State of Nature Conservation in Malaysia 2025, 421–436
doi: 10.62613/sonc2025.v2fnc08

CHAPTER 8

A conservation review of the critically endangered Southern River Terrapin (*Batagur affinis*) in Malaysia

SHU XUAN NG[1], PELF-NYOK CHEN[2]* and SRI RAHMATUL LAILA[3]

Abstract: The Southern River Terrapin (*Batagur affinis*), one of Southeast Asia's most critically endangered freshwater turtles, has undergone dramatic population declines across its historical range in Malaysia, Sumatra, and Cambodia due to overexploitation, habitat degradation, and low recruitment. Once widely distributed along major river systems of Peninsular Malaysia, the species now persists only in small, fragmented populations. This review consolidates published and grey literature, supported by unpublished field data, to assess the current understanding of *B. affinis* in Malaysia. A total of 49 sources, including scientific articles, institutional reports, and conservation records, were examined to evaluate information on its taxonomy, ecology, population trends, genetics, health, and conservation management. The synthesis identifies continuing pressures from sand mining, pollution, and egg harvesting, alongside limited integration of genetic and health monitoring in existing recovery programmes. Although hatchery-based conservation has contributed to protecting eggs and hatchlings, long-term success remains constrained by inadequate population monitoring and habitat restoration. While the review is primarily literature -based, it contextualises scientific findings within ongoing management practices, highlighting the need for coordinated national action, improved inter-agency collaboration, and sustained ecological and genetic research to ensure the long-term survival of *B. affinis* in the wild.

INTRODUCTION

The Southern River Terrapin (*Batagur affinis*), locally known as *tuntung sungai*, is one of the most critically endangered freshwater turtle species in Southeast Asia (Figure 1). The local name *tuntung* is derived from the rhythmic "tung-tung-tung" sound made by the female terrapin as she lifts and drops her body against the sand after laying eggs. Once distributed widely along the major rivers of Peninsular Malaysia, Sumatra, and Cambodia, *B. affinis* has undergone drastic population declines caused by overharvesting, egg collection, and loss of natural nesting habitats (Moll 1976; Moll *et al.* 2015). The species is now listed as Critically Endangered on the IUCN Red List and included in Appendix I of CITES, reflecting the urgency of its conservation status (Turtle Conservation Coalition 2018; Horne *et al.* 2019). Beyond its biological significance, the species also holds ecological and cultural importance in Malaysian riverine communities, serving as an emblem of freshwater biodiversity loss in the region (Tan *et al.* 2021).

Belonging to the family Geoemydidae, *B. affinis* exemplifies the vulnerability of large riverine turtles to environmental and anthropogenic pressures. Its dependence on intact hydrological systems, sandy nesting banks, and stable estuarine conditions has made it particularly sensitive to habitat disturbance and changes in river flow regimes (Moll *et al.* 2015). Historical overexploitation, combined with modern threats such as sand mining,

[1] Veterinary Professional Education Programme, School of Veterinary Medicine and Biomedical Sciences, IPB University, Bogor, Indonesia.
[2] Turtle Conservation Society of Malaysia (TCS), 13538, Lorong Solehah 3A, Taman Desa Solehah, 24000 Kemaman, Terengganu, Malaysia.
[3] Division of Anatomy, Histology and Embryology, School of Veterinary Medicine and Biomedical Sciences, IPB University, Bogor, Indonesia.
***Corresponding author: pelf@turtleconservationsociety.org.my**

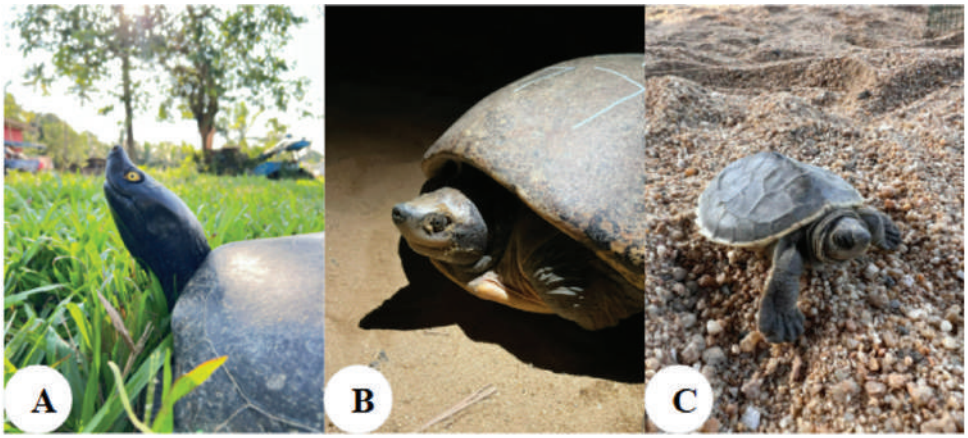

Figure 1. The critically endangered *Batagur affinis* in Malaysia.
(A) Adult male; **(B)** Adult female; **(C)** Hatchling.

pollution, and riverbank erosion, has led to the near disappearance of natural nesting populations across most of its historical range (Moll 1984, 1990; Moll and Moll 2000). In Malaysia, the species now survives mainly in small, isolated colonies along the rivers of Perak, Setiu, and Kemaman (Moll 1980; Chan and Chen 2011a; Chen 2017). Despite long -standing conservation efforts, including hatchery-based protection and community-driven management, wild populations remain precariously small and slow to recover (Chan and Chen 2011a; Chen 2019).

Scientific understanding of *B. affinis* has evolved progressively since the 1970s, though the overall body of knowledge remains fragmented. Early studies focused largely on taxonomy, morphology, and nesting ecology (Moll 1978a; Praschag *et al.* 2009), while more recent investigations have expanded into molecular genetics, conservation biology, and health assessment (Ismail *et al.* 2022; Mohd Salleh *et al.* 2023a, 2023b). These studies have improved taxonomic resolution and provided insights into genetic diversity and disease risks, yet they remain geographically limited and often lack methodological consistency. Consequently, a coherent understanding of population structure, recruitment, and long-term viability is still lacking, which complicates the development of adaptive and evidence-based management strategies.

While field initiatives have contributed valuable observational data, much of the available information remains dispersed across grey literature, institutional archives, and unpublished conservation reports. The absence of a consolidated synthesis has hindered critical evaluation of progress and restricted the ability to translate research findings into coordinated management actions. Furthermore, ecological, genetic, and veterinary aspects of conservation are often treated in isolation, reducing the potential for integrated planning at a national scale.

This review therefore seeks to compile and synthesise existing knowledge concerning the biology, ecology, genetics, health, and conservation management of *B. affinis* in Malaysia. It draws primarily upon peer-reviewed publications and grey literature, supplemented by unpublished data from ongoing conservation programmes, to place scientific findings within the context of on-the-ground realities. The review aims to identify recurring knowledge gaps, highlight overlaps between research themes, and outline directions for more holistic, evidence-informed management. Although largely based on secondary sources, this synthesis serves to bridge literature-based understanding with applied conservation practice, supporting the long-term protection and recovery of one of Malaysia's most imperilled freshwater turtles.

METHODOLOGY

This review adopted a narrative and thematic approach to collate and assess the current knowledge available on the Southern River Terrapin (*Batagur affinis*) in Malaysia. A structured framework was developed to identify and organise studies under major thematic categories, including taxonomy, morphology and life history, natural distribution, threats, population status, conservation efforts, genetics, conservation gaps and recommendations, and medical or health considerations. These themes guided both the search strategy and synthesis process, ensuring that biological, ecological, and conservation dimensions were addressed comprehensively. Although a PRISMA-style workflow was used to document the literature search process and enhance transparency, this review is narrative in nature and does not constitute a systematic review or meta-analysis.

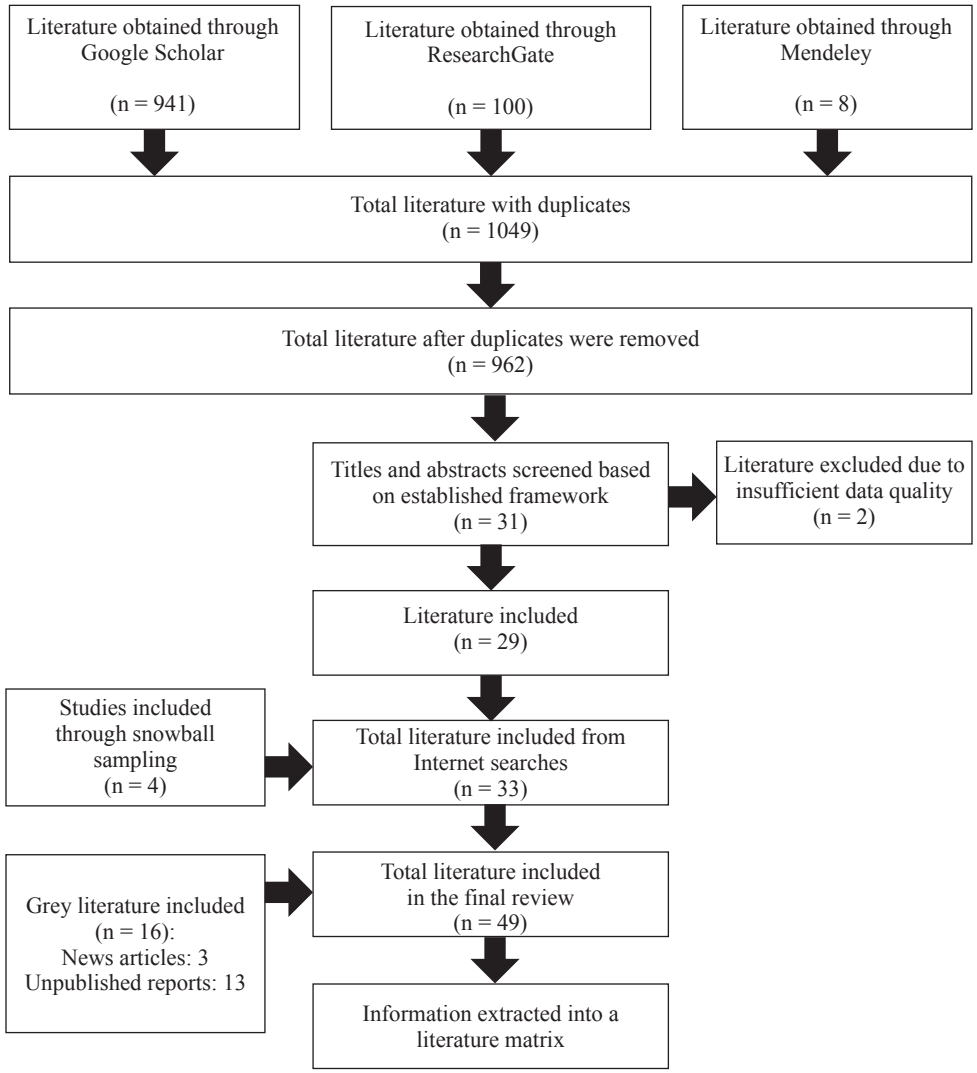

Figure 2. PRISMA workflow diagram of the literature review process for the studies of *Batagur affinis* in Malaysia.

Relevant literature was retrieved primarily through online databases, including Google Scholar, ResearchGate, and Mendeley, using the keywords "terrapin", "Southern River Terrapin", "*Batagur affinis*", and "*Batagur baska*" (the species' historical nomenclature), applied independently and in combination with Boolean operators. The search process imposed no restrictions on publication year or language in order to capture both historical

and contemporary studies. The initial search generated 1,049 records, of which 962 unique entries remained after removing duplicates. Following title and abstract screening, 31 documents were selected for full-text assessment. Two were excluded due to insufficient data quality, leaving 29 eligible documents. A citation-chasing approach was then employed to identify additional references from bibliographies of these papers, yielding four more publications, bringing the subtotal to 33. Thirteen unpublished reports and three news articles were also included to incorporate local observations, government documentation, and community-based conservation records. In total, 49 documents were included for detailed review, comprising thirty-three scientific publications, thirteen unpublished reports, and three news articles.

Each document was examined in full and its content extracted into a literature matrix designed to facilitate comparative analysis across thematic categories. This process enabled the identification of recurring trends, knowledge gaps, and inconsistencies across the reviewed sources. Unpublished data were incorporated where appropriate to provide contextual understanding of recent developments not yet represented in peer-reviewed literature. Such inclusion was intended not to substitute empirical research, but to ensure that the synthesis reflected both academic and applied conservation perspectives. The overall literature selection process is summarised in Figure 2.

TAXONOMY

The Southern River Terrapin is taxonomically classified as follows:

Kingdom	: Animalia
Phylum	: Chordata
Class	: Reptilia
Order	: Testudines
Family	: Geoemydidae
Genus	: *Batagur*
Species	: *Batagur affinis* (Cantor, 1847)

The species was originally described as *Tetraonyx affinis* by Cantor (1847) based on juvenile specimens collected from Penang. Due to the absence of adult material and comparative specimens from other regions, later researchers synonymised it with *Batagur baska* (Gray, 1830), the Northern River Terrapin. As a result, for much of the twentieth century, terrapins from Peninsular Malaysia and Sumatra were erroneously recorded as *B. baska* in both published and grey literature.

Subsequent advances in molecular systematics prompted a reassessment of the evolutionary relationship among *Batagur* species and subspecies. Phylogenetic analyses of mitochondrial cytochrome *b* sequences revealed that northern and southern *Batagur* populations represent two genetically distinct but closely related lineages (Praschag *et al.* 2007). A re-examination of historical museum collections later demonstrated that the original *B. baska* type series comprised multiple taxa. To resolve this taxonomic ambiguity, Praschag *et al.* (2008) designated a lectotype representing the southern population, thereby reinstating *B. affinis* as a valid species restricted to the southern river systems of Peninsular Malaysia and Sumatra.

Morphological and distributional evidence further support this taxonomic distinction. Consistent differences in carapace contour, plastron pigmentation, head shape, and cranial markings have been documented between the populations of the west and east coasts of Peninsular Malaysia (Praschag *et al.* 2009). Consequently, two subspecies are now recognised: *Batagur affinis affinis*, found along the rivers of Perak and Kedah extending into Sumatra,

and *Batagur affinis edwardmolli*, distributed along the east coast of Peninsular Malaysia and the Sre Ambel River system in Cambodia. The latter was named in honour of Dr. Edward O. Moll for his extensive contributions to the study and conservation of river terrapins.

Recent molecular studies have contributed further insight into the taxonomy of *B. affinis*. The publication of a near-complete mitochondrial genome (Mohd Salleh *et al.* 2023a) and a DNA barcoding analysis based on cytochrome oxidase I (COI) sequences (Mohd Salleh *et al*. 2023b) have provided useful molecular reference data. However, these studies relied on limited sample sizes and mitochondrial markers derived mainly from captive individuals, which restricts their ability to resolve subspecies boundaries, population structure, or broader evolutionary relationships within the *Batagur* complex.

Although mitochondrial and morphological evidence strongly support the recognition of two subspecies, comprehensive genome-wide nuclear data from wild populations remain essential to confirm their taxonomic validity and guide future conservation management. Improved molecular resolution, combined with morphological and ecological data, would provide a more robust framework for defining management units and informing breeding and reintroduction programmes aimed at the long-term survival of *B. affinis*.

MORPHOLOGY AND LIFE HISTORY

Batagur affinis is a large freshwater turtle adapted to the dynamic estuarine and riverine systems of Southeast Asia. Early descriptions characterised juveniles as having a broadly oval carapace with distinct dorsal keels and serrated posterior margins (Cantor 1847). The species is typically olive-grey with fine brown spotting, black interdigital membranes, and greenish-yellow webbing between the fourth and fifth toes. Diagnostic features that distinguish *B. affinis* from related taxa such as *B. baska* include its conical head, short pointed snout, and finely toothed jaws (Praschag *et al.* 2009).

Adult *B. affinis* exhibit a deep, moderately domed carapace with pronounced lateral curvature, an adaptation that provides hydrodynamic stability in slow-moving and tidal waters (Moll 1980). Both sexes possess fully webbed limbs with four claws on each forelimb and bicuspid upper jaws with well-developed longitudinal ridges (Moll *et al.* 2015). Males typically measure between 400 and 502 mm in carapace length, while females are larger, ranging from 430 to 546 mm, with carapace lengths of up to 625 mm and weights approaching 38 kg (Moll *et al.* 2015). Females are generally heavier-bodied with shorter tails, whereas males display proportionally longer tails and more slender physiques. Hatchlings possess spiny marginal scutes and serrated shells that gradually smooth as they mature (Moll 1980; Moll *et al.* 2015).

The species exhibits a primarily herbivorous diet, consisting largely of aquatic vegetation, fruits, and leaves, although molluscs and crustaceans are occasionally consumed (Davenport and Wong 1986; Davenport *et al.* 1992). The strong, ridged jaws and robust musculature are adaptations for shearing fibrous plant material, particularly the leaves and fruits of *Sonneratia caseolaris* (Moll 1978b, 1980). Morphological traits, including the broad carapace and powerful limbs, also reflect adaptation to fluctuating freshwater and estuarine environments where the species forages and nests.

Morphological and colour differences between *B. affinis affinis* and *B. affinis edwardmolli* further support subspecific differentiation. The east coast form, *B. a. edwardmolli*, typically has a more elongated carapace, darker pigmentation, and more prominent cranial markings, whereas *B. a. affinis* exhibits a broader carapace with lighter plastral colouring and less distinct head patterns (Praschag *et al.* 2008, 2009). These distinctions, summarised in Table 1, are consistent across populations and are considered important for subspecies identification and conservation management.

Table 1. Morphological and distributional differences among *Batagur affinis affinis*, *Batagur affinis edwardmolli*, and *Batagur baska.*

	Batagur affinis affinis	***Batagur affinis edwardmolli***	***Batagur baska***
Geographical distribution	West coast of Peninsular Malaysia and Sumatra	East coast of Peninsular Malaysia and Sre Ambel River, Cambodia	Northeastern India, Bangladesh, and Myanmar
Carapace shape	Broader and more oval in dorsal view	More elongated and tapered posteriorly	High-domed, more robust and symmetrical
Plastron colouration	Pale yellowish to light cream with minimal pigmentation	Darker yellow to greyish, often with distinct blotches or diffuse pigmentation	Yellowish to tan, uniform without distinct blotches
Head and neck pattern	Less distinct striping; lighter cranial markings	Prominent dark streaks on head and neck, especially in males	Distinct light streaks along jaw and temporal region
Cranial morphology	Slightly narrower snout	Broader snout and flatter skull	Longer, narrower head with slightly upturned snout
Male breeding colouration	Less intense; head and neck turn olive or grey during breeding season	More vivid; head turns black with contrasting white or pale yellow jaws	Head and neck become dark grey and bluish-black during nesting season

(Sources: Praschag *et al.* 2007, 2008, 2009; Moll *et al.* 2009, 2015)

Reproductive activity in *B. affinis* is strongly seasonal and closely aligned with hydrological cycles. Nesting generally occurs during the dry season, between November and January along the west coast and February to March along the east coast (Moll 1976, 1980). Females migrate upstream to sandy banks located above the tidal zone to lay their eggs. Clutch sizes range from 23 to 30 eggs, with an incubation period of approximately 88 days, and a pivotal sex-determining temperature near 31.5ºC (Kuchling *et al.* 2007). The species is long-lived and slow to mature, requiring up to two decades to reach sexual maturity in the wild. This protracted life history, combined with high nest predation and low juvenile recruitment, contributes significantly to its vulnerability under continued anthropogenic pressures (Chan *et al.* 2014).

The morphological, ecological, and reproductive characteristics of *B. affinis* limit the species' resilience to environmental change. Understanding its life history parameters is therefore critical to informing effective conservation management, particularly in relation to habitat protection, head-starting programmes, and reintroduction strategies aimed at restoring viable wild populations.

NATURAL DISTRIBUTION

Batagur affinis is known from Peninsular Malaysia and Sumatra, while *B. baska* historically ranged from northeastern India and Bangladesh to at least the Ayeyarwady and Bago estuaries in Myanmar (Moll *et al.* 2009, 2015). Although earlier work sometimes treated *B. affinis* and *B. baska* as conspecific, molecular and morphological evidence now supports their distinction, with the eastern Peninsular Malaysia population often referred to as *B. affinis edwardmolli* (see Genetics section).

Despite this taxonomic clarification, information on the distribution of *B. affinis edwardmolli* remains limited. Moll (1980) produced one of the earliest distribution maps of "Malaysian *Batagur*," although this likely included *B. borneoensis* due to their morphological

similarities. On the east coast of Peninsular Malaysia, confirmed records of *B. affinis* are largely restricted to the state of Terengganu. As early as 1976, the Department of Wildlife and National Parks (PERHILITAN) established a hatchery and head-starting facility in Kuala Berang to safeguard populations from the Terengganu and Dungun Rivers. Subsequent conservation and research efforts were initiated in the Setiu River in 2004 (Chan *et al.* 2008a), and further investigations through questionnaire-based surveys with fishermen across ten major rivers in Terengganu revealed the presence of *B. affinis* in the Kemaman and Kerteh Rivers (Chan and Chen 2010; Chen 2017).

Within river systems, *B. affinis* shows highly specific habitat use rather than a uniform distribution. Recent work in the Kemaman River demonstrates that adult females preferentially occupy slow-flowing reaches (0.1 – 0.2 m s^{-1}) with moderate depths (2.0 – 3.0 m), while nesting activity is concentrated on sandy banks with fine to medium grain sizes (0.06 – 2.0 mm) and gentle slopes of approximately 7 – 9º (mean 8.55º) (Mohd Yusof *et al.* 2019). In contrast, canopy cover appears to exert limited influence on habitat selection, and no consistent preference was detected for total suspended solids. These findings indicate that the natural distribution of *B. affinis* within rivers is strongly constrained by localised hydraulic and geomorphological conditions, helping to explain its patchy occurrence and dependence on intact sandbank habitats in remaining strongholds such as the Kemaman River.

Species distribution modelling indicates that *B. affinis* may occur across a broader coastal and inland area than its currently known range, but effective protection remains limited. Tan *et al*. (2021) showed that only a small proportion of suitable habitat overlaps with protected areas, and this is further reduced when permanent freshwater availability is considered, with particularly low coverage in Malaysia. Although future projections suggest a northward and inland shift in suitable conditions, many of these areas fall outside protected landscapes and are associated with high uncertainty, indicating limited long-term security under existing reserve networks.

Recent evidence has expanded the known range to include the Kuantan River, Pahang, where 41 *B. affinis* eggs were collected and 22 of them successfully hatched, representing the first verified nesting record for the state (Meng 2025a). Anecdotal reports also suggest the species may occur in the Pahang River. However, these records remain unverified and are primarily based on personal communications with local fishermen. Targeted field surveys and long-term monitoring are necessary to confirm the presence of remnant nesting or foraging populations beyond the currently recognised range.

Accurate documentation of the current distribution of *B. affinis* remains challenging due to its rarity and cryptic behaviour. Wilson *et al*. (2017) showed that environmental DNA (eDNA) detection is feasible in river systems within approximately 1 km of known individuals, indicating its potential for confirming presence in areas where visual encounters or captures are unlikely. Although eDNA currently yields presence–absence data only, its application offers a practical means of identifying remnant populations, assessing local extirpation, and guiding targeted field surveys, thereby improving understanding of the species' contemporary distribution across river systems in Malaysia.

THREATS

Populations of *Batagur affinis* have undergone severe declines primarily as a result of overexploitation and habitat degradation. Early studies along the Perak and Terengganu rivers documented intensive harvesting of both adults and eggs, while anthropogenic disturbances such as tin mining, deforestation, and agricultural expansion further degraded

nesting habitats (Moll 1976, 1978a, 1978b; Pan 1988). By the late 1970s, annual egg collection in the Perak River had fallen from over 600,000 to approximately 20,000, reflecting the collapse of nesting populations and the species' extreme susceptibility to exploitation. Habitat deterioration caused by riverbank clearing, siltation, and the discharge of industrial effluents further reduced the availability of suitable nesting sites, compounding the rate of population decline.

During subsequent decades, *B. affinis* continued to face escalating pressures from human activities. Sand mining, riverbank modification, mangrove clearance, and incidental capture in fishing gear have all contributed to ongoing habitat loss and mortality (Moll 1990). Genetic analyses have indicated that such prolonged exploitation and habitat disturbance have eroded genetic diversity within and between river systems (Praschag *et al.* 2007, 2009). Despite legal protection under national wildlife legislation, egg poaching and adult hunting persist, exacerbated by inadequate enforcement and local market demand (Moll *et al.* 2009). River regulation, including dam construction and aquaculture development, has altered hydrological regimes, disrupted sediment flow, and caused the erosion of natural sandbanks critical for nesting. Additionally, artificial lighting near riverbanks has been reported to disorient nesting females and emerging hatchlings, further reducing reproductive success (Sharma and Tisen 2000).

Predation and environmental pressures impose additional constraints on recruitment and survival. Nest predation by monitor lizards, rats, ants, and other animals frequently results in high egg mortality, even within managed nesting sites (Kasinathan *et al.* 2016; Chen 2017). Riverbank erosion, poor water quality, and anthropogenic disturbances reduce the number of viable nesting locations each year. Given the species' slow maturation and low natural recruitment, these factors collectively hinder population recovery, even under ongoing conservation intervention.

Recent years have introduced further challenges to conservation management. Sand extraction and infrastructure development continue to modify river morphology and nesting habitats. Agricultural runoff and industrial pollution have compromised water quality, while plastic waste and ghost fishing gear pose entanglement and ingestion risks. The COVID-19 pandemic further disrupted conservation operations by limiting field monitoring and hatchery maintenance, leading to increased disease incidence among captive hatchlings (Whyte 2020; Chen *et al.* 2022). Furthermore, habitat modelling studies suggest that suitable habitats for *B. affinis* overlap poorly with existing protected areas, leaving many populations vulnerable to unregulated human activities (Tan *et al.* 2021).

Emerging threats have also been reported from more recent observations, including egg poaching in previously secured nesting sites, entanglement in discarded nets, and new incidences of microbial infections in captive-rearing facilities (Chen *et al.* 2025; Meng 2025b; Rahman 2025). The cumulative effect of these pressures has been the progressive fragmentation and isolation of remaining populations, reducing their genetic exchange and resilience to environmental change.

POPULATION STATUS

Populations of *B. affinis* are now severely reduced across much of their historical range and have been extirpated from several former localities (Moll *et al.* 2015). The review by Moll *et al*. (2015) provided the first comparative assessment of nesting data across Peninsular Malaysia, revealing substantial spatial and temporal variation in nesting activity. However, since the 1950s, population estimates have largely relied on indirect measures, primarily egg collection data, rather than direct counts of nesting females or robust mark–recapture analyses (Chan and Chen, 2011b; Moll *et al.* 2015).

Early records documented *B. affinis* in the Perak, Terengganu, and Kedah river systems (Moll 1980). Prior to the Japanese Occupation of Malaya (1942–1945), the Perak River alone was estimated to support over 10,000 nesting females, producing 375,000 – 500,000 eggs annually (Loch 1950; Mohamed Khan 1964). Intensive harvesting during the Occupation, driven by food shortages, resulted in a near-collapse of these populations.

In the 1970s, mark-recapture studies were conducted to estimate population size, but small and inconsistent sample sizes limited their reliability (Moll 1976, 1978a, 1980). Subsequent PERHILITAN assessments were based on partial nest counts, acknowledging that individual females may lay multiple clutches per season (Moll 1980). PERHILITAN records indicate that no more than 40 wild nests were reported from the Perak River, with no confirmed nesting after 2009 (PERHILITAN, unpublished data). Similarly low nesting activity has been reported elsewhere; in 2011, only 20 – 30 nests were estimated along the Setiu River, 85 – 100 along the Terengganu River, and 15 – 30 along the Dungun River (Chan and Chen 2011b).

More recently, long-term conservation efforts in the Kemaman River have improved understanding of wild population status. A community-based programme initiated in 2011 by the Turtle Conservation Society of Malaysia (TCS) implemented systematic monitoring, including microchipping of post-nesting females. Mark-recapture analyses based on microchip returns estimated the Kemaman River population between 200 and 300 individuals using the Schnabel Index (Chen, unpublished).

Recent surveys have also expanded the known reproductive range of *B. affinis* in Malaysia. In 2025, four nests containing a total of 41 eggs were documented along the Kuantan River, Pahang, representing the first confirmed evidence of reproduction by the species in the state (Chen *et al.* 2026). Twenty-two hatchlings successfully emerged from these nests, confirming active breeding by a previously undocumented population. Although the size and status of this population remain unknown, the discovery suggests that remnant breeding populations may persist outside currently recognised strongholds and highlights the importance of continued surveys in river systems where the species has not been historically monitored.

CONSERVATION EFFORTS

Conservation initiatives for z*B. affinis* in Malaysia have evolved significantly over the past five decades, transitioning from government-led ex situ programmes to more inclusive, community-based conservation approaches. Early conservation measures were initiated by PERHILITAN in the late 1960s and 1970s, primarily to address widespread egg collection and population decline. The establishment of River Terrapin Conservation Centres (Pusat Konservasi Hidupan Liar, PKHL) marked the beginning of formalised conservation for the species (Moll 1976; 1980). These facilities focused on the protection of eggs, artificial incubation, and the head-starting of hatchlings for later release into the wild (Chen 2017).

The PKHL at Bota Kanan, Perak—established in 1967—was the first dedicated facility of its kind and is recognised as the world's longest-running freshwater turtle conservation centre. By 2013, it had successfully released more than 36,000 hatchlings into the Perak River. Similar programmes were subsequently established at Kuala Berang in Terengganu (1976) and Bukit Pinang in Kedah (1977). The Kuala Berang centre had released over 9,100 hatchlings by 2013, while the Bukit Pinang centre had released more than 6,000 hatchlings by 2008 (Chan *et al.* 2008b). Collectively, these initiatives laid the foundation for Malaysia's national approach to freshwater turtle conservation and provided valuable insights into captive management and head-starting techniques. However, despite

the substantial number of hatchlings released through these programmes, systematic long-term monitoring of post-release survival and recruitment into wild populations remains limited, making it difficult to assess the overall conservation outcomes of these hatchery initiatives.

Building upon these early ex situ programmes, conservation strategies have expanded to incorporate community participation and education. In 2011, TCS launched a long-term community-based initiative in the Kemaman River, representing a major step towards integrating local knowledge and stewardship in species recovery. The project recruits and trains villagers—many of whom were previously engaged in egg poaching—as "Terrapin Guardians" responsible for patrolling nesting areas, protecting eggs, and assisting with hatchery management (Chen, 2017). This approach has strengthened local involvement and increased awareness of conservation goals while providing alternative income opportunities that reduce reliance on egg harvesting. Since its inception, the Kemaman programme has secured more than 11,500 eggs, produced over 7,300 hatchlings, and released more than 7,000 juveniles into the river (Chen, unpublished). Post-release monitoring of head-started juveniles is currently ongoing; however, recapture rates to date have been low and remain insufficient to reliably estimate survival or recruitment into the wild population.

GENETICS

Genetic research on *B. affinis* in Malaysia remains limited in both scope and resolution, with most studies relying on low-resolution molecular markers or mitochondrial DNA. Early efforts focused on developing basic genetic tools for species identification, including the use of Random Amplified Polymorphic DNA (RAPD) markers, which produced the first molecular profiles for the species but offered limited reproducibility and minimal population-level insight (Norkarmila *et al.* 2002).

Subsequent studies employed mitochondrial DNA to address long-standing taxonomic uncertainty within the genus *Batagur*. Analyses of the cytochrome b gene demonstrated clear genetic differentiation between Indian *B. baska* and populations from Malaysia and Indonesia, supporting the recognition of *B. affinis* as a distinct species (Praschag *et al.* 2007). Examination of historical museum specimens further confirmed genetic continuity between historical and contemporary Malaysian populations (Praschag *et al.* 2008). Additional mitochondrial evidence, together with morphological data, revealed consistent genetic separation between east and west coast populations of Peninsular Malaysia, leading to the recognition of *B. affinis affinis* and *B. affinis edwardmolli* as two valid subspecies (Praschag *et al.* 2009; Moll *et al.* 2015).

Recent advances in molecular techniques have enabled non-invasive monitoring of *B. affinis* through eDNA. Wilson *et al*. (2017) developed a species-specific assay targeting a short fragment of mitochondrial cytochrome *b*, demonstrating reliable detection of *B. affinis* from water samples under both controlled and natural river conditions. The study highlights the potential of eDNA as a valuable genetic tool for surveying rare and elusive freshwater turtles, while also acknowledging the limitations of this method in tropical systems, such as DNA degradation, high sediment loads, contamination risks, and the inability of current eDNA techniques to infer population size or density. Despite these constraints, eDNA monitoring represents a useful complement to conventional genetic and field-based survey approaches.

Beyond taxonomy, relatively few studies have investigated genetic diversity or population structure in *B. affinis*. Cross-species microsatellite markers, adapted from related freshwater turtles, have been validated and currently provide one of the few nuclear tools

available for population-level analyses (Ismail *et al.* 2016). These markers have indicated reduced genetic diversity and elevated inbreeding in long-established captive populations compared with wild populations, highlighting potential genetic risks associated with prolonged head-starting and limited founder representation (Ismail *et al.* 2022). However, the spatial coverage of sampling remains restricted, and most population-level estimates are derived from small datasets.

Although limited, existing genetic studies have provided valuable baseline insights. Microsatellite analyses across multiple sites in Peninsular Malaysia revealed moderate heterozygosity and detectable population structuring, suggesting restricted gene flow between river systems, although resolution was constrained by the small number of loci analysed (Mohd Salleh and Esa 2022a). Complementary mitochondrial COI barcoding identified distinct haplotypes between west-coast (*B. affinis affinis*) and east-coast (*B. affinis edwardmolli*) individuals, adding reference data for species identification while emphasising the need for higher-resolution genomic approaches to better inform conservation management (Mohd Salleh *et al.* 2023b).

Overall, despite decades of conservation intervention, *B. affinis* remains one of the least genetically characterised large freshwater turtles in Southeast Asia. The absence of genome-wide nuclear data limits current understanding of its population structure, adaptive variation, inbreeding levels, and evolutionary distinctiveness among remnant populations. Addressing these knowledge gaps will be necessary before reliably informing conservation management units, guiding translocation and release efforts, and ensuring the long-term genetic viability of both wild and captive-managed populations.

HEALTH CONSIDERATIONS

Health-related research on *B. affinis* has been limited and largely opportunistic, focusing primarily on contaminant exposure, captive husbandry, and sporadic disease outbreaks. Early observations highlighted the risks posed by chlorinated hydrocarbon pesticides such as dichlorodiphenyltrichloroethane (DDT) and dieldrin, which were widely used in riverine fisheries and posed potential threats to terrapins and human consumers through egg contamination (Moll 1976). These findings provided some of the earliest evidence of pollutant bioaccumulation in large freshwater turtles.

Subsequent work identified husbandry-related health problems in captive hatchlings. Diets consisting solely of *Ipomoea aquatica* led to shell softening consistent with calcium deficiency and metabolic bone disease, underscoring the importance of nutritionally balanced feeding regimes in head-starting programmes (Norkarmila *et al.* 2002; Chen 2004). Poor water quality and inadequate hygiene were later associated with fungal infections in eggs and hatchlings at conservation centres, demonstrating that the hatchery environment is a key determinant of rearing success (Kasinathan *et al.* 2016).

Veterinary health monitoring has historically been minimal, with routine pathogen screening rarely conducted prior to the release of head-started juveniles. This raises concerns regarding the inadvertent introduction of pathogens into wild populations (Chen 2017). A parasitological survey at the Perak Wildlife Conservation Centre documented gastrointestinal infections, including *Ascaris* sp. and *Oesophagostomum* sp., with most morbidity attributed to overcrowding, poor sanitation, and suboptimal husbandry rather than primary disease processes (Premaalatha *et al.* 2018).

Parasitic infections remain an under-recognised health concern for *B. affinis*, particularly in captivity. At the PKHL facility in Bota Kanan, Perak, morbidity and mortality events were associated with helminth infections. Faecal examinations revealed thick -walled ascarid eggs (approximately 140 – 160 μm), while post-mortem findings confirmed *Oesophagostomum* spp. nematodes in the intestines (Premaalatha *et al.* 2018). These observations highlight the susceptibility of captive terrapins to parasitic disease under suboptimal husbandry conditions and emphasise the need for regular parasitological screening, appropriate treatment, and improved management to reduce health-related losses in conservation and head-starting programmes.

Infectious disease outbreaks have occasionally been reported in captive populations. Ocular infections associated with poor water quality were successfully treated through isolation and topical therapy (Whyte 2020). During the COVID-19 lockdowns, reduced maintenance led to bacterial infections at the TCS River Terrapin Conservation Centre, with *Pseudomonas aeruginosa* and *Providencia rettgeri* identified as the causative agents (Chen *et al.* 2022). These outbreaks were linked primarily to declining water quality and inadequate husbandry rather than to novel pathogens.

Gut microbial communities represent an emerging but still poorly understood aspect of health in *B. affinis*. Using 16S rRNA metabarcoding, Mohd Salleh *et al*. (2022b) provided the first baseline characterisation of the faecal bacterial communities of captive and wild individuals, demonstrating clear differences in bacterial composition and diversity between the two groups. The microbiota were dominated by *Firmicutes*, *Bacteroidetes*, *Proteobacteria*, and *Fusobacteria*. Although the functional and clinical significance of these differences remains unclear, this baseline highlights the need for further research linking gut microbiota, husbandry conditions, and health outcomes in both captive and wild populations.

Technical constraints further limit health-related research in *B. affinis*. Blood sampling in large individuals is challenging due to handling risks and limited vascular access, restricting routine diagnostic and physiological assessments. Anaesthetic protocols for freshwater turtles are also poorly standardised, and inappropriate dosing has been shown to prolong recovery and increase the risk of respiratory complications, reinforcing the need for species-specific clinical guidelines (Justo *et al.* 2023).

Overall, health-related research on *B. affinis* remains fragmented and reactive, with a clear need for systematic veterinary surveillance, standardised husbandry protocols, and improved clinical methodologies to support both conservation management and future research.

CONSERVATION GAPS AND RECOMMENDATIONS

Abdul Rahman *et al.* (2019) established a baseline of community knowledge on *B. affinis* in Mukim Bota, showing high awareness of the species' presence, legal protection, and perceived population decline, and highlighting the potential role of local communities in conservation. However, the study also reveals clear gaps in species-specific ecological knowledge, indicating that general awareness alone is insufficient for effective conservation action. Moreover, reliance on self-reported perceptions and descriptive analyses limits insight into how awareness translates into participation or measurable conservation outcomes. Camara and Jamil (2021) moved beyond perception studies by evaluating a community-based awareness programme for *B. affinis*, showing high levels of conservation knowledge and positive attitudes, and a clear association between knowledge and pro-conservation attitudes. This supports the role of education and outreach in river terrapin conservation.

Despite measurable gains achieved through ex situ head-starting programmes, significant conservation gaps persist for *B. affinis*. Current recovery efforts remain disproportionately reliant on hatchery-based interventions, while in situ habitat protection and restoration have not progressed at a comparable pace. Ongoing sand mining and riverbank erosion continue to degrade critical nesting beaches and foraging habitats, directly constraining natural recruitment. In addition, systematic population monitoring and long-term demographic studies are absent from most river systems, limiting the ability to evaluate population trends, survival rates, and the effectiveness of ongoing interventions.

A further limitation is the insufficient integration of genetic management and veterinary health considerations into conservation planning. At present, government-managed PKHL do not routinely incorporate genetic screening to minimise inbreeding risks, nor do they implement standardised disease surveillance prior to the release of head-started juveniles (Ismail *et al.* 2022). This omission poses long-term risks to population viability, particularly given the prolonged use of limited founder stocks and repeated releases into the same river systems.

Conservation efforts are also hindered by the absence of a coordinated national strategy for *B. affinis*. Fragmented management responsibilities and limited data sharing among agencies and institutions have resulted in slow progress in research, inconsistent monitoring approaches, and inefficient use of available conservation resources. Addressing these shortcomings will require a more integrated and strategic conservation framework. Key priorities include: (1) long-term ecological and demographic monitoring of wild populations, (2) river basin-level management plans that safeguard nesting and nursery habitats from extractive and polluting activities, (3) the routine application of molecular tools to assess genetic diversity and guide release strategies, and (4) the implementation of standardised veterinary health screening and biosecurity protocols across all hatchery facilities.

Strengthening collaboration among PERHILITAN, academic institutions, and non-governmental organisations such as TCS is essential to ensure that conservation actions are evidence-based, adaptive, and nationally coordinated. Collectively, these measures will enhance the long-term viability of *B. affinis* populations, complement forthcoming genetic research, and establish a stronger foundation for sustainable recovery and health management across Malaysia's remaining river systems.

CONCLUSION

The Southern River Terrapin (*Batagur affinis*) remains on the brink of extinction, symbolising the wider decline of Malaysia's riverine biodiversity. Despite over five decades of conservation intervention, the species continues to face critical threats from habitat degradation, exploitation, and loss of genetic diversity. This review reaffirms the urgent need for a coordinated, evidence-based approach that integrates habitat restoration, genetic management, and veterinary health monitoring. Strengthening collaboration among government agencies, conservation organisations, and local communities will be essential to sustain progress and ensure effective implementation of conservation actions. Looking forward, long-term population recovery will depend on the successful integration of science-driven strategies with practical management and public engagement, securing the future of *B. affinis* as both a species of national heritage and a flagship for freshwater ecosystem conservation.

Acknowledgements: The author (SXN) expresses sincere gratitude to the Turtle Conservation Society of Malaysia (TCS) for hosting him during the Thematic Fieldwork Internship (Kuliah Kerja Nyata Tematik, KKNT), which provided important field exposure and contributed to the development of this study. Financial support for the KKNT internship programme was provided by IPB University, Bogor, Indonesia.

REFERENCES

Abdul Rahman, M.F., Abd Manaf, L. and Ho, M. 2019. Knowledge and awareness of a local community on river terrapins in Sungai Perak, Malaysia. *Journal of Sustainability Science and Management* 14(5): 128–134.

Camara, M. and Jamil, N.R. 2021. Evaluation of community-based species awareness programme: A case study of critically endangered freshwater river turtle *Batagur affinis* in Kg Pasir Gajah, Terengganu, Malaysia. Proceedings of the Zoological Society 74: 52–61. https://doi.org/10.1007/s12595-020-00359-x

Cantor, T. 1847. Catalogue of reptiles inhabiting the Malayan Peninsula and islands. In *Journal of the Asiatic Society of Bengal* (Vol. 16), W. B. O'Shaughnessy and J. W. Laidley (Eds.). Calcutta: Baptist Mission Press.

Chan, E.H., Kuchling, G., Soh, C.L. and Chen, P.N. 2008a. Setiu river terrapin research and recovery program. 6th Annual Symposium on Conservation and Biology of Freshwater Turtles, Tucson, Arizona, USA, 17–20 September 2008.

Chan, E.H., Rozidan, M.Y., Shabrina, M.S., Rahim, A., Noor Nazirah, M.Y. and Sugenah, M.K. 2008b. Overview of the Southern River Terrapin, *Batagur affinis* (Cantor, 1847) Conservation Program in Malaysia. Paper presented at the 6th World Congress of Herpetology, Manaus, Brazil, 17–22 August 2008.

Chan, E.H. and Chen, P.N. 2011a. Nesting activity and clutch size of *Batagur affinis edwardmolli* from the Setiu River, Terengganu, Malaysia. *Chelonian Conservation and Biology* 10(1): 129–132. https://doi.org/10.2744/CCB-0829.1

Chan, E.H. and Chen, P.N. 2011b. Current status of *Batagur* in Malaysia. Conservation of Asian Tortoises and Freshwater Turtles: Setting Priorities for the Next Ten Years, Singapore, 21–24 February 2011.

Chan, E.H., Chen, P.N. and Stamatopoulos, C. 2014. Von Bertalanffy Growth Model applied to Southern River Terrapins. Paper presented at the 12th Annual Symposium on Conservation and Biology of Freshwater Turtles, Orlando, Florida, USA.

Chen, P.N. 2004. Head-starting of river terrapins (*Batagur baska*): Feeding trials of hatchlings and juveniles. Master's thesis. Kuala Terengganu: Institute of Oceanography, Universiti Malaysia Terengganu.

Chen, P.N. 2017. Conservation of the Southern River Terrapin *Batagur affinis* (Reptilia: Testudines: Geoemydidae) in Malaysia: A case study involving local community participation. *Journal of Threatened Taxa* 9(4): 10035–10046. https://doi.org/10.11609/jott.3267.9.4.10035-10046

Chen, P.N. 2019. Community-based conservation of southern river terrapins in Malaysia. In Strategies for conservation success in herpetology, S.C. Walls and K.M. O'Donnell (Eds.), pp. 13–16. Society for the Study of Amphibians and Reptiles.

Chen, P.N., Mohamed Sidique, S.N., Ali, M.A., Che Abd Aziz, N. and Abd Wahid, M.E. 2022. Microbiota occurrence during COVID-19 at the Southern River Terrapin (*Batagur affinis*) hatchery in Terengganu, Malaysia. *Malayan Nature Journal* 74(3): 381–384.

Chen, P.N., Madi, A. and Abdullah, M.E. 2025. Assessing the status and conservation challenges of Southern River Terrapins (*Batagur affinis*) and Painted Terrapins (*Batagur borneoensis*) in Perak and Kedah Rivers. *Malayan Nature Journal* 77(1): 93–95. https://doi.org/10.62613/mnj.25771.06

Chen, P.N., Mohamed, M. and Madi, A. 2026. First evidence of reproduction of the Southern River Terrapin, *Batagur affinis* (Cantor, 1847) (Reptilia, Testudines, Geoemydidae), in the Kuantan River, Pahang, Malaysia. *Check List* 22(2): 253–260. https://doi.org/10.15560/22.2.253

Davenport, J. and Wong, T.M. 1986. Observations on the water economy of the estuarine turtles *Batagur baska* (Gray) and *Callagur borneoensis* (Schlegel and Müller). *Comparative Biochemistry and Physiology Part A: Physiology* 84A(4): 703–707. https://doi.org/10.1016/0300-9629(86)90391-9

Davenport, J., Wong, T. M. and East, J. 1992. Feeding and digestion in the omnivorous estuarine turtle *Batagur baska* (Gray). *Herpetological Journal* 2: 133–139.
Horne, B.D., Chan, E.H., Platt, S.G. and Moll, E.O. 2019. *Batagur affinis* (errata version published in 2019). The IUCN Red List of Threatened Species 2019: e.T170501A152041284. https://dx.doi.org/10.2305/IUCN.UK.2019-1.RLTS.T170501A152041284.en
Ismail, N.A., Ab Ghani, N.I., Chen, P.N., Abd Manaf, L., Jamil, N.R. and Ismail, A. 2016. Cross-species microsatellite amplification of river terrapin (*Batagur affinis*). *Acta Biologica Malaysiana* 5(2&3): 75–79. https://doi.org/10.7593/abm/5.2-3.75
Ismail, N.A., Chen, P.N., Abd Manaf, L., Ismail, A. and Ab Ghani, N.I. 2022. A preliminary inbreeding study of Malaysian endangered Southern River Terrapin (*Batagur affinis*) from captive population of Bota Kanan, Perak and wild population of Kemaman, Terengganu. In *Proceedings of the International Conference on Natural Resources and Sustainable Development,* pp. 500–506. SCITEPRESS. https://doi.org/10.5220/0009905200002480
Justo, A.A., Dutra, G.H.P., Carregaro, A.B. and Cortopassi, S.R.G. 2023. The fraction of inspired oxygen does not affect the time to extubation in mechanically ventilated, sevoflurane -anesthetized green sea turtles (*Chelonia mydas*). *American Journal of Veterinary Research* 84(5):1–8. https://doi.org/10.2460/ajvr.23.01.0008
Kasinathan, Y., Rahman, S. and Hambali, K. 2016. A study on the factors affecting the hatching success of river terrapin (*Batagur affinis*) egg in artificial pond at Wildlife Conservation Centre, Bota Kanan, Perak. In Proceedings of the Seminar Ekologi Malaysia 2016 (Malaysia Ecology Seminar 2016), Putrajaya International Convention Centre, Malaysia, November 8, 2016.
Kuchling, G., Chan, E.H. and Soh, C.L. 2007. Temperature-dependent sex determination studies in the River Terrapin. *Turtle Survival Alliance Newsletter*: 18.
Loch, J.H. 1950. Notes on the Perak River turtle. *Malayan Nature Journal* 5: 157–160.
Meng, Y.C. 2025a, Mar 23. Rare find a reason to shell-ebrate. *The Star*. https://www.thestar.com.my/news/nation/2025/03/23/rare-find-a-reason-to-shell-ebrate
Meng, Y.C. 2025b, Aug 27. Fish traps posing threat to T'ganu's river terrapins, says NGO. *The Star*. https://www.thestar.com.my/news/nation/2025/08/27/fish-traps-posing-threat-to -t039ganu039s-river-terrapins-says-ngo
Mohamed Khan, M.K. 1964. A note on *Batagur baska* (the river terrapin or tuntung). *Malayan Nature Journal* 18: 184-186.
Mohd Salleh, M.H. and Esa, Y. 2022a. Microsatellite loci reveal heterozygosis and population structure in the critically endangered southern river terrapin (*Batagur affinis* ssp.) of Peninsular Malaysia. *Chemistry Proceedings* 10(1): 11. https://doi.org/10.3390/iocag2022-12230
Mohd Salleh, M.H., Esa, Y., Ngalimat, M.S. and Chen, P.N. 2022b. Faecal DNA metabarcoding reveals novel bacterial community patterns of critically endangered Southern River Terrapin, *Batagur affinis*. *PeerJ* 10: e12970.
Mohd Salleh, M.H., Esa, Y. and Gan, H.M. 2023a. Characterization of the complete mitochondrial genome of the critically endangered Southern River Terrapin, *Batagur affinis affinis* (Reptilia: Geoemydidae). *Mitochondrial DNA Part B: Resources* 8(7): 719–722. https://doi.org/10.1080/23802359.2023.2222851
Mohd Salleh, M.H., Esa, Y. and Mohamed, R. 2023b. Global terrapin character-based DNA barcodes: Assessment of the mitochondrial COI gene and conservation status revealed a putative cryptic species. *Animals* 13: 1720. https://doi.org/10.3390/ani13111720
Mohd Yusof, F., Jamil, N.R., Chen, P.N., Johan, S., Hashim, N., Mohd Sah, S.A., Abdul Malik, N.K. and Rosli, M.H. 2019. Habitat suitability index of the Southern River Terrapin, *Batagur affinis* (Cantor, 1847) in Peninsular Malaysia. In Proceedings of the 4th International Conference on Environmental Research and Technology (ICERT 2020), pp. 24–30. Serdang: Universiti Putra Malaysia.
Moll, E.O. 1976. Ecology and management of the tuntong (*Batagur baska*) in Malaysia. Petaling Jaya: World Wide Fund for Nature, Malaysia
Moll, E.O. 1978a. Report of research on the distribution, ecology and management of coastal nesting turtles in Terengganu, West Malaysia (May–August 1978). Peninsular Malaysia: Game Department of West Malaysia.
Moll, E.O. 1978b. Drumming along the Perak. *Natural History* 87: 36–43.
Moll, E.O. 1980. Natural history of the river terrapin, *Batagur baska* (Gray), in Malaysia (Testudines: Emydidae). *Malayan Journal of Science* 6(A): 23–62.

Moll, E.O. 1984. River Terrapin recovery plan for Malaysia. *The Journal of Wildlife and Parks* 3: 37–47.
Moll, E.O. 1990. Status and management of the river terrapin (*Batagur baska*) in tropical Asia. Peninsular Malaysia: World Wide Fund for Nature, Malaysia
Moll, E.O. and Moll, D. 2000. Conservation of river turtles. In *Turtle Conservation*, Klemens, M.W. (Ed.), pp. 126–155. Washington, D.C.: Smithsonian Institution Press.
Moll, E.O., Platt, K., Platt, S.G., Praschag, P., and van Dijk, P.P. 2009. *Batagur baska* (Gray 1830) – Northern River Terrapin. In *Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group* (Chelonian Research Monographs No. 5), A.G.J. Rhodin, P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, J.B. Iverson and R.A. Mittermeier (Eds.), pp. 037.1–037.10. Chelonian Research Foundation. https://doi.org/10.3854/crm.5.037.baska.v1.2009
Moll, E.O., Platt, S.G., Chan, E.H., Horne, B.D., Platt, K., Praschag, P., Chen, P.N. and van Dijk, P.P. 2015. *Batagur affinis* (Cantor 1847) – Southern River Terrapin, Tuntong. In *Conservation Biology of Freshwater Turtles and Tortoises: A Compilation Project of the IUCN/SSC Tortoise and Freshwater Turtle Specialist Group* (Chelonian Research Monographs No. 5), A.G.J. Rhodin, P.C.H. Pritchard, P.P. van Dijk, R.A. Saumure, K.A. Buhlmann, J.B. Iverson and R.A. Mittermeier (Eds.), pp. 090.1–090.17. Chelonian Research Foundation. https://doi.org/10.3854/crm.5.090.affinis.v1.2015
Norkarmila, D., Hifni, B. and Siti Azizah, M.N. 2002. Towards conservation of the freshwater river terrapin, *Batagur baska*: Preliminary data on the biology and development of genetic markers. In Proceedings of the 4th IMT-GT UNINET Conference 2002, pp. 386–387. Pulau Pinang: Universiti Sains Malaysia.
Pan, K.A. 1988. An account of river terrapin (*Batagur baska*) nesting season 86/87 in Bota Kanan, Perak. *The Journal of Wildlife and Parks*.
Praschag, P., Hundsdörfer, A.K. and Fritz, U. 2007. Phylogeny and taxonomy of endangered South and South-East Asian freshwater turtles elucidated by mtDNA sequence variation (Testudines: Geoemydidae: *Batagur*, *Callagur*, *Hardella*, *Kachuga*, *Pangshura*). *Zoologica Scripta* 36(5): 429–442. https://doi.org/10.1111/j.1463-6409.2007.00293.x
Praschag, P., Sommer, R.S., McCarthy, C., Gemel, R. and Fritz, U. 2008. Naming one of the world's rarest chelonians, the southern Batagur. *Zootaxa* 1758: 61–68.
Praschag, P., Holloway, R., Georges, A., Päckert, M., Hundsdörfer, A.K. and Fritz, U. 2009. A new subspecies of *Batagur affinis* (Cantor, 1847), one of the world's most critically endangered chelonians (Testudines: Geoemydidae). *Zootaxa* 2233: 57–68.
Premaalatha, B., Jamnah, O., Tang, W.W. and Chandrawathani, P. 2018. Helminths in local river terrapins (*Batagur affinis*) in the Wildlife Conservation Centre, Perak. *Malaysian Journal of Veterinary Research* 9(2): 171–174.
Rahman, M.A. 2025. Bangkai tuntung ditemukan tersangkut di pukat. *Suara Timur*. https://suaratimur.com.my/?p=7009
Sharma, D.S.K. and Tisen, O.B. 2000. Freshwater turtle and tortoise utilization and conservation status in Malaysia. In *Asian Turtle Trade*, van Dijk, P.P., Stuart, B.L., and Rhodin, A.G.J. (Eds.), pp. 120–128. Proceedings of a Workshop on Conservation and Trade of Freshwater Turtles and Tortoises in Asia, 1–4 December 1999, Phnom Penh, Cambodia. Chelonian Research Monographs No. 2. Chelonian Research Foundation.
Tan, W.C., Ginal, P., Rhodin, A.G.J., Iverson, J.B. and Rödder, D. 2021. A present and future assessment of the effectiveness of existing reserves in preserving three critically endangered freshwater turtles in Southeast Asia and South Asia. *Frontiers of Biogeography* 13(4): e50928. https://doi.org/10.21425/F5FBG50928
Turtle Conservation Coalition. 2018. *Turtles in Trouble: The world's 25+ most endangered tortoises and freshwater turtles*. California (US): Hemlock Printers.
Whyte, E. 2020, September 21. Sick Malaysian wild terrapins saved by social media SOS. *The Star*. https://www.thestar.com.my/lifestyle/living/2020/09/21/wild-rare-terrapins-on-verge-of-blindness-are-saved-by-social-media-sos
Wilson, J.J., Sing, K.W., Chen, P.N. and Zieritz, A. 2017. Tracking the Southern River Terrapin (*Batagur affinis*) through environmental DNA: Prospects and challenges. *Mitochondrial DNA Part A: DNA Mapping, Sequencing, and Analysis* 29(6): 862–866. https://doi.org/10.1080/24701394.2017.1373109