with plantation expansions can alter river structure, increase sedimentation, and degrade water quality. These environmental changes reduce the availability of suitable habitats for feeding, nesting, and shelter, and disrupt ecological processes that sustain freshwater biodiversity. For example, Moll and Moll (2000) documented heavy commercial exploitation from sand mining operations in Lampung-Sumatra (Indonesia) and Johor (Malaysia) that impact nesting beaches used by river turtles, and possibly *Orlitia*.

Harvest for Food and Trade. — The most widely documented threat to the species has been intensive exploitation for trade during the Asian turtle trade boom of the 1990s and early 2000s, when tens of thousands were exported annually and it ranked among the top species in markets (Shepherd 2000; van Dijk et al. 2000; CITES 2002). It was targeted as a food source as its meat is highly prized in East Asian markets (particularly China) (CITES 2002). It was believed in the Chinese medicinal trade that the organs, bile, and bones of many reptile species, including *O. borneensis*, are cures for various diseases such as smallpox and fever, while the blood is used to boost stamina (Moll and Moll 2004; Mardiastuti et al. 2021). In West Malaysia, it was regularly sought by the Chinese as well as by indigenous people (Moll, pers. obs.).

Confiscations of illegal turtle shipments (such as a large 2001 confiscation in Hong Kong [CITES 2002]) have included significant numbers of *Orlitia* (Horne et al. 2020). Sharma and Tisen (2000) reported that 21,972 individuals of *O. borneensis* were exported from West Malaysia from January to October 1999, based on records from the Department of Wildlife and National Parks. Furthermore, Shepherd (2000) included an image taken in September of 1999 from a holding facility in Medan, Sumatra, where daily shipment of hundreds of *O. borneensis* awaited export to the food and traditional medicine markets in East Asia (Fig. 10).

There has been major exporting of live *Orlitia* to China, where markets offer high prices, turtles are often butchered and sold by the kilo, and where unusually large specimens are known as "thousand-year turtles," in allusion to their large size and presumed great age (Lovich

Figure 10. *Left*: Daily shipment of hundreds of *Orlitia borneensis* awaiting export to East Asia from a holding facility in Medan, Sumatra in 1999. *Right*: Close-up of turtle in center of left photo. Photos by Chris R. Shepherd / TRAFFIC Southeast Asia, reproduced from Shepherd (2000) and van Dijk et al. (2000).

et. al. 2000). The total volume of this trade remains to be accurately quantified but is likely large. No populations of *Orlitia* exist anywhere close to the borders of China, and the turtles seen in markets there derive from Indonesian and/or Malaysian sources. Shepherd (2000) observed that *Orlitia*, despite total protection in Indonesia, was one of the two most heavily exported species from Sumatra.

Our intermittent monitoring of social media over the last five years suggests that *O. borneensis* is now also commonly hoarded by middlemen, and kept by hobbyists and reptile enthusiasts, with records indicating its presence in both private and public collections across much of Sumatra and Kalimantan (Jayanto, Rahmawati, and Hardian, unpubl. data), as well as in Jakarta and Bangkok (E.V. Goode, pers. comm.), where it was openly sold in pet shops at least through 2012 (Fig. 11). Although *O. borneensis* has been protected in Indonesia since 1999 and listed on Appendix II of CITES since 2003, an illegal trade still persists today, but is likely reduced since the intense overexploitation of the 1990s.

Collectors have indicated that *O. borneensis* is regarded as a species of declining commercial interest at the local level; nonetheless, individuals are purchased and retained when they are presented by fishermen, indicating that a latent market demand persists and that no voluntary release practice is in place. This pattern reflects the broader dynamic of the trade, whereby fishermen sell all organisms captured incidentally—a practice driven by the presence of buyers willing to accept any riverine wildlife.

These pressures are further intensified by non-selective capture practices and limited species awareness among fishermen, who typically sell all bycatch. Misidentification with widely traded species such as *Amyda cartilaginea* and *Cuora couro* is common, as these taxa are often broadly perceived as similar "*kura-kura*," leading to confusion in trade and the unintentional circulation of *O. borneensis* without recognition of its protected status (Muslim 2016). Fishermen may capture individuals and pretend that they are more commonly traded species, particularly *Amyda*, and hold them in anticipation of buyers, including for consumption markets.

These patterns demonstrate how bycatch, intentional misidentification, and market expectations collectively contribute to the continued extraction of the species across its range (A. Rusandi, pers. comm.). Such conditions reflect broader challenges highlighted in the IUCN Red List assessment, including weak enforcement and limited awareness at the local level (Horne et al. 2020). When encountered, individuals are typically sold for local consumption, while their shells are processed alongside those of other turtle species. The shells are broken down or grounded into powder to facilitate transport and trade (J. Guntoro, I. Shinyo, and P. Kasno, pers. comm.). Nevertheless, after the Asian turtle trade boom of the 1990s, and especially from around 2010 to the present, some middlemen assert that there has been no specific export demand for *O. borneensis*.

In parts of its range, indigenous communities may hunt *O. borneensis* for subsistence or small-scale trade (Moll

Figure 11. Large Malaysian Giant Turtle (*Orlitia borneensis*) for sale in a Jakarta pet shop, 2012. Photo by Turtle Conservancy.

and Moll 2004; Masyithah et al. 2016; Mardiastuti et al. 2021; Tiara et al. 2025). For example, in Riau (Sumatra) local Orang Asli and Jambi Suku Anak Dalam people are known to catch the turtle for food or to sell to middlemen (Masyithah et al. 2016). Sharma and Tisen (2000) noted that in some areas of Malaysia, the Orang Asli hunt the species for food during cultural and religious celebrations by burning swamps to force the animals out of hiding. Moll (pers. obs.) has observed local people spearing *O. borneensis* from dugouts as they glided through shallow water areas of Tasik Bera and Tasik Cini, Pahang, West Malaysia. Locals also hunt this species by hand—feeling for turtles in cavities under banks along streams and rivers (Moll, pers. obs.).

In parts of West Kalimantan (e.g., Sejiram and Batang Lupar) and Central Kalimantan (e.g., Babai and Sebabi), particularly in inland areas, middlemen commonly sell *O. borneensis* to local communities for consumption. In some cases, individuals are kept temporarily before being consumed, both for daily use and during festive occasions. During 2024–2025, a single middleman was reported to handle more than 15 *Orlitia* individuals annually alongside other turtle species. Based on photographic records, these individuals were estimated to average around 60 cm CCL. Among local communities, collectors, meat vendors, and hobbyists, individuals of this size are typically sold for approximately IDR 150,000–350,000 per animal (USD $9–21) (Jayanto and Rahmawati, unpubl. data). On Bangka and Belitung islands, however, local people traditionally do not hunt for this species or even sell them outside the region, as they tend to release them back into the wild voluntarily if incidentally trapped (Hardian, pers. obs.).

Data from confiscated individuals can provide indirect evidence of size structure in exploited populations. In a confiscated shipment of approximately 10,000 whole and broken turtle plastra originating from Java, Indonesia, 33 were *O. borneensis*, with 26 females, 6 males, and one of unknown sex (Kendrick and Ades 2009a,b). Curved maximum plastron lengths (CPL) from these confiscated shells indicated a median range of 36.1–37.0 cm overall for females, but for males the median range was 42.1–43.0 cm, with the largest plastron being a male at just under 50 cm CPL (Kendrick and Ades 2009a, 2009b). Extrapolating measurements taken with large tree calipers from a male *Orlitia* (see Fig. 1; SCL of 40.7 cm and straight plastron length of 37.9 cm) suggests that these exploited turtles had approximate SCL ranges of 42.1–43.0 cm for females, 45.2–46.2 cm for males, and the largest male was just under 53.7 cm SCL.

Habitat Loss and Degradation. — The species' lowland wetland habitats are under intense pressure from human development. Large areas of swamp forest and riverine habitat in Malaysia and Indonesia have been converted for agriculture, especially for oil palm, rubber, rice culture, and black pepper plantations, or lost to logging for timber products. Wetland drainage, canalization of rivers, and dam construction have reduced or altered available habitat (CITES 2002). Another challenge relates to overlapping land claims and unresolved tenure arrangements between communities, private sector actors, and state authorities, which create uncertainty in land management. Such tenurial disputes can weaken protection of forested watersheds and make conservation measures more difficult to implement.

On Bangka and Belitung islands, the species is threatened by environmental damage from tin mining and palm oil plantations, and also as by-catch, as most of these communities rely on fishing via traps and nets (Hardian, pers. obs.). Addressing these threats will require integrated conservation strategies that combine habitat protection, improved freshwater management, and collaboration with local communities to promote practices that reduce risks to the species while supporting sustainable livelihoods. Nevertheless, occurrences in many post-fire habitats suggest that the species may be resilient to certain stressors (Jayanto, pers. obs.).

Conservation Measures Taken. — *Orlitia borneensis* is listed as Critically Endangered in the IUCN Red List (Horne et al. 2020) and has been included in CITES Appendix II as of 2003 (CITES 2002). An ongoing "zero quota on wild specimens for commercial purposes" was added in June 2013 to its CITES Appendix II status, which has been that way for animals from Malaysia since 2007 and Indonesia since 2023. Interestingly, Brunei Darussalam also has a zero quota for *Orlitia*, despite the fact that there are no published records of the species native there.

The species has been protected in Indonesia since 1999 (Samedi and Iskandar 2000). Similarly, in Sarawak the species is on the First Schedule of Totally Protected animals under the Wildlife Protection Ordinance of 1998. In Sabah, it is listed as a protected species with collection allowed only by license by the Wildlife Conservation Enactment of 1997. In Malaysia, Sharma (1999) recommended that *Orlitia* be afforded protection under Schedule 1 of the Malaysian Protection of Wildlife Act (Sharma and Tisen 2000) and now it is listed as a "Totally Protected Wildlife" species under the Wildlife Conservation Act 2010 (West Malaysia), which prohibits any hunting or trade.

Recent "One Plan Approach" to conservation efforts at WRC Jogja, Yayasan Konklusi, and Gembira Loka Zoo have focused on improving knowledge of the species' ecology in the wild while developing *ex-situ* measures to support long-term conservation. Recognizing the importance of establishing in-country conservation breeding programs (e.g., Wahyuni and Ruyani 2026), efforts have been initiated on Java to develop an assurance colony for the species. The long-term objective of this program is to support population reinforcement in the species' native habitats once suitable conservation conditions are secured.

In parallel with the establishment of an assurance colony, genetic work is currently underway to support evidence-based population management. This research aims to map haplotypes and develop a genetic reference library for the species to strengthen colony management and inform future reintroduction plans (e.g., Hardian et al. 2026a,b). These data will help guide breeding pair selection, maintain genetic diversity, and ensure that any future releases are aligned with appropriate genetic lineages.

Protected Areas. — Despite ongoing threats, a positive aspect for this species is that many populations still occur within protected areas (CITES 2002). In Indonesia, known occurrences include in Berbak National Park (162,700 ha), Zamrud National Park (31,480 ha), Way Kambas National Park (125,631 ha), and Kerumutan Nature Reserve (1,332,169 ha) in Sumatra (Samedi and Iskandar 2000). In Kalimantan, key sites include Danau Sentarum National Park (32,000 ha) and Sebangau National Park (568,700 ha) (Samedi and Iskandar 2000), with possible occurrences in Tanjung Puting National Park (415,040 ha), Gunung Palung National Park (108,000 ha), Kutai National Park (198,629 ha), and Muara Kaman Sedulang Nature Reserve (64,700 ha).

The species is also important for designating Other Effective Area-Based Conservation Measures (OECMs), such as Restorasi Ekosistem (Riau), Hutan Harapan (Jambi), Tebat Rasau Geosite (Bangka-Belitung), the Katingan–Mentaya Project (Central Kalimantan), and the Mesangat–Suwi Ecosystem Essentials area (East Kalimantan) (CITES 2002; Jayanto, unpubl. data).

In Malaysia, the species historically occurred in Taman Negara National Park (434,351 ha) and possibly Endau-Rompin National Park (87,000 ha), although its current presence there is uncertain. Records also exist from the Tasik Bera Ramsar Reserve (38,446 ha) in Pahang (https://www.protectedplanet.net/555705775?site_pid=555705775), though no recent status data are available for this site.

Local Conservation Actions. — Engaging local communities will be crucial to protect this species in the long-term. On the Indonesian island of Belitung, the Tebat Rasau Community resides along the Lenggang River, and many depend on the river and surrounding land by fishing in the shallows, tending *kelekak* (i.e., old but productive home gardens), and harvesting forest resources. However, environmental changes threatening the Lenggang River have inspired collective concern of the Tebat Rasau Community villagers, who are now using their knowledge of *Byuku* turtles (*O. borneensis*) to help conserve their region. To elders in East Belitung, *Byuku* is not simply an animal, but rather it is *penunggu air dalam* (i.e., the keeper of the deep water). We note that communities in Belitung use the term *Bjuku* (pronounced *Bejuku*).

According to Belitung elders, *O. borneensis* prefers river depressions reaching 3–4 m in depth known as *lubuk* or *lembung*. During the dry season, when the river shrinks and forms isolated pools, these deeper pockets become crucial refuges for the species. Old stories passed down tell of a time when the river would "turn quiet" before floods or long droughts, and sightings of large turtles surfacing were interpreted as signs that the river was adjusting its balance. Based on stories shared by local community members, encounters with *O. borneensis* by fishermen were relatively frequent up until around 2019. However, in recent years, sightings have become rarer, and *O. borneensis* is now much more difficult to find. Instead, its presence is seen indirectly by damaged fishing gear, half-eaten aquatic plants, or an occasional accidental capture in a traditional trap.

Parts of the surrounding forest on Belitung have been converted into industrial monocultures of palm oil and black pepper plantations, which have increased runoff into the Lenggang River. Locals believe that if *Byuku* remain, however, then the river is still alive. As a result, community-based protection schemes have been enacted where local people are employed as rangers or guardians, and the development of awareness programs to reduce hunting.

In areas like Riau where the Orang Asli hunt the species, providing alternative protein sources or livelihoods could alleviate pressure. Education campaigns highlighting the species' rarity and legal status may help dissuade poachers and encourage fishermen to modify fishing practices to reduce by-catch. However, we note that evidence suggests that rarity and protected status are what actually increases the desirability in trade, especially if enforcement is non-existent.

Surveys of indigenous tribes in Sumatra revealed that most were aware of the conservation status of *Orlitia*, most agreed that the habitat should be conserved, and that freshwater turtles should be released when they are captured (Tiara et al. 2025). Ultimately, strengthening community stewardship, recognizing local ecological knowledge, and fostering collaborative management approaches can help ensure that conservation actions are socially grounded, locally supported, and sustainable. Integrating community perspectives into conservation planning will therefore be essential for securing both habitat protection and the long-term persistence of *O. borneensis* in the wild.

Conservation Measures Proposed. — Many aspects of the population status, biology, ecology, and natural history of *O. borneensis* remain poorly understood, including its exact distribution, population size and structure, nesting, diet, survivorship, longevity, habitat use, movement, and seasonal activity (Horne et al. 2020; Wahyuni and

Ruyani 2026). Standardized surveys are therefore needed across West Malaysia, Sumatra, Kalimantan, Sarawak, and Sabah to locate remaining populations, assess their viability, identify priority habitats, and establish baseline data for evidence-based conservation.

These efforts should combine mark-recapture studies, trapping with catch-per-unit effort, occupancy and population estimation, food-market surveys, and long-term monitoring. Some approaches have begun in the Lenggang River around Tebat Rasau Geosite on Belitung and are planned for Berbak National Park in Sumatra. The overarching conservation goal is to maintain the integrity of the habitat where the prime populations of the species occur, which is best achieved by understanding the remaining wild populations, determining if they are viable, and assessing their ecological role across their entire range. Further, if population-level extirpation occurs, *ex-situ* efforts will help to ensure the species can survive in captivity and potentially be reintroduced.

Strengthen Trade Regulations. — Given that illegal trade is likely continuing and could be growing in some areas, stricter enforcement of existing domestic and the CITES Appendix II zero quota regulations would help curb trade. We note that international trade may still be authorized by the granting of an export permit or re-export certificate for non-commercial purposes and captive-bred specimens. However, such provisions may create opportunities for the laundering of wild-caught specimens as captive-bred animals, particularly where the origin and captive-breeding claims of specimens cannot be reliably verified. This practice can undermine the effectiveness of trade regulations and potentially facilitate the continued illegal collection and trafficking of wild specimens.

Strengthening requirements for demonstrating legal origin, verifying captive-breeding claims, and ensuring effective traceability of specimens would therefore be important to prevent the laundering of wild-caught individuals into legal trade. Ultimately, collaboration between Indonesia, Malaysia, and consumer countries (e.g., China), and greater awareness of airlines and other international shipping companies, will be helpful to limit the illegal transport of individuals across borders (Salleh et al. 2022).

Figure 12. Captive enclosures for the Malaysian Giant Turtle (*Orlitia borneensis*) designed to imitate their natural habitat. *Top left*: A pond in Wildlife Rescue Centre (WRC) Jogja lets the water level naturally fluctuate following the water level dynamic of the natural river nearby as the water resource. Enclosures in Gembira Loka Zoo (*Top right* and *Bottom right*) and Ragunan Zoo (*Bottom left*) receive water from controlled water channels keeping the nesting area dry. Photos by Andreas B. Hardian and Cisca Nurfi'aini.

Habitat Protection and Restoration. — Habitat degradation and loss are increasingly recognized as major threats to the species. Freshwater ecosystems and surrounding forests that support *O. borneensis* are particularly vulnerable to land-use change, especially driven by the expansion of monoculture commodity systems, including oil palm, timber plantations, and other commercially valuable crops. Such activities alter hydrological regimes, degrade and pollute river systems, and ultimately affect both turtle populations and the communities that depend on these ecosystems. Conservation plans call for securing and managing critical habitats, such as establishing new protected areas or expanding existing ones to cover important wetlands and river systems where the turtle still survives, especially the remaining swamp forests in Sumatra and Borneo.

Captive Breeding and Reintroduction. — The development of assurance colonies while integrating *in-situ* and *ex-situ* conservation strategies under a unified management framework should be expanded to additional institutions within the species' native range through coordinated and cooperative programs. By aligning captive breeding, genetic management, field research, and habitat protection, this approach can strengthen long-term conservation outcomes and improve prospects for the recovery of *O. borneensis* populations in the wild.

Available knowledge of which zoos currently keep populations or even individuals of *Orlitia* would greatly aid in the establishment of assurance colonies. Several institutions maintain *O. borneensis* for conservation purposes, such as the colony at Gembira Loka Zoo, Zoo Melaka in Malaysia, which houses multiple individuals (at least two males), a water park in Melaka, which has a group of eight individuals (five males and three females) (Auliya and Chen 2024), many zoos in Europe (Palupčíková et al. 2012; Brockmann et al. 2013), and the USA (e.g., Bronx Zoo). However, there does not appear to be a publicly available list for these institutions to better coordinate activities. Such a breeding program across zoos in Europe and Asia would help maintain genetic diversity in captivity, aid in reintroduction efforts, and establish head-starting programs in areas where poaching is under control.

Research, Monitoring, and Education. — There is an urgent need for field research on *Orlitia,* as the lack of data on the biology and ecology of this species hampers conservation efforts. Proposed actions include ecological studies examining movement, reproduction, habitat use, and diet across seasons and life stages. Telemetry using hydroacoustics, GPS loggers, accelerometers, or radiotelemetry could estimate home ranges and movements and support post-release monitoring of head-started or rescued animals. Stable-isotope analysis could clarify the species' position in local food chains, while eDNA surveys in deep, turbid rivers could guide live-capture and diet-sampling efforts. Diet studies should include stomach or fecal records with item counts, volumes, or frequency of occurrence, as well as fecal DNA metabarcoding to identify soft-bodied prey and link diet to habitats such as backwaters, deep pools, and oxbows.

Conservation actions must also address human use and trade. Education and awareness programs for fishermen should be paired with demand-reduction efforts targeting turtle-meat consumers and sellers, including guidance for distinguishing *O. borneensis* from legally traded freshwater turtles. Socio-economic and interdisciplinary research is needed to understand consumption behavior and trade networks, particularly in West and Central Kalimantan, where the species is commonly consumed. Mandatory release and capture-reporting protocols for incidentally caught protected species would also be beneficial. Continued collaboration among range-country scientists and international turtle experts, including training local researchers in turtle field methods, will strengthen these efforts. Together, these actions can help maintain important habitats, evaluate potential sites for population reinforcement or reintroduction, and support *ex-situ* populations if local extirpations occur.

Captive Husbandry. — Most of the following information on captive husbandry comes from published information in Brockmann et al. (2013) and from work with the species at the WRC Jogja and Gembira Loka Zoo in Yogyakarta, Indonesia.

Within the captive population managed in WRC Jogja and Gembira Loka Zoo, the sex ratio appears strongly male-biased. Out of 19 adult individuals derived from past confiscation events examined, only one female has been confirmed. This pattern is consistent with male-biased sex ratios reported in other confiscated populations and further highlights the difficulty of accurately sexing this species. Successful breeding of *O. borneensis* in captivity has been documented at Zoo Dresden, Germany, in 2012 (Brockmann et al. 2013), at the Prague Zoo, Czech Republic, in 2007 (Velensky 2013), at the Bronx Zoo, USA, and at the Gembira Loka Zoo, Indonesia. Successful reproduction under captive conditions is evident at WRC Jogja, where 19 confiscated individuals in one enclosure increased to 47 individuals over 15 years with minimal intervention (Rahmawati, Jayanto, and Hardian, unpubl. data).

Housing. — In general, *O. borneensis* is a low-maintenance species. However, it is not well-suited for transparent aquarium enclosures designed for high visibility. This is largely due to its cryptic behavior and its tendency to exhibit aggressiveness, especially when held in high-density enclosures. Unlike many freshwater turtles that bask in open areas, this species rarely engages in visible basking and instead prefers deeper aquatic environments. Based on our observations, individuals do best in ponds with substantial deep water and dense canopy cover that mimic wild habitats (Fig. 12). They spend most of their time submerged or hidden underwater, and mating occurs entirely underwater.

Housing design is therefore a critical factor in the captive management of *O. borneensis*, influencing health, reproductive behavior, and long-term welfare. Enclosures should be spacious, provide sufficient water depth, and include secure retreats as well as a properly designed terrestrial nesting area (Brockmann et al. 2013). The species' behavior should guide enclosure design as it tends to avoid exposed spaces, making dense canopy cover or shade-providing structures essential. The strong tendency to hide, together with underwater mating, also makes submerged retreats an important component of the enclosure.

Successful housing of *O. borneensis* has been reported by Brockmann et al. (2013) from a converted 90 m² facility consisting of a 66 m² water area and a 24 m² terrestrial area, with a maximum water depth of 70 cm. However, based on our observations at WRC Jogja, greater water depth (approximately 2–3 m) appears to be more consistent with the species in the wild. Enclosure design should also incorporate a gradual slope between aquatic and terrestrial zones, reflecting the gently sloping riverbanks typical of the species' natural habitat. The substrate should be a soft material, such as sand, as bare concrete bottoms are implicated in plastral abrasion and infection (see below). The provision of underwater hiding structures is also important. Ideally, these shelters should be 35–45 cm high and open-ended on both sides, allowing turtles to enter and exit freely. They should not be placed directly against pond walls, and removable materials are preferred to facilitate routine pond maintenance. Permanent concrete structures should be avoided where possible, to minimize shell abrasion.

Adequate enclosure space, effective water quality management, and sufficient hiding areas are essential when maintaining adult *O. borneensis* in communal enclosures, particularly in male-biased groups. Nevertheless, successful reproduction may still occur in shallower water conditions. For example, breeding activity has been observed in a pond at Gembira Loka Zoo, Yogyakarta, with water depths ranging from approximately 60 cm to a maximum of 1 m. The enclosure, measuring only ca. 9.5 m × 13 m, was renovated from an unused pond and currently houses 19 adult individuals, including one confirmed female.

Water Quality. — Water sourced from natural rivers should be regularly monitored to ensure suitable quality for captive management. In Gembira Loka Zoo, water quality is assessed monthly using an instant water test kit measuring pH, ammonia, nitrite, nitrate, general hardness, carbonate alkalinity, chlorine, and carbon dioxide. The use of river-fed water systems may result in slightly elevated chlorine levels, likely originating from household detergents and soap contamination upstream. Consequently, effective filtration is essential to reduce chlorine concentration and organic loading. A multi-stage filtration system has been recommended and successfully implemented in captive facilities. For example, at Dresden Zoo a system consisting of two commercial pond filters—one equipped with ultraviolet (UV) sterilization—combined with a self-built 300-litre mechanical filter was used to maintain water quality (Brockmann et al. 2013). Altered water quality might be an important predisposing factor to several superficial skin lesions in captive *O. borneensis*, as shell rot and pododermatitis tend to appear in water with ammonia levels >4 ppm, higher chlorine levels (0.8 ppm), higher nitrate levels (>10 ppm), and water pH >8.0 (Hardian, unpubl. data).

Temperature and Lighting. — In tropical regions such as Indonesia, ambient environmental temperatures are generally suitable for this species and therefore do not require significant modification. Adult animals maintained in outdoor enclosures under natural canopy cover typically receive sufficient natural sunlight and may not require artificial UVB supplementation. However, individuals housed indoors should still be provided with appropriate lighting to ensure adequate UV exposure. For hatchlings, considering enclosure size, behavioral requirements, and the availability of equipment in Indonesia, a suitable indoor configuration would involve installing a Zoo Med UV T5 HO 5.0 linear fluorescent bulb positioned approximately 20–25 cm above the basking area. The basking site can be created using a brick or similar structure that protrudes above the water surface, allowing the turtles to bask while receiving appropriate levels of UV radiation.

In captive environments located in temperate regions with pronounced seasonal climates, such as Dresden Zoo, environmental temperatures must be carefully regulated to replicate tropical conditions. In these facilities, air temperature within the enclosure was maintained above 30°C, while water temperature ranged between 28–32°C. Maintaining these tropical temperature conditions is essential for supporting metabolic processes, digestion, and reproductive cycling. Hatchlings were maintained under slightly warmer conditions, with air temperatures of 30–34°C and water temperatures of 28–32°C (Brockmann et al. 2013). Artificial UVB lighting was also provided for juveniles using a fluorescent tube (Repti-Glo UVB 5.0, 40 W) positioned approximately 30 cm above the enclosure, with around eight hours of daily illumination. Adequate lighting is critical for the healthy growth and development of juvenile turtles, as insufficient UV radiation can lead to serious health problems such as metabolic bone disease. Based on ecological information and field observations of *O. borneensis*, this species appears to fall between Ferguson Zones 2 and 3, corresponding to a recommended UV index (UVI) range of approximately 0.9–2.6 (Ferguson et al. 2010).

Stocking Density. — *Orlitia borneensis* can display strong intraspecific aggression, particularly when housed

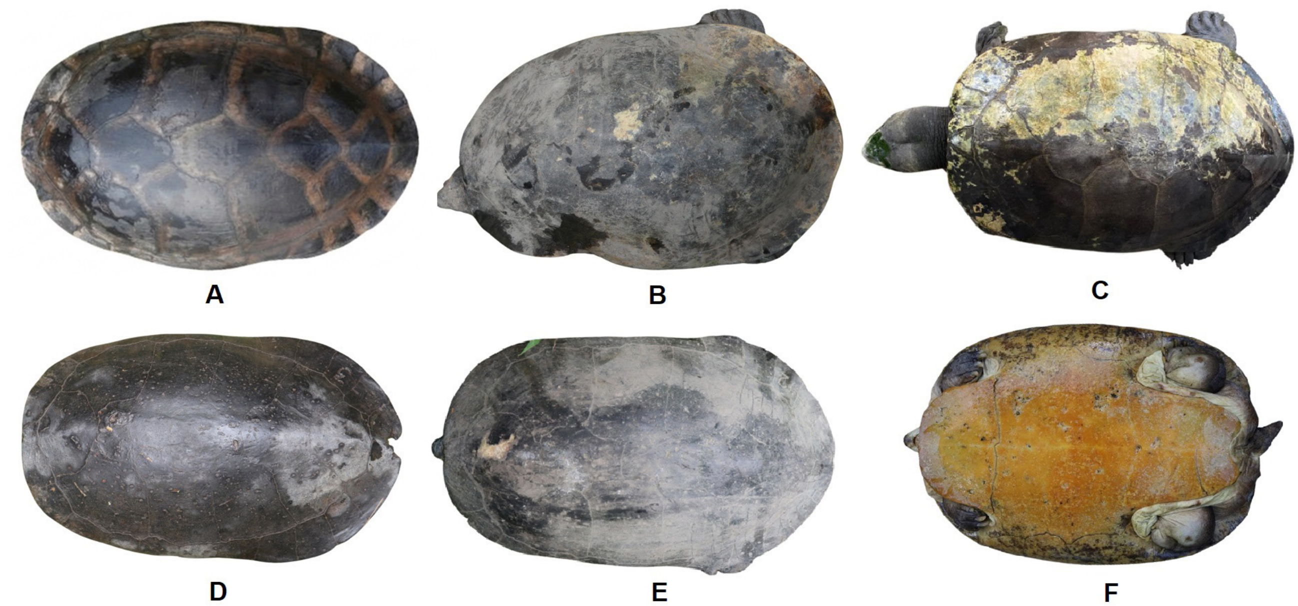

Figure 13. Normal to deformed shells in a captive population of Malaysian Giant Turtles (*Orlitia borneensis*). **A**. Relatively normal healthy carapace of wild-caught individuals appears shiny, intact with complete undamaged scutes; note that light brown discoloration lining each scute suture that might indicate early superficial abrasion. **B**. Potentially congenitally deformed carapace shows deformity in the left cranial peripheral bones. **C**. Severe shell rot appears as pale-yellow discoloration on the carapace contrasting with the dark green background coloration. **D**. Chipped caudal marginal and anal scutes might be associated with aggression. **E**. Mild early shell rot. **F**. Multiple pits of various size are evident on the plastron of captive individuals kept on rough substrates with minimum water circulation; ulcerations also occur on the hind footpads, suggesting a microbial infection. Photos by Andreas B. Hardian and Cisca Nurfi'aini.

in inadequate space. In our program at WRC Jogja, Yayasan Konklusi, and Gembira Loka Zoo, the species has shown a strong preference for secluded areas and tends to avoid crowded conditions, particularly among adults of the same sex. During a temporary holding period, 10–12 adult males were kept in a 10 × 5 m pond with water depth below 1 m and limited hiding structures. Under these conditions, intraspecific aggression was observed, including chasing and tail-biting between individuals. Undetected bite wounds can develop into secondary infections, in some cases progressing to septicemia and even mortality. These observations indicate that adequate space and sufficient hiding areas are essential to reduce aggression, particularly in adult same-sex groups. Brockmann et al. (2013) reported that two adult individuals had to be separated by plexiglass dividers due to bite injuries, and a permanent tripartite enclosure was later constructed. Animals were only brought together under supervision for controlled mating. When introducing new individuals into an existing population, intensive monitoring should be conducted, particularly during the first week after integration, to detect any signs of aggressive behavior. It is recommended that introductions initially take place in a controlled environment with ample hiding opportunities, which can help reduce aggression among adult individuals.

Diet. — In captivity, *O. borneensis* readily accepts a varied diet consisting of plant matter, fruits, and animal-based protein, and generally adapts well to captive feeding regimes. At Yogyakarta, we maintained adult *O. borneensis* on a primary diet with an approximate ratio of 80% fruits and vegetables (including leafy greens) and 20% animal-based protein. Plant components included a variety of fruits and green leafy vegetables, while animal protein sources consisted mainly of raw small fish and chopped chicken. Commercial aquatic turtle pellets (Mazuri) were also provided to improve overall nutritional balance, particularly during the conditioning phase aimed at supporting reproductive performance. Hatchlings were provided with a varied diet consisting of leafy vegetables (such as water spinach, mustard greens, and spinach), fruits (primarily papaya and banana), insects (mealworms and crickets), and animal-based protein such as chicken or beef.

Food items were rotated throughout the week to maintain dietary diversity, with feeding conducted once daily during daytime. During the early hatchling stage, diet composition often required adjustment as individuals adapted to feeding. A more stable feeding formula was typically established when hatchlings reached approximately two to three months of age. To optimize breeding, pellet supplementation was increased to provide additional protein and micronutrients that support egg production and overall reproductive condition. Papaya was also used therapeutically as a natural laxative for individuals that had ingested fishing hooks (Pressler et al. 2003), helping

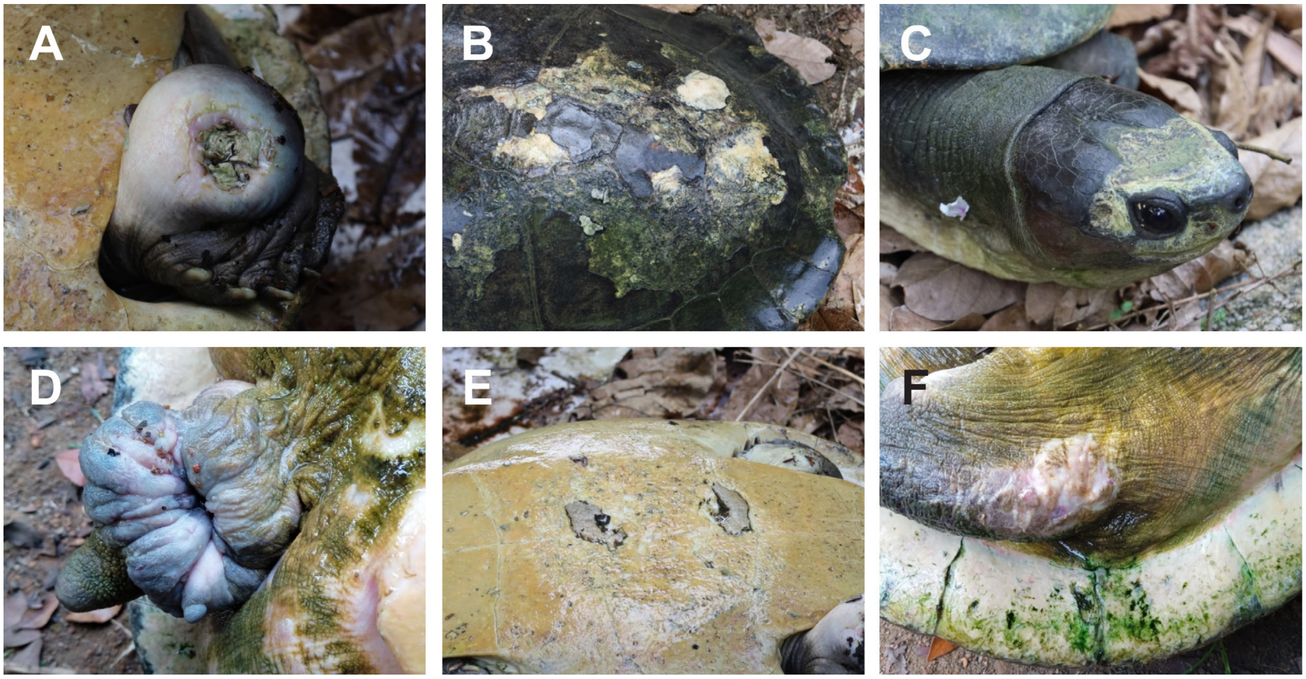

Figure 14. Various skin lesions in captive Malaysian Giant Turtles (*Orlitia borneensis*). **A**. Pododermatitis mostly develops on the hind foot pads, creating a cavernous crater with necrotic tissue debris and caseous exudates. **B**. Shell rot appears as a partial or complete loss of the keratinized epidermis, contrasting pale discoloration with adjacent healthy dark green or grey carapace surface. **C and E**. Shell rot is not only limited to the carapace but is also known on the plastron and other heavily keratinized skin and scales. **D**. A rare case of a swollen edematous cloaca with multiple lumps, with no abrasion or ulceration, corresponding to potentially neoplastic growth. **B and F**. Chipped marginal or anal scutes and common skin abrasions in non-heavily keratinized skin are generally related to aggression or mechanical friction. Photos by Daniel F. Hughes and Andreas B. Hardian.

to facilitate the passage of foreign objects through the digestive tract where possible.

Feeding practices reported from other institutions show similar dietary diversity. At Dresden Zoo, adults were fed twice per week on a rotating menu that included fruits, vegetables, eggs, shrimp, turkey, and young rats. Hatchlings were fed daily with freshly-molted mealworms, fish fillets, grape pieces, dandelion leaves, commercial turtle pellets (ReptoMin, Tetra), and a self-prepared jelly diet composed of fish, poultry bones, brown shrimp, dandelion, carrots, apples, a vitamin–mineral supplement (Korvimin ZVT), and gelatine (Brockmann et al. 2013). At Brno Zoo, tube feeding was employed during recovery from severe illness, using a semi-fluid mixture of bananas, fish, earthworms, insects, and fruit supplemented with calcium (Knotkova et al. 2005). Once animals had recovered, a balanced diet was provided ad libitum, including grapes, bananas, fish, rats, earthworms, insects, and calcium-supplemented gelatine containing fruit pieces (Knotkova et al. 2005).

Health and Disease. — Veterinary care practices have been successful in treating injured or sick individuals. Two major parasite concerns have been documented in captive *O. borneensis*: gastrointestinal nematodes and hemogregarine blood parasites. At Yogyakarta, fecal flotation examinations have detected roundworm (ascarid) eggs in approximately half of the individuals tested (Hardian, unpubl. data).

Similarly, Knotková et al. (2005) found ascarid eggs in all nine *O. borneensis* examined upon arrival at Brno Zoo. Treatments have included fenbendazole in routine management, while turtles at Brno Zoo were treated with oral mebendazole (25 mg/kg body weight) administered twice over a 14-day period. Further, Knotkova et al. (2005) documented recovery from intra-erythrocytic hemogregarine parasites (leech-vectored) in the same nine turtles, which exhibited lethargy, ulcerations, and caseous necrosis of the plastron. The turtles had parasitemia ranging from 0.2–28.2% (mean 59 parasites per 5,000 red blood cells).

After eight months of treatment consisting of antibiotics, debridement, and scrubbing of lesions with enilconazole or povidone iodine, rehydration, deworming, and tube feeding, Knotkova et al. (2005) found that lymphocytes, basophils, eosinophils, heterophils, and azurophils returned to their normal ranges, while concentrations of hematocrit, red-blood cell, and hemoglobin were within normal ranges in 24 months. Overall, after 32 months of supportive care, parasitemia declined to an average of 3 parasites per 5,000 red blood cells.

At Yogyakarta, chronic pneumonia was identified in two captive adult male turtles, which both received treatment and recovered successfully. Respiratory disease should be considered a differential diagnosis in any individual showing lethargy, open-mouth breathing, buoyancy abnormalities, or nasal discharge.

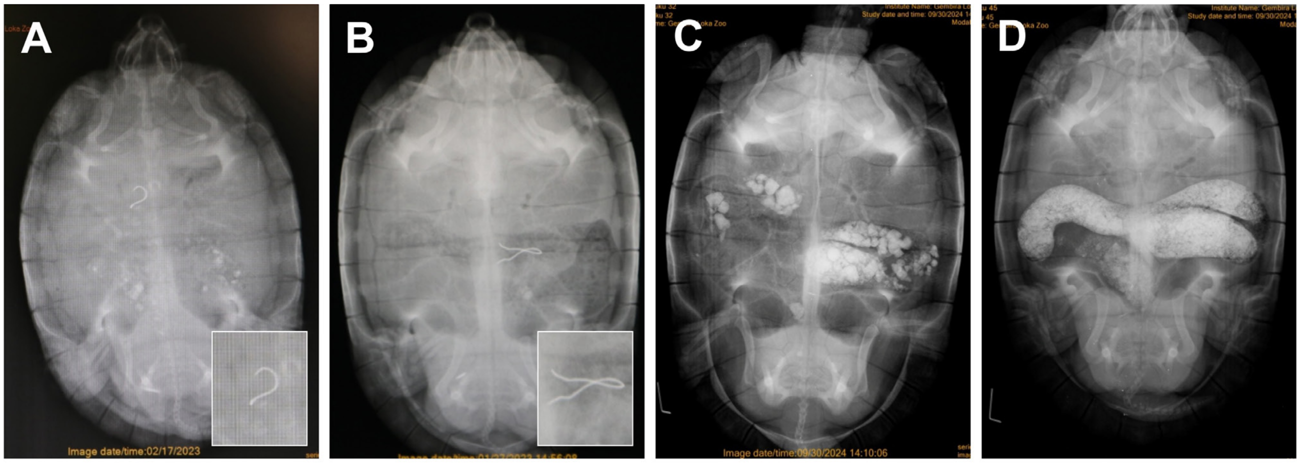

Figure 15. Radiographic images of several captive Malaysian Giant Turtles (*Orlitia borneensis*) with foreign bodies. Fishing hooks were found in two individuals (**A**) in our captive population and metal-wire-like material was reported in an individual (**B**). Soil materials in the gastrointestinal tract were found in almost all of our captive individuals (**C and D**); however, complications corresponding to the digestive system were not ever reported. Photos by Gembira Loka Zoo.

Shell Deformities and Skin Lesions. — A possible congenital shell deformity was observed in our captive population at the zoo (Hardian, unpubl. data), characterized by a slightly depressed and abnormally shaped carapace (Fig. 13). This deformity primarily affected the left anterior peripheral and costal bones, but did not appear to affect internal organs or the use and retractability of the forelimb.

Within this captive population in Indonesia, at least three individuals have been found with multiple chipped marginal scutes, mostly in the posterior marginal scutes, which could have resulted from aggression among individuals. Carapace abrasion and ulceration—commonly known as "shell rot"—were found in several individuals in various degrees that in some cases were related to water quality and decreased immune status. Adult to geriatric individuals tend to develop small, pitted areas on the plastron, which were associated with prolonged abrasion with the hardened, rough enclosure substrate, followed by secondary infections (Hardian, unpubl. data).

The two most commonly found skin lesions in captive individuals are hind footpad pododermatitis and shell rot (Fig. 14). Both of these are strongly associated with aquatic microbial infection and/or low water quality related to poor enclosure design. Pododermatitis is basically ulceration of the skin indicated by focal loss of the entire epidermal to dermal layers, allowing infections to develop in the deeper subcutaneous tissues. Grossly, there is necrotic, exfoliating tissue debris in the ulcerative area filled with built-up pale-yellow caseous exudate in the center of the lesion. Inflammation may be caused by increasing blood flow to the affected area creating a hyperemic red rim and tissue swelling surrounding the ulcer. We found 11 individuals suffering this lesion and most of them had been kept in captivity with rough-surfaced cement or concrete bedding with very low to absent water level so that none of the individuals were fully submerged or able to float. This condition is almost entirely absent in individuals living in enclosures with natural soil, grassy areas, and sandy bottoms with adequate water level and circulation (Hardian, unpubl. data).

Shell rot can occur on the carapace or plastron (or both) and is characterized by degradation of the superficial scute keratin; often accompanied by infection by opportunistic microbes to the deeper layers. Grossly, it starts with pale grey or green discoloration of the shell that progresses to loss of the keratinized epidermal layer, exposing tissues underneath, creating pale yellow discoloration and infection, but the inflammatory response is often insignificant and in the worst cases, the underlying bone may be exposed. These lesions are apparently not only limited to the shell but were also noted in other heavily keratinized or scale-covered skin surfaces. A significant lesion was also noted in a captive individual that had a swollen and edematous prolapsed cloaca with multiple hard lumps measuring 3–10 mm in diameter, though without signs of abrasion or ulceration (Fig. 14D).

Incidentally Consumed Objects. — At Gembira Loka, several foreign bodies were located through routine radiographic checks of confiscated *O. borneensis* individuals that came from WRC Jogja, including a fishing hook, a metal wire, and gravel-like and sand-like materials (Fig. 15). The fishhook was unsurprising because this species is often a by-catch from fishing (Pressler et al. 2003), while the metal wire might have been consumed by the turtle as a possible aquatic prey item.

Current Research. — There is ongoing collaboration between WRC Jogja, Yayasan Kolaborasi Inklusi Konservasi (Konklusi), and Gembira Loka Zoo, and several ongoing projects at Yogyakarta that will eventually provide medical references for *O. borneensis* in Indonesia, especially as the basis of healthy parent stock for captive breeding (e.g., Hardian et al. 2026a,b, in review).

We (Jayanto, Rahmawati, and Hardian) are continuing to analyze the hematology and biochemical characteristics of this species' leukocytes and refining our initial results with wider population and resampling across seasons (i.e., Hardian et al. 2026b). We are investigating several shell-based diseases of *O. borneensis* based on anatomical pathology and statistically analyzing any predisposing factors affecting the disease occurrence, including water quality and care aspects. We are initiating population monitoring in its native habitat and testing our detection method using eDNA to determine the presence of *O. borneensis*, which we can use to develop population density baselines and improve species distribution models that can better predict any suitable sites for release, while supporting efforts to advocate for habitat protection. Further molecular studies to explore the cloacal microbiome, phylogeographic variation, and parentage in captive *O. borneensis* are ongoing.

Community conservation efforts focused on *O. borneensis* are ongoing on Belitung Island. The Yayasan Tebat Rasau Lintang (founded in 2018), also known as the Tebat Rasau Community, has initiated conservation work and monitoring focused on the population of *O. borneensis* in the Lenggang River watershed. In 2020, the Tebat Rasau Community was formally recognized as a Lanun Tourism Awareness Group (Kelompok Sadar Wisata Lanun), established through an official designation by the Head of Lintang Village and subsequently endorsed by the East Belitung Regency Office of Culture and Tourism. In 2025, the WRC Jogja, in collaboration with the Faculty of Veterinary Medicine of Brawijaya University and supported by the YSEALI Professional Fellowship Program, together with the Tebat Rasau Community, began field activities to better understand *O. borneensis* and its habitat on Belitung Island.

Needed Future Research. — Many fundamental aspects of the biology, ecology, and natural history of *O. borneensis* remain poorly understood, especially in the wild. Research should prioritize locating and characterizing nesting areas so that critical nesting habitats can be monitored and protected. Standardized mark-recapture and telemetry studies are also needed to estimate population size, survivorship, movement, and habitat use across the species' range. Diet and trophic ecology should be examined using field samples, stable isotopes, and DNA metabarcoding, while eDNA could help detect populations in deep, turbid rivers. Finally, socio-economic research on local use and trade is needed to guide conservation interventions. Regional collaboration and training in standardized field methods will be essential for addressing these knowledge gaps.

Acknowledgments. — Between the first and last positions, the authorship order is alphabetical to reflect the collaborative nature of this work where all authors contributed to summarizing the literature, which was organized, edited, and synthesized by Daniel Hughes. The first draft was written some years ago by Ed Moll, who recently passed away, and we dedicate this contribution to his memory. We gratefully acknowledge the support of our partners, PERHILITAN, and the Ministry of Forestry of the Republic of Indonesia. Some of the work in Indonesia that provided some of the information in this manuscript was supported by the IUCN SSC ASAP (Asian Species Action Partnership) and Nordens Ark in Sweden (Emma Nygren and Jimmy Helgesson). Most importantly, we extend our deepest thanks to the many local champions and other colleagues, including Pak Nasidi, Pakdhe Kasno, Iwan Shinyo, Andi Rusandi (Yuspiandi), Raul Gonzalez, Joko Guntoro, Lonnie McCaskill, Aceng Ruyani, Marwan Hasan, Peter Paul van Dijk, and Eric Goode, who have generously shared their wisdom, knowledge, and time in accompanying us in the field, or provided other information. Without them, this work would not have been possible. We thank Sabine Schoppe, Chris Shepherd, Gembira Loka Zoo, and Turtle Conservancy for the use of their photographs, and Anders Rhodin, John Iverson, and Peter Paul van Dijk for helpful reviews and editing that improved this manuscript.

Literature Cited

ATTWG [Asian Turtle Trade Working Group]. 2000. *Orlitia borneensis*. The IUCN Red List of Threatened Species 2000: e.T15509A4698687.

Auliya, M. and Chen, P.N. 2024. A note on carapace size of the Malaysian giant turtle, *Orlitia borneensis* (Testudines: Geoemydidae) in Peninsular Malaysia, and the species' conservation status. Malayan Nature Journal 76:143–149.

Badenhorst, D., Stanyon, R., Engstrom, T., and Valenzuela, N. 2013. A ZZ/ZW microchromosome system in the spiny softshell turtle, *Apalone spinifera*, reveals an intriguing sex chromosome conservation in Trionychidae. Chromosome Research 21:137–147.

Baillie, J. and Groombridge, B. 1996. The 1996 IUCN Red List of Threatened Animals. Gland, Switzerland: IUCN, 368 pp.

Berghuis, H.W.K., van den Bergh, G., van Kolfschoten, T., Wibowo, U.P., Kurniawan, I., Adhityatama, S., Sutisna I., Verheijen I., Pop E., Veldkamp A., and Joordens, J.C. 2025. First vertebrate faunal record from submerged Sundaland: the late Middle Pleistocene, hominin-bearing fauna of the Madura Strait. Quaternary Environments and Humans 3:100047.

Boulenger, G.A. 1897. Description of a new genus and species of tortoises from Borneo. Journal of Natural History 19:468–469.

Boulenger, G.A. 1912. A vertebrate fauna of the Malay Peninsula from the Isthmus of Kra to Singapore including the adjacent islands. London: Taylor and Francis, 294 pp.

Brockmann, T., Hoffmann, M., and Ziemssen, E. 2013. Report on keeping and breeding success of Malaysian Giant Turtle (*Orlitia borneensis* Gray, 1873) at Dresden Zoo, Germany. Der Zoologische Garten 82:8–25.

Bursey, C.R. and Kinsella, J.M. 2003. *Falcaustra greineri* n. sp. (Nematoda: Kathlaniidae) from *Orlitia borneensis* (Testudines: Emydidae). Journal of Parasitology 89:961–964.

Carr, J.L. and Bickham, J.W. 1986. Phylogenetic implications of karyotypic variation in the Batagurinae (Testudines: Emydidae). Genetica 70:89–106.

Chiangkul, K., Trivalairat, P., Kunya, K., and Purivirojkul, W. 2021. *Placobdelloides tridens* sp. n., a new species of glossiphoniid leech found feeding on captive *Orlitia borneensis* in Thailand, and an update to the host distribution of *P. siamensis*. Systematic Parasitology 98:141–154.

CITES. 2002. Proposal to include *Orlitia borneensis* in Appendix II (CoP12 Prop. 12.27).

Cox, M.J., van Dijk, P.P., Nabhitabhata, J., and Kumthorn, T. 1998. A Photographic Guide to Snakes and other Reptiles of Peninsular Malaysia, Singapore and Thailand. Sanibel Island, USA: Ralph Curtis Publishing, 144 pp.

Das, I. 1995. An illustrated key to the turtles of insular Southeast Asia. Hamadryad 20:27–32.

Das, I. 2026. A Field Guide to the Reptiles of Borneo. Princeton, New Jersey: Princeton University Press, 376 pp.

De Rooij, N. 1915. The Reptiles of the Indo-Australian Archipelago. Vol. I. Lacertilia, Chelonia, Emydosauria. Leiden, Netherlands: E.J. Brill Ltd. 384 pp.

Ernst, C.H. and Barbour, R.W. 1989. Turtles of the World. Washington, DC: Smithsonian Institution Press, 313 pp.

Ferguson, G.W., Brinker, A.M., Gehrmann, W.H., Bucklin, S.E., Baines, F.M., and Mackin, S.J. 2010. Voluntary exposure of some western hemisphere snake and lizard species to ultraviolet B radiation in the field: how much ultraviolet B should a lizard or snake receive in captivity? Zoo Biology 29:317–334.

Figueroa, A., Low, M.E.Y., and Lim, K.K.P. 2023. Singapore's herpetofauna: updated and annotated checklist, history, conservation, and distribution. Zootaxa 5287:1–378.

Flower, S.S. 1937. Further notes on the duration of life in animals. Proceedings of the Zoological Society of London 107(1):1–40.

García-De la Peña, C., Rodríguez-Vivas, R.I., Zegbe-Domínguez, J.A., Valenzuela-Núñez, L.M., Herrera, C.A.M., and Siller-Rodríguez, Q. 2020. Blood cell morphometry of wild *Gopherus flavomarginatus* (Bolson tortoises) in the Chihuahuan desert. Veterinaria México 7:1–9.

Gonzalez, R. 2026. Unpublished video observations of semi-captive *Orlitia borneensis*. https://www.facebook.com/media/set/?vanity=djcoolraul85&set=a.23887495860888992.

Gray, J.E. 1873. On a new freshwater tortoise from Borneo (*Orlitia borneensis*). Annals and Magazine of Natural History 11:156–157.

Hardian, A.B., Rahmawati, I.P., Tirtayani, J.V., Rusli, N., Alviyanto, B., Kusuma, R., Kumaralalita, A.I., Widigdaya, D., Pribadi, S.K., Utari, T.S., Ekasari, F., Wahyuningtyas, A.C., Widayanti, R., and Jayanto, H. 2026a. Mitochondrial genetic diversity in a captive Malaysian Giant Turtle (*Orlitia borneensis*) population: implications for conservation breeding. HAYATI Journal of Biosciences 33:974–991.

Hardian, A.B., Rahmawati, I.P., Tirtayani, J.V., Alviyanto, B., Kusuma, R., Kumaralalita, A.I., Widigdaya, D., Nugroho, M.A., Putri, A.A., and Jayanto, H. 2026b. Haematological profile of captive critically endangered Malaysian Giant Turtles (*Orlitia borneensis*) in Indonesia. Bulgarian Journal of Veterinary Medicine, doi:10.15547/bjvm.2026-0014.

Hardian, A.B., Rahmawati, I.P., Tirtayani, J.V., Alviyanto, B., Kusuma, R., Kumaralalita, A.I., Widigdaya, D., Raffaneisha, M., Sari, S.R., Ali, N.S., Jayanto, H., Cindyasputri, N.A., and Hughes, D.F. In review. Morphometric allometry and prediction of body mass in captive Malaysian Giant Turtles (*Orlitia borneensis*), a critically endangered freshwater species from Southeast Asia. Integrative Conservation.

Hasan, V., Rahmawati, I.P., Guntoro, J., South, J., Valen, F.S., Tamam, M.B., Hardian, A.B., Andriyono, S., Nurjirana, N., and Kamarudin, A.S. 2025. *Orlitia borneensis* (Gray, 1873) (Testudines, Geoemydidae), Malaysian Giant Turtle, from Belitung Island, Indonesia: filling a distribution gap. Check List 21:807–812.

Hernández, J.D., Castro, P., Saavedra, P., Ramírez, P., and Orós, J. 2017. Morphologic and cytochemical characteristics of the blood cells of the Yellow-bellied Slider (*Trachemys scripta scripta*). Anatomia, Histologia, Embryologia 46:446–455.

Hirayama, R. 1984. Cladistic analysis of batagurine turtles. Studia Palaeocheloniologica 1:140–157.

Horne, B.D., Das, I., Hamidy, A., Kusrini, M.D., Guntoro, J., and As-singkily, M. 2020. *Orlitia borneensis*. The IUCN Red List of Threatened Species 2020: e.T15509A724972.

Iskandar, D.T. 2000. Turtles and Crocodiles of Insular Southeast Asia and New Guinea. Bandung, Indonesia: PAL Media Citra, 189 pp.

Iverson, J.B. 2022. A review of chelonian type specimens (order Testudines). Megataxa 7:1–85.

Iverson, J.B., Ewert, M.A., and Moll, E.O. 2024. Egg size vs. mass relationships in turtles. Chelonian Conservation and Biology 23:128–129.

Iverson, J.B., Ennen, J., and Lovich, J. 2025. Life-history and ecology data for the turtles of the World. Chelonian Conservation and Biology 24:136–141.

Karl, H.-V., Safi, A., and Philippen, H.-D. 2019. Evidences of cheloniophagy by early hominid (*Homo erectus*) during middle of Pleistocene from beds of Trinil's layers in central Java (Indonesia), with an updated list of Trinil's Testudines, and a redescription of *Duboisemys isoclina* (Dubois, 1908). International Journal of Zoology Studies 4(6):73–84.

Kendrick, R.C. and Ades, G.W.J. 2009a. Turtle plastron study report 2006–09. Hong Kong: Fauna Conservation Department, Kadoorie Farm & Botanic Garden, Publication Series No. 5, 14 pp.

Kendrick, R.C. and Ades, G.W.J. 2009b. Taxonomic and morphometric analysis of a trade confiscation of turtle shells from Java, Indonesia. TurtleLog No. 4, http://www.iucn-tftsg.org/turtlelog_online_newsletter/tln004/.

Kimmel, C.E. 1980. A diet and reproductive study for selected species of Malaysian turtles. Masters Thesis, Eastern Illinois University, Charleston, Illinois, USA.

Knotkova, Z., Mazanek, S., Hovorka, M., Sloboda, M., and Knotek, Z. 2005. Hematology and plasma chemistry of Bornean river turtles suffering from shell necrosis and haemogregarine parasites. Veterinární Medicína 50:421–426.

Le, M., McCord, W.P., and Iverson, J.B. 2007. On the paraphyly of the genus *Kachuga* (Testudines: Geoemydidae). Molecular Phylogenetics and Evolution 45:398–404.

Lim, B.L. and Das, I. 1999. Turtles of Borneo and Peninsular Malaysia. Kota Kinabalu, Borneo: Natural History Publications. 151 pp.

Lovich, J.E., Mittermeier, R.A., Pritchard, P.C.H., Rhodin, A.G.J., and Gibbons, J.W. 2000. Powdermill Conference: trouble for the world's turtles. Turtle and Tortoise Newsletter 1:16–17.

Manthey, U. and Grossmann, W. 1997. Amphibien und Reptilien Südostasiens. Münster, Germany: Natur und Tier Verlag, 512 pp.

Mardiastuti, A., Masy'ud, B., Ginoga, L.N., Sastranegara, H., and Sutopo. 2021. Traditional uses of herpetofauna practiced by local people in the island of Sumatra, Indonesia: implications for conservation. IOP Conference Series: Earth and Environmental Science 762:012003.

Masyithah, H.B. and Kartika, W.D. 2016. Kajian etnozoologi hewan yang dikonsumsi pada komunitas Orang Rimba di Taman Nasional Bukit Duabelas Kabupaten Sarolangun. Bio Site: Biologi dan Sains Terapan 2(2):1–50.

McDowell, S.B. 1964. Partition of the genus *Clemmys* and related problems in the taxonomy of the aquatic Testudinidae. Proceedings of the Zoological Society of London 143:239–278.

McKnight, D.T., Ard, K., Auguste, R.J., Barhadiya, G., Benard, M.F., Boban, P., Dillon, M.L., Downs, C.T., DeGregorio, B.A., Glorioso, B.M., Goodman, R.M., Hird, C., Hollender, E.C., Kennedy, M., Rosie Kidman, A., Massey, A., McGovern, P., Mühlenhaupt, M., Ostovar, K., Podgorski, D., Price, C., Reinke, B.A., Streeting, L.M., Venezia, J., Young, J., and Nordberg, E.J. 2023. Nocturnal basking in freshwater turtles: a global assessment. Global Ecology and Conservation 43:e02444.

Mo, M. 2020. Only in captivity? An interaction between two threatened chelonians, an Asian Giant Tortoise (*Manouria emys*) and a Malaysian Giant Turtle (*Orlitia borneensis*). Reptiles and Amphibians 27:89–90.

Moll, D. and Moll, E.O. 1990. The Slider Turtle in the neotropics: adaptation of a temperate species to a tropical environment. In: Gibbons, J.W. (Ed.). Life History and Ecology of the Slider Turtle. Washington, DC: Smithsonian Institution Press, pp. 152–161.

Moll, D. and Moll, E.O. 2004. The Ecology, Exploitation and Conservation of River Turtles. New York: Oxford University Press, 393 pp.

Moll, E.O. 1980. Natural history of the river terrapin, *Batagur baska* (Gray) in Malaysia (Testudines: Emydidae). Malaysian Journal of Science 6:23–62.

Moll, E.O. 1997. Effects of habitat alteration on river turtles of tropical Asia with emphasis on sand mining and dams. In: van Abbema, J. (Ed.). Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles: An International Conference. Purchase, NY: State University of New York, pp. 37–41.

Moll, E.O. and Moll, D. 2000. Conservation of river turtles. In: Klemens, M.W. (Ed.). Turtle Conservation. Washington, DC: Smithsonian Institution Press, pp. 126–155.

Muslim, T. 2016. Eksploitasi Reptil di das Mahakam Kalimantan Timur [Reptile Exploitation at Mahakam River on East Kalimantan]. Prosiding Seminar Nasional Lahan Basah Tahun 2016, Universitas Lambung Mangkurat, pp. 135–140.

Neely, W.J., Freeman, J.M., Greiner, E.C., and Dronen, N.O. 2017. A sample of endohelminths from four species of Malaysian freshwater turtles (Geoemydidae) confiscated in 2001 by authorities in Hong Kong, People's Republic of China. Comparative Parasitology 84:201–205.

Nieto-Claudín, A., Palmer, J.L., Brenn-White, M., Esperón, F., and Deem, S.L. 2024. Haematology and plasma biochemistry reference intervals of Española, San Cristobal and Eastern Santa Cruz Galapagos tortoise species. Conservation Physiology 12:coae055.

Ng, T.H. and Lim, K.K.P. 2010. Introduced aquatic herpetofauna of Singapore's reservoirs. Cosmos 6:117–127.

Nyckel, D. 1984. Observations on relationships between limb measurements and mode of locomotion in Malaysian Turtles. Masters Thesis, Eastern Illinois University, Charleston, Illinois, USA.

Palupčíková, K., Somerova, B., Protiva, T., Rehak, I., Velenský, P., Hulva, P., Gunalen, D., and Frynta, D. 2012. Genetic and shell-shape analyses of *Orlitia borneensis* (Testudines: Geoemydidae) reveal limited divergence among founders of the European zoo population. Zootaxa 3280:56–66.

Pressler, B.M., Goodman, R.A., Harms, C.A., Hawkins, E.C., and Lewbart, G.A. 2003. Endoscopic evaluation of the esophagus and stomach in three loggerhead sea turtles (*Caretta caretta*) and a Malaysian giant turtle (*Orlitia borneensis*). Journal of Zoo and Wildlife Medicine 34:88–92.

Reid, B.N., Le, M., McCord, W.P., Iverson, J.B., Georges, A., Bergmann, T., Amato, G., Desalle, R., and Naro-Maciel, E. 2011. Comparing and combining distance-based and character-based approaches for barcoding turtles. Molecular Ecology Resources 11:956–967.

Salleh, M.H.M. and Esa, Y. 2024. The first complete mitochondrial genome of the critically endangered Malaysian Giant Turtle, *Orlitia borneensis*. Journal of Genetics 103:18.

Salleh, M.H.M., Esa, Y., Salleh, S.M., and Sah, S.A.M. 2022. Turtles in Malaysia: a review of conservation status and a call for research. Animals 12:2184.

Salleh, M.H.M., Esa, Y., Izam, N.A.M., Zainudin, A.A.Z., Romli, K.A., Nawang, W.N.F.S.W., Bakri, A.M., Hussin, N.J., and Halim, S.A.A.A. 2023. The first mitochondrial control region dataset: critically endangered freshwater turtles in Malaysia, *Orlitia borneensis* and *Batagur borneoensis*. Malaysian Journal of Fundamental and Applied Sciences 19:679–684.

Samedi and Iskandar, D.K. 2000. Freshwater turtle and tortoise conservation and utilization in Indonesia. In: van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.). Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs No. 2, pp. 106–111.

Schilde, M. 2004. Asiatische Sumpfschildkröten. Die Familie Geoemydidae in Südostasian China und Japan. Münster: Natur und Tier Verlag, 192 pp.

Setiyabudi, E., Takahashi, A., and Kaifu, Y. 2016. First certain fossil record of *Orlitia borneensis* (Testudines: Geoemydidae) from the Pleistocene of central Java, Indonesia. Current Herpetology 35:75–82.

Sharma, D.S.K. 1999. Tortoise and freshwater turtle trade and utilization in Peninsular Malaysia. Petaling Jaya: TRAFFIC Southeast Asia, 39 pp.

Sharma, D.S.K. and Tisen, O.B. 2000. Freshwater turtle and tortoise utilization and conservation status in Malaysia. In: van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.). Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs No. 2, pp. 120–128.

Shepherd, C.R. 2000. Export of live freshwater turtles and tortoises from North Sumatra and Riau, Indonesia: a case study. In: van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.). Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs No. 2, pp. 112–119.

Shi, H., Lau, M., Chen, T., and Parham, J.F. 2002. The status of the trade. Captive breeding, research and conservation of the chelonians in China, including Hong Kong and Taiwan. Country report and presentation, Technical Workshop on Conservation and Trade in Freshwater Turtles and Tortoises in Asia. Kunming, Yunnan, People's Republic of China, 25–28 March 2002.

Shine, R. and Iverson, J.B. 1995. Patterns of survival, growth and maturation in turtles. Oikos 72:343–348.

Siebenrock, F. 1902. *Brookeia baileyi* E. Bartlett und *Adelochelys crassa* Baur. Zoologischer Anzeiger 25:671–673.

Siebenrock, F. 1904. Zur Systematik der Schildkröten-Gattung *Orlitia* Gray. Zoologischer Anzeiger 27:580–582.

Sites, J.W., Jr. Bickham, J.W., Pytel, B.A., Greenbaum, I.F., and Bates, B.A. 1984. Biochemical characters and the reconstruction of turtle phylogenies: relationships among batagurine genera. Systematic Biology 33:137–158.

Solihuddin, T. 2014. A drowning Sunda Shelf model during last glacial maximum (LGM) and Holocene: a review. Indonesian Journal on Geoscience 1:99–107.

Spinks, P.Q., Shaffer, H.B., Iverson, J.B., and McCord, W.P., 2004. Phylogenetic hypotheses for the turtle family Geoemydidae. Molecular Phylogenetics and Evolution 32:164–182.

Tiara, A., Kusrini, M.D., Sunkar, A., and Guntoro, J. 2025. Local community's knowledge and perception towards freshwater turtle conservation in southern Sumatra, Indonesia. Jurnal Manajemen Hutan Tropika 31:99–113.

Thomson, R.C., Spinks, P.Q., and Shaffer, H.B. 2021. A global phylogeny of turtles reveals a burst of climate-associated diversification on continental margins. Proceedings of the National Academy of Sciences 118:e2012215118.

TTWG [Turtle Taxonomy Working Group: Rhodin, A.G.J., Iverson, J.B., Gallego-García, N., Fritz, U., Georges, A., Shaffer, H.B., and van Dijk, P.P.]. 2025. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (10th Ed.). In: Rhodin, A.G.J., Iverson, J.B., van Dijk, P.P., Stanford, C.B., Goode, E.V., Buhlmann, K.A., and Mittermeier, R.A. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs 10:1–575.

TTWG [Turtle Taxonomy Working Group: Rhodin, A.G.J., Iverson, J.B., Gallego-García, N., Fritz, U., Georges, A., Ihlow, F., Shaffer, H.B., and van Dijk, P.P.]. In prep. Turtles of the World: Annotated Checklist and Atlas of Taxonomy, Synonymy, Distribution, and Conservation Status (11th Ed.). In: Rhodin, A.G.J., Iverson, J.B., van Dijk, P.P., Stanford, C.B., Buhlmann, K.A., and Mittermeier, R.A. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs.

Van der Meer Mohr, J.C. 1934. Korte Zoologische Aanteekeningen II: *Orlitia borneensis* Gray. De Tropische Natuur 23:192–193.

van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.). 2000. Asian Turtle Trade: Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia. Chelonian Research Monographs No. 2, 164 pp.

Velensky, P. 2013. Nine year effort to breed Spiny Hill Turtle (*Heosemys spinosa*) succeeds at Prague Zoo, Czech Republic. Turtle Survival Alliance Magazine. https://colombia.wcs.org/Portals/113/TSA_Magazine_2013.pdf#:~:text=,a%20priority%20for%20the%20TSA.

Wahyuni, R. and Ruyani, A. 2026. Strategi konservasi integratif kura-kura raksasa (*Orlitia borneensis*) sebagai upaya mitigasi kepunahan di Provinsi Bengkulu. Jurnal Biologi dan Pembelajarannya 13:94–105. [In Indonesian].

Wermuth, H. and Mertens, R. 1977. Liste der rezenten Amphibien und Reptilien: Testudines, Crocodylia, Rhynchocephalia. Tierreich 100:1–174.

Citation Format for this Account:

Hughes, D.F., Auliya, M., Chen, P.N., Hardian, A.B., Hasan, V., Jayanto, H., Nurfi'aini, C., Rahmawati, I.P., Rusli, N., Sukmawati, J.G., Tirtayani, J.V., and Moll, E.O. 2026. *Orlitia borneensis* Gray 1873 – Malaysian Giant Turtle, Bornean River Turtle, Kura-Kura Byuku, Kura-Kura Raksasa. In: Rhodin, A.G.J., Iverson, J.B., van Dijk, P.P., Stanford, C.B., Goode, E.V., Buhlmann, K.A., and Mittermeier, R.A. (Eds.). Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group. Chelonian Research Monographs 5(20):140.1–25. doi: 10.3854/crm.5.140.borneensis.v1.2026; www.iucn-tftsg.org/cbftt/.