STATE OF NATURE CONSERVATION IN MALAYSIA 2025

Volume 2: Fauna



Edited by
Vivian Soon
Ng Sean Fong
Donovan Louis

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State of Nature Conservation in Malaysia 2025

Volume 2: Fauna

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Vivian Soon, Ng Sean Fong, Donovan Louis

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CHAPTER 1

The state of Malaysia's birds – status, threats and conservation

DING LI YONG[1]*, GEOFFREY DAVISON[2], CHONG LEONG PUAN[3], CHIN AIK YEAP[4], CHOON MIN SEE[4], CHOO ENG TAN[4], ROSLI OMAR[4], AMAR-SINGH H.S.S.[5], JIA JIE NG[4] and ALLEN JEYARAJASINGHAM[4]

Abstract: A total of 864 bird species has been recorded in Malaysia, 728 of them in Peninsular Malaysia, 566 in Sarawak and 619 in Sabah to date. Of these, at least 568 species have (or had) known or presumed resident populations, while about 216 species have regularly migratory populations and 160 are vagrants. Eight are endemic or have distributions mostly restricted to Malaysia. As of 2025, 13 species are 'Critically Endangered', 18 'Endangered' and a further 49 'Vulnerable' on the IUCN Red List. Lowland forests below the steepland boundary support the highest species richness but are the most threatened vegetation type and remain at high risk of conversion to plantation agriculture, imperilling many species. Peat swamp forests are now reduced to a few large patches, mostly in Malaysia Borneo, threatening species such as Storm's Stork *Ciconia stormi* and Wrinkled Hornbill *Rhabdotorrhinus corrugatus*. Coastal wetlands such as mudflats and mangroves are used by a high diversity of migratory species, but are threatened by coastal development, whilst major gaps in protection persist. Illegal trapping to supply markets for pet birds further affects at least ten species, including the Straw-headed Bulbul *Pycnonotus zeylanicus* (CR), *Copsychus* spp. and most leafbirds. Strengthening the conservation of bird species in Malaysia may be achieved through a combination of targeted species action plans and recovery programmes for high profile threatened species (e.g. Straw-headed Bulbul, Milky Stork) alongside efforts to secure the conservation of key habitats in protected and managed areas, where possible in collaboration with local communities. There is also scope to strengthen the conservation of birds in agricultural landscapes such as rice fields, as already practiced elsewhere in the region. While there is some ongoing effort to track bird population trends through monitoring programmes, with initiatives already in place for raptors, waterbirds and urban species, there is an opportunity to expand such programmes through citizen science initiatives, whilst developing a national red list to guide conservation actions for them most threatened species.

INTRODUCTION

Malaysia sits on the upper ranks of the world's mega-biodiverse nations, supporting exceptionally high diversity of many taxonomic groups ranging from vascular plants and insects to birds (Latiff 2018). Presently, 864 bird species are listed for Malaysia (MNS Bird Conservation Council, in prep.), of which 568 species have (or had) known or presumed resident populations, and approximately 216 are regularly occurring migratory species (Lim *et al.* 2020; Puan *et al.* 2020; MNS Bird Conservation Council 2021; see Table 1). Some 45 species have both resident and migrant populations. A summary of data is given in Table 1, based on Wells (1999, 2006), Jeyarajasingham and Pearson (2000), and MNS Bird Conservation Council (in prep.). Over the past two decades, the steady increase in Malaysia's bird list has

[1] BirdLife International (Asia Division), 354 Tanglin Road, #01-16/17, Tanglin International Centre, Singapore 247672
[2] National Parks Board Singapore, 1 Cluny Road Singapore Botanic Gardens Singapore 259569
[3] Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor Darul Ehsan, Malaysia.
[4] Malaysian Nature Society, JKR 641, Jalan Kelantan, Bukit Persekutuan, 50480 Kuala Lumpur, Malaysia.
[5] Malaysian Bird Report, 31400 Ipoh, Perak Darul Ridzuan, Malaysia.
***Corresponding author: dingli.yong@birdlife.org**

been driven by the annual addition of species that are migratory stragglers such as the Collared Pratincole *Glareola pratincola*, Black Tern *Chlidonias niger* and the Northern Lapwing *Vanellus vanellus* (see MNS-BCC 2024; MNS-BCC 2026), as well as species that are new for science, notably the Spectacled Flowerpecker *Dicaeum dayakorum* (Saucier et al. 2019) and Cream-eyed Bulbul *Pycnonotus pseudosimplex* (Shakya *et al*. 2019).

Table 1. Total species of birds recorded in Malaysia, broken across Peninsular Malaysia, Sabah (including Federal Territory Labuan) and Sarawak. Numbers are affected by taxonomic changes, uncertainties in status (e.g., breeding assumed rather than proven), as well as intensity of geographical coverage. Numerous species have both resident and migrant populations (e.g. Grey Heron *Ardea cinerea*, Black-winged Stilt *Himantopus himantopus*), and definitions of vagrants are imprecise.

Region	Total species	Resident native (R and X)	Introduced resident (F)	Migratory (M)	Vagrant (V)	Endemic (E)
Peninsular Malaysia	728	449	19	194	102	6
Sarawak	566	380	7	149	51	1
Sabah	619	418	11	147	77	3
Total	**864**	**568**	**23**	**216**	**160**	**10**

Malaysia's diverse vegetation, landscapes and extensive mountainous geography are key drivers of high bird species richness and endemism. Among forest types, lowland and hill dipterocarp forests support the most diverse breeding bird communities in Malaysia, as with other parts of Sundaland, with species-rich assemblages of families such as bulbuls, woodpeckers and hornbills in landscapes such as Taman Negara and Danum Valley Conservation Area (Jeyarajasingham and Pearson 2000; Lim *et al.* 2020). Niches (understorey, middle storey and canopies) provided by the complex environment of lowland forests support a high diversity of terrestrial species (e.g., pittas), insectivores (e.g., babblers among foliage, woodpeckers on timber), frugivores (e.g., barbets and hornbills), cavity nesters (e.g., trogons, hornbills, woodpeckers, kingfishers, owls), leafball nesters (e.g., Short-toed Coucal *Centropus rectunguis*, pittas, some partridges) and platform nesters (e.g. large raptors) (see Wells 1999, 2006; Jeyarajasingham and Pearson 2000; Phillipps and Phillipps 2014). The avifauna of submontane and montane forests in Malaysia is less species-rich but characterised by higher endemism—most species with distributions restricted to Malaysia (e.g. Friendly Bush Warbler *Locustella accentor*, Mountain Peacock-pheasant *Polyplectron inopinatum*) occur in montane forests (Sheldon *et al*. 1999; Wells 1999; Moyle and Wong 2002; Puan *et al*. 2020).

Wetlands (excluding forested wetlands such as peat swamps) from the coasts to the floodplains of Malaysia's major river systems support significant assemblages of waterbirds and several passerines, although there is substantial species turnover from coastal to freshwater wetlands. Coastal intertidal wetlands such as mangroves and mudflats provide habitat for over 30 species of migratory shorebirds (Scolopacidae, Charadriidae), terns (Lariidae) and two storks, the Milky Stork *Mycteria cinerea* and Lesser Adjutant *Leptotilos javanicus*, of which the most significant are on the west coast of Peninsular Malaysia, western Sarawak coast (Bakewell *et al*. 2017; Teepol *et al*. 2021; Effendi *et al.* 2024) and potentially Sabah (Makbul *et al*., in review). Inland wetlands including freshwater marshland and lakes, and rice paddies are also used by large congregation of waterbirds including several species of herons, rails, and cormorants, alongside the Oriental Darter *Anhinga melanogaster* and Asian Openbill *Anastomus oscitans*, recent colonists from mainland Southeast Asia (Zainul-Abidin *et al*. 2017).

The conservation challenges faced by birds in Malaysia are complex and represent the full spectrum of threats faced by wildlife more widely in Southeast Asia. The single most important threat and driver of decline for both forest and wetland species is habitat loss

especially coastal wetlands (Yeap *et al*. 2007; Teepol *et al*. 2021; Effendi *et al*. 2025). There is ample evidence to implicate agricultural expansion in both Peninsular Malaysia and Malaysian Borneo as the leading driver of habitat loss (Lambert and Collar 2002; Azhar *et al.* 2011), possibly less so at montane elevations (Soh *et al*. 2021), alongside urbanisation (Puan *et al*. 2019). Hunting and trapping, including that for the caged bird trade (Ng *et al.* 2017), affects several songbird species and waterbirds, and is only better understood in recent years from surveillance and increased enforcement (Yong *et al*. 2024). On the other hand, species historically not known or were very rare in Malaysia, such as the Asian Openbill *Anastomus oscitans*, Painted Stork *Mycteria leucocephala* and several starling species have shown notable distributional range extensions (Zainul-Abidin *et al*. 2017), likely driven by a combination of human-mediated changes (e.g., land use, agriculture, urbanisation) and climatic factors. This paper reviews and summarises these threats, alongside the conservation status of key habitats and groups of birds in Malaysia. We then identify next steps to improve the conservation status of Malaysia's birds, with particular emphasis on forest and wetland habitats

SYSTEMATIC REVIEW

Lowland forest birds

Malaysia's forests are particularly rich in lowland forest groups such as babblers (previously all grouped in Timaliidae, now split among several families), woodpeckers, barbets, and some charismatic groups such as hornbills and pittas (Wells 1999, 2006; Puan *et al*. 2020). Malaysia's forest avifauna is characterised by a few large families (each with many species) and many small genera (each of one or two species) that have been tough to position in traditional taxonomies. Examples of the latter include Crested Jayshrike *Platylophus galericulatus*, Bornean bristlehead *Pityriasis gymnocephala*, Grey-headed Canary-flycatcher *Culicicapa ceylonensis*, White-bellied Erpornis *Erpornis zantholeuca*, and Malaysian Rail-babbler *Eupetes macrocercus*, all birds that have been bounced around from family to family. Reasons include long divergence times since isolation, lack of close relatives, geographical isolation from related taxa, and evolution of distinctive or unique morphological traits.

Much research has looked at the effects of forest disturbance (logging) on birds across the board (Meijaard *et al*. 2005), mostly by comparison of areas before and after logging, or comparison of areas after differing recovery periods (Johns 1992, 1996), but the conclusions tend to be quite general. There have been few studies on the effects of logging on individual species. Problems are compounded by changes in visibility and audibility in disturbed forest. The best data come from prolonged mist-netting at a few sites in extreme lowlands (Pasoh, Kuala Lompat, Danum Valley) (Wong 1985, 1986; Zakaria and Francis 1999, 2001; Francis and Wells 2003), on which conservation techniques could be built. Research has compared sounds and sighting rates, as proxies for population density, but there are limited data on changed foraging patterns, diet (Murray *et al*. 2020), nest site availability (Kaur *et al.* 2020), individual movements, or reproductive success and mortality. The genetic consequences of population change through logging are virtually unknown except for a study of genetic differences between populations in forest fragments for a handful of understorey species (Soh 2019).

Among the problems faced by lowland forest birds are loss of absolute area of habitat, loss of forest in the level lowlands, changed microhabitats and microclimates, and isolation of scattered populations in fragments of forests. Mention of some broad categories of ecological niches (see above) hardly touches on the topic of why there are short-distance differences in species composition, even within the same forest type. Autecological studies often seek to correlate population density or presence/absence with forest structure such as number of big trees, understorey density or fallen timber, but these are very hard to translate into conservation actions. These are all factors potentially under local or national control. There are also multiple problems of climate change that are beyond the control of any one country.

Peat swamp forest

Peat swamp forests share the bulk of their avifauna with other lowland forest types such as lowland dipterocarp, mangroves and back-mangrove forests, and heath or '*kerangas*' forests, but their distributions are far more limited, being largely restricted to the lower floodplains of major rivers and situated close to coasts (UNDP 2006). It is estimated that 23 – 30% of the Malaysian avifauna occurs in peat swamps (Posa *et al.* 2011), whilst several lowland forest species regularly use peat swamp forests, the best examples being Wrinkled Hornbill *Rhabdotorrhinus corrugatus* (EN) and Storm's Stork *Ciconia stormii* (EN). A handful of species are strongly associated with peat swamps, notably the Black Partridge *Melanoperdix nigra*, Hook-billed Bulbul *Setornis criniger* (in Borneo) and Grey-breasted Babbler *Malacopteron albogulare* in particular (Posa and Marques 2012; Yong *et al*. 2014; Lim *et al.* 2020). The ecology of bird communities in peat swamps in Malaysia is not well known given the difficulty of access to most sites, although there have been mist-netting surveys in south Pahang, north Selangor and the remnant peat swamps in Sabah's Klias Peninsula (e.g. Sheldon *et al*. 2014; Hawa *et al*. 2016). The extent of peat swamp forests in Malaysia have declined substantially, with an estimated 25% of the original extent remaining in Peninsular Malaysia and 36% in Malaysian Borneo as at 2010 (Posa *et al*. 2011). Since then, further losses have occurred due to logging, drainage and agricultural conversion (Amit *et al*. 2011; Hawa *et al*. 2016) and forest fires (Yong and Peh 2016). Anecdotal information suggests that the threatened Wrinkled Hornbill in both Peninsular Malaysia and Malaysian Borneo has become increasing rare, possibly linked to the loss of peat swamp and other lowland forest types, while Storm's Stork is now possibly on the verge of extinction in the peninsula with very few recent records (Wells 1999; Yong *et al*., in prep).

Montane forest birds

Among about 110 resident species that are dependent on montane forest and/or the broader sweep of hill slopes below, Malaysia supports interesting endemics or near-endemics. Ecologically integrated into the montane avifauna is a smaller number of forest-dependent migrants (e.g., Eyebrowed Thrush *Turdus obscurus*). Most mountains offer small areas of suitable habitat—typically less than a few tens of km^2—or, if they form mountain ranges (e.g., Crocker Range, Titiwangsa Range), the habitat is elongated, narrow, and easily fragmented by roads and tourism developments. Due to the altitudinal zonation within montane forest, few species can be found throughout. Populations of some species may be pocketed into valleys by intervening ridges, or vice versa. Documentation of Malaysia's montane avifauna are predominantly from a handful of well visited sites, where highland tourism and agriculture can potentially eat out the cores of protected areas. The popularity of hiking and birdwatching has increased the range of sites visited, but there are still large gaps in coverage.

When climate change is added to the mix, the lower elevational limits of montane species are expected to rise, confining them to increasingly smaller areas of higher ground and eventually forcing them off the peaks of 'sky islands' (Soh *et al.* 2021). Furthermore, elevation limits of lowland birds may be raised, complicating competition between them.

Small geographical range size is one of the best predictors of extinction risk amongst species (Harris and Pimm 1995). Montane endemics have generally smaller ranges than their lowland counterparts and are therefore more vulnerable (Long 1995). It is fortunate that Gunung Tahan and Gunung Kinabalu are within large and well-established protected areas, but neither of them supports the full suite of montane birds (see Sheldon *et al.* 1999; Wells 1999; Harris *et al*. 2012); every mountain tends to have a slightly differing subset of the whole montane bird community, making it necessary to protect a variety of montane landscapes for representativeness, covering Malaysia's different mountain ranges. Alonside these problems, the study and conservation of montane birds suffer from the same poor information base already highlighted for lowland forests.

Status of hornbill conservation and large forest landscapes

Some birds require very large forest landscapes to maintain genetically viable populations, either because food sources occur at low density or because they range over large areas. Hornbills have been documented travelling many kilometres between scattered, fruiting trees in forest landscapes. Medway and Wells (1971) suggested that viable hornbill populations might need more than 2,500 km^2 of forest, a size only achieved by Taman Negara among Peninsular Malaysia's protected areas. For species such as the Plain-pouched Hornbill *Rhyticeros subruficollis* that undertake seasonal migrations along the Malay Peninsula to non-breeding areas in Kedah and Perak (i.e. Ulu Muda, Belum-Temengor; see Kaur *et al*. 2011; Yeap *et al*. 2017), there is a need for the conservation of not just large forest landscapes, but also a connected network of forest landscapes across its distribution, including sites where the species stage.

As a result of habitat loss, the majority of Malaysian hornbill species are now globally threatened, with the exception of two species. The Helmeted Hornbill *Rhinoplax vigil* is the most imperilled, impacted not just by habitat loss, but is also targeted by hunters for its casques, and hunting is widely acknowledged to be the cause of its decline across its Southeast Asian distribution (Jain *et al*. 2020).

Status of pheasants and other Galliformes

Malaysia is rich in ground-living birds. There are 24 species of Galliformes (15 each in Peninsular Malaysia and in Malaysian Borneo), following recent taxonomic changes (Wells 1999; Mann 2008; Lim *et al.* 2020; Puan *et al.* 2020). Of these, only the Green Peafowl *Pavo muticus* is definitively extinct (Wells 1999; Table 2) although Peninsular Malaysia was probably only marginal to its historical range, where it was known from a few large rivers such as the Pahang, inhabiting seasonally shifting sandbanks and the immediately adjacent forest, and specialised vegetation types behind the east coast dunes (Robinson and Chasen 1936; Wells 1999). One re-introduction has been attempted (Othman 1998), but the outcomes unclear. Three species are endemic or near-endemic to Peninsular Malaysia and a fourth (Malaysian Peacock-pheasant *Polyplectron malacense*) may now be extinct in neighbouring countries. Eight are endemic to Borneo, of which two (lowland Sabah Partridge *Tropicoperdix graydoni* and hill-slope dependent Dulit Partridge *Rhizothera dulitensis*) are nearly or wholly endemic to Malaysia. The last-named species has not been reliably documented since 1902 (Berryman and Boakes 2023; Table 2).

Several pheasants have unusual mating systems of scientific interest. Nests of several species have never been found, and for others there are just a handful of records. One such species is the Malayan Crested Argus *Rheinardia nigrescens* (NT), primarily confined to the submontane and lower montane forests of Peninsular Malaysia and only recently recognised as a distinct species (Davison *et al*. 2020). Calls of several species are poorly documented or unknown, and diets virtually unknown. Thus, even basic facts needed for surveys and planning are lacking. Recent photography sites (e.g. Gunung Trus Madi, Sabah) have begun to yield new information that might be relevant to conservation of species such as the Bulwer's Pheasant *Lophura bulwerii* (Zaini 2024).

Globally, pheasants and partridges are among the most imperilled groups of birds, and a large proportion of species are listed on the IUCN Red List. While Galliformes tend to be charismatic attractions for ecotourism revenue, they are also vulnerable to indiscriminate ground traps and snares set by poachers (Yong *et al.* 2022). Devising conservation measures other than total protection for Malaysia's threatened pheasants is challenging. Captive breeding has been attempted for several species in Malaysia (see Othman 1998) but could be a drain on wild populations if numbers trapped exceed numbers released. Production of significant numbers of genetically unrelated individuals, and development of effective release techniques, have not yet succeeded.

Table 2. List of birds that may have been extirpated as breeding species in Malaysia. Species marked '?' may not have been totally extirpated.

Common name	Scientific name	IUCN Red List (2025)	Peninsular Malaysia	Sabah	Sarawak
White-winged Duck[1]	*Asarcornis scutulata*	CR	+		
Green Peafowl[2]	*Pavo muticus*	EN	+	?	?
Dulit Partridge	*Rhizothera dulitensis*	DD			?
Silvery Pigeon	*Columba argentina*	CR			
Sarus Crane[1]	*Antigone antigone*	VU	+	?	?
Beach Stone-curlew	*Esacus magnirostris*	NT	+		
Milky Stork[2]	*Mycteria cinerea*	EN	+		+
White-shouldered Ibis	*Pseudibis davisoni*	CR			
Red-headed Vulture	*Sarcogyps calvus*	CR	+		
White-rumped Vulture[1]	*Gyps bengalensis*	CR	+		
Slender-billed Vulture[1]	*Gyps tenuirostris*	CR	+		

[1] Species that are likely never more than marginal to Malaysian territory within the historical period.
[2] Species whose wild populations are certainly extirpated in Malaysia, but where reintroductions are either recently attempted or has recently reintroduced populations.

Status of migratory waterbirds

Close to 150 waterbird species are known from Malaysia, the largest families being the sandpipers (Scolopacidae), plovers (Charadriidae) and terns (Lariidae), the majority long -distance migrants from eastern and northern Asia (see also See *et al*. 2026). At least 24 species of sandpipers, including Nordmann's Greenshank Tringa guttifer (EN), Great Knot Calidris tenuirostris (EN), and Far Eastern Curlew Numenius madagascariensis (EN), regularly overwinter in Malaysia. Recent surveys show that coastal wetlands in Penang and Selangor supports some of the largest wintering congregations of Nordmann's Greenshank in the region (Effendi *et al.* 2024; Crosby *et al*. 2025), while Sarawak's Buntal Bay and the adjacent Sejingkat ash ponds host at least 1% of the world population of the Far Eastern Curlew (Bakewell *et al*. 2017; Teepol *et al*. 2023). Most migratory waterbirds in Southeast Asia are dependent on coastal wetlands such as intertidal mudflats as foraging habitat, alongside mangrove forests and adjacent areas of man-made wetlands such as fishponds and ash ponds as high tide roosts (Teepol *et al.* 2021) although the Masked Finfoot *Heliopais personata* uses mostly forested wetlands further inland (Chowdhury *et al*. 2020).

Whilst there are limited data on the long-term population trends of most migratory waterbirds in Malaysia, several species of shorebirds have expectedly declined, notably the Curlew Sandpiper *Calidris ferruginea*, and corroborated by monitoring data from other parts of the region (BirdLife International 2026). The Masked Finfoot, a regular non-breeding visitor until the 2010s, has not been definitively recorded for over a decade (Chowdhury *et al*. 2020). A recent exercise to prioritise wetlands of flyway-level importance for waterbirds identified seven coastlines, with mainland Penang (Kuala Muda–Teluk Air Tawar coast) and north-central Selangor coast of the highest priority (Crosby *et al*. 2025). Little is known about the importance and value for Sabah's coastline for migratory waterbirds but recent surveys by Makbul *et al*. (in review) suggest that Marudu Bay and Tawau coast are likely significant for migratory waterbirds, including for species such as Far Eastern Curlew. The discovery of wintering Spoon-billed Sandpiper *Calidris pygmaea* (Teepol *et al.* 2023) and small groups of Chinese Crested Tern *Thalasseus bernsteini* (Ng, J.J. in litt. 2025, Bakewell, D. in litt. 2026) in the coast of Sarawak and Sabah (Up to five individuals per Bakar, J. in litt. 2025) allude to the need for further work in Malaysian Borneo (BirdLife International 2025).

Status of raptors

Raptors in Malaysia have also attracted considerable attention from birdwatchers and local researchers. The country's ecosystems support a highly diverse raptor assemblage, comprising 47 diurnal and 22 nocturnal species that occupy a wide range of habitats. These include forests, wetlands, mangroves and limestone karsts, as well as human-modified landscapes, where raptors are ecologically important as apex or meso predators. Approximately 20 raptor species are migratory and are associated with the East Asian-Australasian, Central Asian and West Asian-East African flyways, with the Crested Honey Buzzard *Pernis ptilorhynchus* being the most prominent and regularly recorded migrant. Long-term migration monitoring at Tanjung Tuan and Taiping has revealed clear, species-specific patterns in northbound and southbound movements as raptors pass through Peninsular Malaysia, respectively (Puan and Yong 2026). In addition, citizen science initiatives have contributed essential data on breeding, behaviour and distribution of resident raptors, much of which has been published in birdwatching bulletins such as the '*Suara Enggang*' and '*Malaysian Bird Report*'. The resident subspecies of the Peregrine Falcon *Falco peregrinus ernesti* is of special interest, breeding mostly on limestone cliffs in Perak that are themselves threatened (Kéry *et al.* 2024), and has been extensively documented by citizen scientists.

In recent years, raptor research has advanced through ecological studies employing more sophisticated approaches, including bioacoustic methods (see Yee *et al*. 2016). The Eastern Barn Owl *Tyto javanica* remains the most widely distributed and intensively studied raptor species in Malaysia, largely due to its success in oil palm plantations, where abundant rodent prey and the widespread provision of nest-boxes facilitate both *in situ* and *ex situ* research (Puan *et al*. 2011). Despite these advances, over 40% of Malaysian raptor species remain poorly studied, particularly nocturnal species such as the Rajah Scops Owl *Otus brookii*, known only from limited records (Puan *et al*. 2015).

The conservation status of Malaysia's raptors has not been fully evaluated, but coastal (or wetland-dependent) raptors such as White-bellied Fish Eagle *Ichthyaetus leucogaster* and Brahminy Kite *Haliastur indus* appear to have held up well. Species such as Grey-headed Fish Eagle *Ichthyaetus icthyophaga* have also been able to take advantage of artificial waterbodies, such as impoundments, occurring even in dams in the Klang Valley (Yong, D.L. pers obs.). Raptors associated with open agriculture such as Black-shouldered Kite *Elanus caeruleus*, migrant harriers, eagles and vultures could all face pressures from habitat change, poaching and agro-chemicals (Puan *et al*. 2020). Species of forested riverscapes and inland forest are least studied and face the usual pressures of habitat loss, fragmentation and degradation. The position of raptor species at the top of food chains makes them susceptible to cascade effects upwards from other trophic levels.

Status of migratory passerines

About 48 species of passerines are regular migratory visitors to Malaysia, the majority chats, robins and flycatchers (Muscicapidae), followed by leaf warblers (Phylloscopidae; seven species), and swallows (Hirundinidae; five species). Few except for the Barn Swallow *Hirundo rustica*, Pallas's Grasshopper Warbler *Helopsaltes certhiola*, and Oriental Reed Warbler *Acrocephalus orientalis*, among the commoner species, were extensive studied through ringing in Sungai Way in the 1960s (Nisbet 1972). Recent migration studies have tracked Pallas's Grasshopper Warbler from eastern Russia to Peninsular Malaysia (Slepsov *et al*. 2023). Tropical lowland forests and paddy fields are the key habitat for most species, with about 30 species known to overwinter in lowland dipterocarp forests, ten species strongly associated with freshwater wetlands (Yong *et al*. 2022), and at least six species in mangroves (Round *et al*. 2026). In the absence of long-term ringing studies, it is difficult to assess species population trends although Wells (1999) reported lower densities of Siberian Blue Robins *Luscinia cyane* in logged and degraded forests (in Pasoh Forest Reserve), suggesting that forest-wintering passerines are more sensitive to the effects of deforestation

than thought. The Himalayan-breeding Large Blue Flycatcher *Cyornis magnirostris* (lumped with the Hill Blue Flycatcher *sensu lato* for a period, *C. banyumas*) winters largely in the lowland forests of the Malay Peninsula and was almost as numerous as Siberian Blue Robin based on bird ringing data from Fraser's Hill in the early 1970s (Medway and Wells 1976), but there are no recent records. On the converse, the Rufous-headed Robin *Luscinia ruficeps*, one of Asia's least known migratory passerines and known previously from one record (Wells 2006), was rediscovered in the Genting Highlands (Gunung Ulu Kali) in the 2010s, where at least one individual was observed over two consecutive winters (Puan *et al*. 2020; Yong *et al*. 2020).

Seabird breeding colonies

Malaysia supports seven breeding seabird species: all terns, except for the Brown Booby *Sula leucogaster*, although Masked Booby *Sula dactylatra* may potentially breed. Over the 2016 – 2019 period, surveys covering islands and rocky islets on the east coast of Peninsular Malaysia between Terengganu and Johor reported large breeding colonies of Black-naped *Sterna sumatrana* and Bridled terns *Amniochorion anethetus*, and potentially smaller groups of Roseate terns *S. dougallii* (Hamza *et al*. 2016a, 2016b, 2019). The islets of Tokong Burung in Johor's Seribuat Archipelago, protected in a series of marine parks (e.g. Tioman, Pulau Tinggi), were found to support 10,000 pairs of Bridled Terns, likely the largest in the region (Hamza and Wong 2020). Recent surveys of the Melaka Straits islands, notably Pulau Perak, confirmed that historically documented breeding colonies of Brown Booby and Brown Noddy still occur (Tan C.E. pers. obs.), albeit only with about 200 individuals of either species (Abdul Rahman *et al*. 2025). Hamza *et al*. (2019) noted that none of these islands are formally protected and are at risk from introduced rats and indiscriminate egg collection and disturbance from fisherman and tourists (also Wells 1999). Off the coast of Malaysian Borneo, the atoll of Layang-Layang remains important for several breeding seabirds, including Greater Crested Tern *Thalasseus bergii* and Brown Booby, with over 1,000 pairs of the former (Marzuki *et al*. 1997; Wells 1999; Tan, C.E. pers. obs.), while most of the islands closer to the Sabah and Sarawak coast typically support breeding Black-naped and Bridled Terns (e.g. Talang-Satang) (Wilson 2002). Presently, there is very limited monitoring or survey work of seabird colonies, or information on breeding populations and recruitment, and there is much scope for long-term studies established at some of the more accessible colonies off the Peninsular east coast, alongside targeted conservation work to, control egg collection, restore habitat at breeding colonies and manage introduced predators.

KEY THREATS

The threats and drivers of decline faced by birds in Malaysia represent the myriad threats faced by species in Southeast Asia (Wells 1999; Puan *et al.* 2020; Yong *et al*. 2022). Presently, 80 species (about 9%) of Malaysia's avifauna are globally threatened. As of 2025, 13 species are 'Critically Endangered', 18 'Endangered' and a further 49 'Vulnerable' (see Table 3). Habitat loss driven by deforestation and exacerbated by fragmentation, is the single biggest threat to species in the country, affecting the widest range of species. In the past two decades, the rate of deforestation in both Peninsular Malaysia and Malaysian Borneo have remained steady, primarily driven by commercial logging and monoculture expansion although the two are not always mutually exclusive. Forested land, especially in the lowlands, is excised for logging, and typically cleared later for palm oil monoculture (Koh and Wilcove 2010; Azhar *et al*. 2011). To date, research on the impacts of logging on forest bird communities has looked at the effects of varying intensities of forest disturbance (logging) (Meijaard *et al.* 2005; Peh *et al*. 2006), comparison of forest areas before and after logging (Johns 1992, 1996; Hawa *et al*. 2016) and disturbance gradients (Nordin *et al.* 2025), and forest fragmentation (Yong *et al*. 2011; Atikah *et al.* 2025). Large-bodied species such as hornbills are most impacted by forest loss, degradation and fragmentation, given the loss of preferred nesting tree species and food sources (Yeap *et al.* 2026), but small-bodied species such as insectivorous birds are also impacted (Yong *et al.* 2011).

Table 3. Global conservation status of threatened, near threatened and data deficient species recorded in Malaysia, whether resident or otherwise. Categories follow the IUCN Red List (2025).

IUCN Category	Peninsular Malaysia	Sarawak	Sabah	Total
Globally Extinct (EX)	0	0	0	0
Extinct in the Wild (EW)	0	0	0	0
Critically Endangered (CR)	10	6	3	13
Endangered (EN)	16	13	13	18
Vulnerable (VU)	34	35	35	49
Near Threatened (NT)	95	88	89	106
Data Deficient (DD)	–	1	2	2

The conversion of coastal intertidal wetlands directly reduces habitat for migratory waterbirds, and its impact on shorebirds, for instance, has been well documented in East Asia. While there remain extensive intertidal mudflats and mangroves on the Peninsular, Sabah and Sarawak coasts, the expansion of port infrastructure and residential development has contributed to the loss and degradation of coastal wetlands in the Peninsular, especially in Johor, Selangor and Penang (Yeap *et al.* 2007; Williams 2016). Few areas of coastal wetlands, and especially intertidal wetlands, are formally protected, exposing much of these key habitats for shorebirds to future conversion to land uses such as aquaculture (Yeap *et al.* 2007; Yong *et al*. 2021). Further inland, three artificial wetland types remain important for birds, former tin-mining areas (especially in Perak) (Mohd Rafi Kudus *et al*. 2010), ash ponds (Teepol *et al.* 2023) and paddy fields (Azman *et al*. 2019). Most tin-mining areas in Peninsular Malaysia have now been reclaimed and redeveloped although there are pockets such as the Taman Alam Kinta preserved for its scenic beauty as part of the Kinta Valley Geopark. Waterbirds that use paddy fields, however, are exposed to the impacts of agricultural intensification, which limits that amount of suitable wetland habitat in a rice farming landscape.

The songbird trade is widely acknowledged to be a major threat for several songbird species (see Krishnasamy and Stoner 2016; Chng *et al.* 2021) and impacts birds in two ways: (1) birds are removed from their wild populations at an unsustainable rate, driving declines, or (2) unintended introductions may result in species invasions of alien species. As with neighbouring Indonesia, the trapping of targeted, high-value species for the cagebirds trade immediately threatens at least ten species, the majority forest species, and most famously leafbirds *Chloropsis* spp., White-rumped Shama *Copsychus malabaricus*, Oriental Magpie Robin *C. saularis*, and several species of bulbuls (Pycnonotidae) (Lim *et al.* 2020; Chng *et al.* 2021), even though all are protected in some way under the wildlife legislation of Peninsular Malaysia, Sabah or Sarawak.

RECOMMENDATIONS AND NEXT STEPS

This paper identifies several priorities to advance the knowledge base on the state of key bird groups and families in Malaysia, whilst highlighting recommendations that can strengthen bird conservation.

First, there is a need for continued work to prioritise key areas of forest landscapes and coastal wetlands for bird conservation, building on existing work to identify, assess and delineate IBAs (Yeap *et al.* 2007). These prioritised areas have long-term potential for site-level conservation activities, including through the designation of protected areas such as state parks (and national parks in Sarawak) and wildlife sanctuaries. The Malaysian Nature Society (MNS) and BirdLife International have to date identified 55 sites as IBAs (Yeap *et al.* 2007), representing the full suite of forest and wetland landscapes important for bird conservation in Malaysia, but over time new areas important for bird conservation have

been identified. Several large forest landscapes in Peninsular Malaysia, including the Dungun forest complex (Liang *et al.* 2018) and coastal wetlands in Sabah (e.g. Makbul *et al*., in review) currently lack comprehensive survey data but are expected to be important for bird conservation.

Second, the identification of priority landscapes and the design of protected areas for bird conservation needs to be guided by the ecological principles of landscape connectivity, given that large-bodied birds such as hornbills and raptors have large foraging ranges, while migratory waterbirds typically disperse extensively across wetland areas for foraging (e.g. Teepol *et al.* 2021). Existing initiatives to promote and advance landscape connectivity are already in place for large mammal conservation (e.g. Malayan Tiger, Asian and Borneo Pygmy Elephants) such as the 'Central Forest Spine' and 'Heart of Borneo' initiatives (Sloan *et al.* 2019) and offers opportunities and mandates for synergy with conservation initiatives targeting forest birds. However, there are also opportunities to build and maintain ecological connectivity within landscapes, even in the Greater Klang Valley where there remain extensive forest patches embedded within a wider suburban matrix (e.g. see *Rantaian* Urban Green Spaces – RUGS; https://www.rugs.my/), as well as wetland sites.

Third, there is a need to strengthen existing levels of protection for species of high conservation priority, and this may involve a combination of compiling a National Red List for Birds in consultation with diverse stakeholders (see Lang *et al.* 2014), alongside species conservation action plans for flagship species. Action plans already exist for species such as the Helmeted Hornbill (Jain *et al.* 2018) outlining the key actions regionally and nationally, but there are opportunities to develop or convene either regional or national-level action plans for other large, charismatic species such as the other hornbills, waterbirds, raptors and several pheasants. Such action plans, however, need to be implemented on the ground in coordination with local stakeholders such as local NGOs, community members, while ensuring that there are clear and tangible benefits for local communities (e.g. livelihood benefits).

Finally, there is a need to strengthen the evidence base for bird conservation through a combination of targeted research (focusing on threatened species, or landscape management) and leveraging on the potential of citizen science (Puan *et al*. 2019), which has grown considerably in Malaysia in the past decade. There are large knowledge gaps on the status and ecology of many threatened species, including species of montane forests and peat swamps, inaccessible habitats which has hampered efforts to collect data here although new technology such as bioacoustic monitoring and the use of camera traps may help address gaps, especially for cryptic, terrestrial species (Liang *et al.* 2018; Berryman and Boakes 2023). The use of ubiquitous tracking technology can also be more widely deployed on species such as hornbills, shorebirds and other large waterbirds to gather data on movements and range size, which can in turn inform conservation. While citizen science tends to bias data availability to the most accessible sites (such as Fraser's Hill, Panti Bird Sanctuary), there are opportunities for citizen science to address knowledge gaps in wetland areas that are near major settlements.

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CHAPTER 2

State of hornbill conservation in Malaysia

CHIN-AIK YEAP[1]*, G.W.H. DAVISON[2] and DING LI YONG[3]

Abstract: Hornbills are widely recognised in Malaysia and hold a deep cultural and spiritual significance to the indigenous communities in Malaysian Borneo. Ecologically, they play an important ecological role as seed dispersers, hence the moniker "farmers of the forest". Ten hornbill species (six genera) are recorded in the country. Small Malaysian states support at least one species, and larger States, usually with large forest areas, can support up to ten species. This paper provides a broad overview of hornbill distribution, ecology, population status, and conservation based on published and unpublished sources, and insights from past and present conservation and citizen science efforts in the country.

INTRODUCTION

Hornbills are iconic birds in the semi-tropical and tropical forests of Asia. To birdwatchers, hornbills are regarded as 'must-see' species in birdwatching trips in pristine forests such as Taman Negara in Peninsular Malaysia and Danum Valley in Sabah (Yong and Low 2018). Culturally, the indigenous Dayak communities of Borneo revere the Rhinoceros Hornbill (*Buceros rhinoceros*), which symbolises purity and strength (Aquarini *et al*. 2022). In Sarawak (East Malaysia), this hornbill species is recognised as the official state bird and is depicted in the state emblem—though it is not Malaysia's national bird, contrary to what is often mistakenly depicted in social media platforms. Ecologically, hornbills consume fruit of many plant species and broadcast the regurgitated or defaecated seeds throughout the forest landscape where they can germinate (Kinnaird and O'Brien 2007; Kitamura 2011). Hence, hornbills are now popularly known as 'farmers of the forest'.

To date, 32 hornbill species (family Bucerotidae) are recognised and spread across 19 range countries (Poonswad *et al.* 2013; Kemp 1995). Indonesia and Thailand have the highest hornbill diversity per country, with 13 species each, followed by Malaysia, Myanmar and the Philippines, each with ten species. Six (*Anthracoceros*, *Berenicornis*, *Anorrhinus*, *Rhabdotorrhinus*, *Rhyticeros*, *Buceros*, and *Rhinoplax*) of the 11 Asian hornbill genera occur in Malaysia. In this context, Malaysia is an important range country for Asian hornbills. Until the 1990s, Malaysia was thought to support nine species, until the Plain-pouched Hornbill (*Rhyticeros subruficollis*) was accepted as the tenth hornbill species in 2000 (Chew and Supari 2000; Records Committee, MNS-BCC 2000). The seasonal presence of hundreds of Plain-pouched Hornbills, first detected in northern Peninsular Malaysia, was attributed to the commoner Wreathed Hornbill (*Rhyticeros undulatus*) before mounting evidence proved it to be a distinct species (Rasmussen 2000).

DISTRIBUTION WITHIN MALAYSIA

Hornbill species distribution differs geographically in Malaysia. All ten species occur in Peninsular Malaysia while Sabah and Sarawak have eight species (Chasen, 1939; Smythies 1999; Wells 1999; Khusaini *et al.* 2015). The Great (*Buceros bicornis*) and Plain-pouched

[1] Malaysian Nature Society, JKR 641, Jalan Kelantan, Bukit Persekutuan, 50480 Kuala Lumpur.
[2] National Parks Board Singapore, 1 Cluny Road, Singapore 259569
[3] BirdLife International (Asia Division), 354 Tanglin Road, #01-16/17, Tanglin International Centre, Singapore 247672
***Corresponding author: hornbills@mns.org.my / msiahornbill@gmail.com**

Hornbills do not occur in Borneo. As almost all hornbill species depend on forests for survival, Malaysian States with remaining sizable forest landscapes generally support high hornbill diversity (Table 1). Perak and Kedah are the only states to have ten species each. Johor, Pahang, and Terengganu support nine species each while Selangor, Negeri Sembilan, Sabah and Sarawak have eight species respectively. Despite being less than 1% of Peninsular Malaysia's landmass, Perlis also supports eight species—all found in Perlis State Park. Surprisingly, only six species have been recorded in Kelantan despite the available forest area. In small States such as Pulau Pinang, Federal Territory Kuala Lumpur, and Melaka, one to three species are encountered. Two hornbill species, the Great and Oriental Pied (*Anthracoceros albirostris*), do occur on islands such as the Langkawi archipelago (Kedah), Pulau Pangkor (Perak), and only Oriental Pied on Pulau Gaya and Pulau Tiga (Sabah) (Sheldon *et al*. 2001; Yeap 2005; Mohd-Taib *et al.* 2019). The Langkawi Archipelago likely supports the largest breeding population of Great Hornbills off the mainland Peninsular Malaysia, where more than 100 individuals have been counted (Hassan and Yatim 2003). However, hornbills are strangely absent in the islands off the east coast of Peninsular Malaysia (e.g., Pulau Tioman, Pulau Redang).

Table 1. The number of hornbill species recorded in Malaysian States, and current forest cover.

State	State area (ha)	Forested area (ha)[a]	Protected area (ha)[b]	No. of hornbill species
Peninsular Malaysia*				
(i) Perlis	81,313	11,140	68	8
(ii) Kedah	946,616	343,466	2	10
(iii) Pulau Pinang	105,916	6,063	2,508	1
(iv) Perak	2,087,573	987,963	4,711	10
(v) Selangor	790,781	250,987	9,892	8
(vi) Federal Territory (Kuala Lumpur, Labuan & Putrajaya)	38,615	153	24	1[c]
(vii) Negeri Sembilan	665,846	154,934	216	8
(viii) Melaka	167,018	5,187	99	3
(ix) Johor	1,908,812	334,491	157,619	9
(x) Pahang	3,592,987	1,588,596	350,734	9
(xi) Terengganu	1,295,725	540,309	103,082	9
(xii) Kelantan	1,503,637	629,881	91,440	6
Subtotal (A)	**13,184,839**	**4,853,170**	**720,395**	
Sarawak**	7,650,000	3,950,000	2,118,249	8
Sabah***	4,600,000	3,575,035	274,129	8
Subtotal (B)	**12,250,000**	**7,525,035**	**2,392,378**	
TOTAL (A+B)	**25,434,839**	**12,378,205**	**3,112,773**	**10**

*Based on Forestry Department Peninsular Malaysia Annual Report 2024.
**Based on Sarawak Forestry Department Annual Report 2023.
***Based on Sabah Forestry Department Annual Report 2024.
[a] Forested Area refers to Forest Reserves in Peninsular Malaysia and Sabah, and Permanent Forest Estates in Sarawak.
[b] Protected Areas refers to National Park, Wildlife Reserve, Wildlife Sanctuary, Birds Sanctuary, Ramsar Sites in Peninsular Malaysia, National Parks, Wildlife Sanctuaries, Nature Reserves, Marine Parks, Wildlife Rehabilitation Centres in Sarawak, and Parks, Wildlife Sanctuaries, Conservation Areas in Sabah.
[c] Kuala Lumpur only.

Hornbills are typically found in most well-forested landscapes in Malaysia. Madoc (1947) remarked that "*most of them are resident in virgin jungle, extending from the mangrove belt to the mountain tops*". Wildlife/biodiversity surveys and birdwatcher sightings in Malaysia have shown that hornbill diversity is greatest in the lowland forests (<300 m a.s.l.), i.e. freshwater/peat swamp to lowland dipterocarp forest, where all ten species can be found. Hornbill diversity then declines gradually from hill to upper dipterocarp forests as elevation increases (Table 2). Only two to five species, i.e. Bushy-crested (*Anorrhinus galeritus*), Wreathed, Great, Rhinoceros, and Helmeted Hornbills (*Rhinoplax vigil*) occur in forests above 1,000 m a.s.l.. Mangroves and coastal vegetation support only a single hornbill species. The Wrinkled Hornbill (*Rhabdotorrhinus corrugatus*) is regarded as a habitat specialist as they prefer peat/freshwater swamp forests (BirdLife International 2026) though it can be seen in or overflying other forest types. The Oriental Pied Hornbill has adapted well to human-modified landscapes such as wooded parks, orchards, gardens, and agricultural lands (Wells 1999; Azhar *et al.* 2011; Jeyarajasingam 2012). They have even been spotted in cities, e.g. Federal Territory Kuala Lumpur, Kuantan, Miri, and Melaka (Tisen and Abang Arabi 2015; Nair 2019; Murali 2020).

Table 2. Hornbill species according to altitudinal distribution and vegetation type* in Malaysia. (Adapted from Smythies 1999; Wells 1999; Harris *et al.* 2012; Jeyarajasingam 2012).

Vegetation Type*	Altitude (m a.s.l.)	Oriental pied	Black	Bushy-crested	White-crested	Wrinkled	Wreathed	Plain-pouched	Great	Rhinoceros	Helmeted	Total number of species
Mangrove	0 – 299	■										1
Coastal vegetation		■										1
Freshwater / peat swamp		■	■	■	■	■			■			6
Lowland dipterocarp		■	■	■	■	■	■	■	■	■	■	10
Hill dipterocarp	300 – 749	■	■	■	■	■	■	■	■	■	■	8
Upper dipterocarp	750 – 1,199	SVV	■	■	■		■	■	■	■	■	8
Montane oak	1,200 – 1,499	VV		■			■		■	■	■	5
Upper montane	≥ 1,500	ZV					■				■	2
Total no. of vegetation types occupied			4	5	4	3	5	3	5	4	5	

Note: *Vegetation classification follows the Forestry Department Peninsular Malaysia.

FOOD PLANTS AND FEEDING ECOLOGY

Asian hornbills and several plant families in the tropical forests have co-evolved together thus retain a close ecological relationship (Viseshakul *et al.* 2011). Hornbill gape sizes (30 – 55 mm) allowed them to exploit and consume many fruit tree species in the rainforest (Corlett 1998, 2017; Kitamura *et al*. 2004; Liang *et al*. 2024). Mid- to large-sized Asian hornbills consume more fruit than small-sized hornbills (e.g., *Anthracoceros*, *Berenicornis*, *Annorhinus*) (Kitamura *et al.* 2004). Cumulatively, Asian hornbills consume fruits of 495 plant species (46 families) (Kinnaird and O'Brien 2007). An unpublished report by Chai and Yeap (MNS Hornbill Conservation Project, unpublished data) that analysed data from local Malaysian journals showed that the six most dominant food plants consumed by hornbills in Malaysia belong to the Lauraceae, Moraceae, Meliaceae, Myristicaceae, Euphorbiaceae, and Annonaceae plant families. Documenting and observing hornbill feeding behaviour in the forests is generally difficult and time-consuming. In Malaysia, most knowledge is derived from opportunistic birdwatching and a handful of hornbill field research projects (Madge 1969; Andrew 1982; Pan 1987b; Lambert 1989; Smythies 1999; Wells 1999; Kaur et al. 2015, 2018; Yeap et al. 2016; Rahman et al. 2019; Yeap 2025).

The consumption of figs (*Ficus* spp.) by hornbills is well-known (Kinnaird and O'Brien 2007). The Helmeted Hornbill is regarded as a 'fig specialist' as their diet consists largely of figs (Lambert 1989; Kinnaird and O'Brien 2007; Kaur *et al*. 2018). Despite their poor nutritional value (Leighton 1982), figs sustain frugivorous animals through periods when other fruit sources are scarce or unavailable (Leighton and Leighton 1983; Lambert and Marshall 1991). Compared to seasonal fruits, figs do not have a distinct fruiting pattern, and monthly rainfall is not known to influence fruiting episodes (Lambert and Marshall 1991). In the Belum-Temengor Forest Complex (BTFC), Perak, hornbills continue to rely on figs after the peak fruiting period of other trees (July to September) (Yeap 2025). In Malaysia, hornbills have been documented consuming at least 26 fig species (*The Figs of Borneo*, n.d.; Lambert 1989; Lambert and Marshall 1991; Wells 1999; Kaur *et al.* 2018) (Figure 1). The Rhinoceros, Helmeted, Black and Bushy-crested Hornbills each consume more than ten fig species. In a study by Lambert (1989), the Helmeted, Rhinoceros, Black, and Bushy-crested Hornbills consumed figs on more than 50 occasions in three years in Tengku Hassanal Wildlife Reserve (formerly Krau Wildlife Reserve). Lambert's (1989) work remains the only long-term research on the relationship between birds and figs in Malaysia to date. In Kinabatangan Wildlife Sanctuary, a nesting pair of Helmeted Hornbills depended mainly on four fig species to feed the chick (Kaur *et al*. 2018).

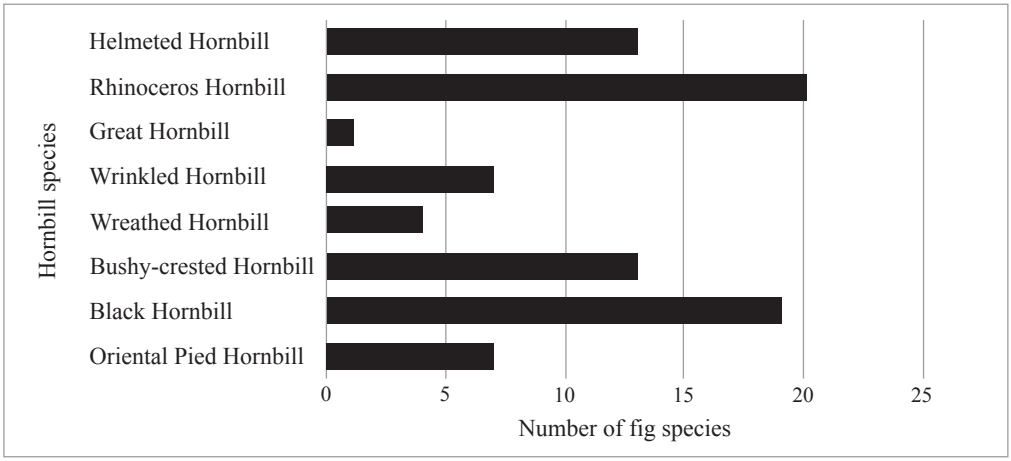

Figure 1. The number of fig (*Ficus*) species known to be consumed by hornbills in Malaysia. (Note: Sample sizes (numbers of observations) are not standardised.)

Apart from consuming fruits, hornbills have been recorded hunting small mammals, small birds, reptiles, and insects in forests and urban/semi-urban areas (Wee 2023). In Sabah, the Oriental Pied and Bushy-crested Hornbills have learnt to catch Wrinkle-lipped Free-tailed Bat (*Mops plicatus*) emerging from caves in the Kinabatangan area (Amar-Singh 2025; Tella *et al.* 2025). They have also been documented catching edible-nest swiftlets (*Aerodramus fuciphagus*) as they leave the entrance to their "swiftlet motel" (Chong *et al.* 2021). The White-crowned Hornbill also consumes a large proportion of animal prey in their diet (Poonswad *et al.* 2013).

NESTING RESOURCES AND ECOLOGY

Hornbill nests are incredibly hard to locate in the forests. Hornbill pairs are often secretive during their nesting period, making them hard to observe. Information on nesting hornbills and their breeding period in Malaysia is patchy and not well defined (Madge 1969; Johns 1982; Pan 1987a, 1987b; Smythies 1999; Wells 1999; Styring et al. 2002; Chong 2011;

Anuar Abdullah McAfee, pers. comm.). Hornbills have been reported in different stages of nesting between January and August based on extant information (Wells 1999) (Table 3). Long-term hornbill monitoring in BTFC revealed that nine hornbill species (except Plain-pouched Hornbill) generally start nesting from February, with chick(s) fledging between May and July (MNS Hornbill Conservation Project, unpublished data). Hornbill pairs would extend their nesting period well into August if they start late in the season. The breeding patterns of hornbills in BTFC corresponded with the flowering and fruiting season—hornbill chick(s) fledged at the height of the fruiting season in June and August. However, Helmeted Hornbills do not seem to have a defined nesting period (MNS Hornbill Conservation Project, unpublished data).

Table 3. Breeding months of the hornbills in the Belum-Temengor Forest Complex (BTFC) and other locations in Malaysia.

Hornbill species	Month												References
	J	F	M	A	M	J	J	A	S	O	N	D	
Outside the Belum-Temengor Forest Complex													
Oriental Pied Hornbill	■	■	■	■	■	■							4,5,7,11
Black Hornbill	■	■		■									6, 7
Bushy-crested Hornbill	■	■	■		■	■	■	■		■			3, 6, 10, 13, 14
White-crowned Hornbill					■	■						■	6, 7
Wrinkled Hornbill	No information												n/a
Wreathed Hornbill	No information												n/a
Great Hornbill	■	■	■	■	■	■							11
Rhinoceros Hornbill	■	■	■	■	■	■							2, 7, 11
Helmeted Hornbill					■	■	■	■	■	■			1, 7, 8, 11
Within the Belum-Temengor Forest Complex													
Oriental Pied Hornbill	■	■	■	■	■	■							12
Black Hornbill			■	■	■	■	■						12
Bushy-crested Hornbill	■		■	■	■	■				■			12
White-crowned Hornbill			■				■	■					12
Wrinkled Hornbill			■	■	■	■	■	■					12
Wreathed Hornbill	■	■	■	■	■	■	■	■					12
Great Hornbill	■	■	■	■	■	■							9, 12
Rhinoceros Hornbill			■	■	■	■	■	■	■				9, 12
Helmeted Hornbill				■	■	■	■	■	■	■	■	■	9, 12

Notes: n/a = Not available

(i) [1] Chong (2011), [2] Johns (1982), [3] Madge (1969), [4] Pan (1987a), [5] Pan (1987b), [6] Smythies (1999), [7] Wells (1999), [8] Kaur *et al.* (2018), [9] Kaur *et al.* (2015), [10] Styring *et al.* (2022), [11] A. A. McAfee (personal communication, April 15, 2018), [12] MNS Hornbill Conservation Project (unpublished data), [13] Lim *et al.* (2020), [14] Wong (2020)

(ii) There are no observations of Plain-pouched Hornbill breeding in Peninsular Malaysia.

For nesting, hornbills often select cavities in trees that are (1) tall and large, (2) commonly found or locally abundant in their area or site, and (3) durable (Poonswad 1995) as they are often reused in the following nesting season. In BTFC, hornbills nested in trees of eight families, i.e., Dipterocarpaceae (four species), Fabaceae (four), Tetramelaceae (one), Meliaceae (one), Euphorbiaceae (one), Sapotaceae (one), Combretaceae (one) and Moraceae (one) (Table 4). The mean diameter at breast height (dbh) of nest trees ranged between 81.2 and 122 cm, depending on species (Table 4). Nine resident hornbill species in BTFC have been confirmed breeding by the MNS Hornbill Conservation Project in the landscape—an effort that took 14 years to achieve, which underscores the difficulty in locating hornbill nests in the forest. The exception is the Plain-pouched Hornbill, which may breed there but is so far known only as a seasonal migrant. Elsewhere in Malaysia,

six hornbill species have been documented nesting in trees of the Meliaceae (*Xylocarpus* sp.), Dipterocarpaceae (*Shorea pauciflora*, *Shorea* sp. 1, *Shorea* sp. 2), Fabaceae (*Koompassia excelsa*), Sapindaceae (*Pometia pinnata*), and Myristicaceae (*Myristica* sp.) families, as well as five unknown tree species (Chasen 1939; Madoc 1947; Pan 1987b; Noramly 1998; Wells 1999; Styring *et al*. 2002; Chong 2011; Kaur *et al.* 2018). To date, hornbills have been reported breeding in Kedah, Perak, Selangor, Pahang, Johor, Terengganu, Sarawak and Sabah based on direct (nest tree) and indirect evidence (presence of juveniles) (Yeap *et al.* 2023). This points to the frequency of observations rather than the distribution of hornbill breeding.

Table 4. Nest tree measurements used by nine hornbill species in Belum-Temengor Forest Complex. (MNS Hornbill Conservation Project, unpublished data).

Species	Nest Tree GBH Range		Mean GBH (cm)	Mean DBH (cm)	Tree Family
	Low (cm)	High (cm)			
Oriental Pied Hornbill	110	429	255	81.2	Dipterocarpaceae, Fabaceae, Tetramelaceae, Euphorbiaceae
Black Hornbill	150	374	220	70.1	Dipterocarpaceae, Fabaceae, Euphorbiaceae
Bushy-crested Hornbill	140	462	276	87.9	Sapotaceae, Dipterocarpaceae, Fabaceae, Tetramelaceae
White-crowned Hornbill	172	323	248	79.0	Dipterocarpaceae, Euphorbiaceae
Wreathed Hornbill	259	399	295	93.9	Dipterocarpaceae, Combretaceae
Wrinkled Hornbill	226	231	229	72.9	Moraceae
Great Hornbill	192	394	292	93.0	Fabaceae, Tetramelaceae, Dipterocarpaceae
Rhinoceros Hornbill	191	730	312	99.4	Fabaceae, Tetramelaceae, Dipterocarpaceae, Euphorbiaceae
Helmeted Hornbill	250	483	383	122.0	Meliaceae, Fabaceae, Dipterocarpaceae

Note: GBH = girth at breast height / DBH = diameter at breast height.

Extraordinarily, Oriental Pied Hornbills have also been documented nesting recently in a karst limestone cavity around Ipoh city (Amar-Singh and Chiu 2024). This behaviour was attributed to a lack of suitable and available natural cavities in the area frequented by the hornbill pair, as large old trees have been chopped down by the city council in favour of replanting other plants for landscaping. At Halong Bay (Vietnam), the same species inhabits many limestone islands that lack both large trees and natural predators, and presumably also nests in rock cavities (Beharrell and Ryder, 2004; G.W.H. Davison, pers. comm.) In Sungai Panjang (Selangor), these hornbills nested in large earthenware water jars for several years (Ismail *et al.* 2015). Recent social media postings amazingly captured Oriental Pied Hornbill pairs sealing letterboxes that were encased in cement gate pillars. Their use of non-tree, and even man-made structures as alternatives to natural tree cavities showcases the resilience and adaptive behaviour of Oriental Pied Hornbills, contrasting with the more specialised nesting conditions required by deep forest specialists.

HORNBILL POPULATION STATUS IN MALAYSIA

Population estimates of the ten hornbill species in Malaysia are presently unavailable, as no national or state-level population census has been attempted. Site-specific, short surveys in protected and non-protected areas have produced some preliminary estimates on hornbill abundance and density through line or belt transects (Kemp and Kemp 1974; Davies and Payne 1982; Lakim and Biun 2005; Mohd Jamil *et al.* 2015; SFC 2017; Davies 2022) (Table 5). In the latter, estimates were largely derived from logging-wildlife studies or assessments in forest reserves (Dahaban 1994; Hussin 1994; Johns 1987; WWFM 1998; Mohd-Azlan *et al.* 2023).

Table 5. Density estimates for 10 hornbill species in protected and non-protected areas in Malaysia.

Species	Status		References*
	Protected Area (individuals/km^2)	Non-Protected Area (individuals/km^2)	
Oriental Pied Hornbill	1	0.1	1, 2
Black Hornbill	0.3 – 2.3	0.6	1, 3
Bushy-crested Hornbill	0.2 – 3.4	0.3 – 1.0	1, 3, 4, 5,
White-crowned Hornbill	0.4	0.8	3
Wrinkled Hornbill	1.6	0.1 – 1.6	3, 4
Wreathed Hornbill	1.2	0.2 – 0.8	4
Plain-pouched Hornbill	No estimate	No estimate	No reference
Great Hornbill	No estimate	No estimate	No reference
Rhinoceros Hornbill	0.5 – 1.0	0.2 – 2.3	1, 3, 4, 5, 6
Helmeted Hornbill	0.2 – 1.9	0 – 2.5	1, 3, 4, 7, 8

Notes: [1] Medway and Wells (1971), [2] Mohd Jamil *et al.* (2015), [3] Kemp and Kemp (1974), [4] Johns (1987), [5] Meredith (1995), [6] Dahaban (1994), [7] Davies (2022), [8] Bennett *et al.* (1997).
*Several studies i.e. SFC (2017), Davies and Payne (1982), Hussin (1994), WWF-Malaysia (1998), Mohd-Azlan *et al*. (2023) were not included in the Table above as hornbill densities were not expressed in different ways and not convertible to the metric used. In Lakim and Biun (2005), hornbill densities were not estimated under usual conditions, as explained in the text below, thus excluded as well.

In intact forest landscapes, hornbill density typically varies between 0.1 – 3.4 individuals/km^2 depending on species. However, density estimates in the Tawau Hills Park (Sabah) showed were unusually high for the Oriental Pied (19.7 individuals/km^2), Black (7.1), Bushy-crested (26.3), Wreathed (11.2), and Rhinoceros Hornbills (5.7) (Estimates not included in Table 5) (Lakim and Biun 2005). These high figures were attributed to hornbills that were attracted to a fruiting fig tree at the time of the census. The availability of hornbill -preferred fruits (figs and non-figs) can attract an influx of hornbills into an area, thus inflating hornbill numbers temporarily (Ardiantiono *et al.* 2020; Koid *et al*. 2021). The numbers also reflect difficulty in defining the boundaries of survey areas when calculating densities of species that can potentially travel long distances. In BTFC, the seasonal arrival of Plain-pouched Hornbills coincides with the peak fruiting period between July and September (Kaur *et al.* 2011; Yeap *et al*. 2015). After September they leave the landscape and are thought to migrate back to southern Thailand. On islands, hornbill density estimates can also be higher than on the mainland, possibly due to island size, reduced interspecific food competitors, reduced predator diversity, or easier definition of study area boundaries. In Pulau Tiga Park (Sabah), a high density of Oriental Pied Hornbills (19.7 individuals/km^2) was reported in a 6.1 km^2 area (Lakim and Biun 2005).

Wildlife assessments in logging concessions in forest reserves in Peninsular Malaysia and Sarawak have also yielded some hornbill density estimates. Hornbill density for eight species in four different-aged, logged concessions in Sungai Tekam (Pahang, Malaysia) was low (Johns 1987). The Bushy-crested, Wreathed, Rhinoceros, and Helmeted ranged from 0.4 – 1.7 individuals/km^2 in the primary forest but dropped to 0 – 1.8 individuals/km^2. The Helmeted Hornbills showed a high density of 2.1 individuals/km^2 in a three- to four-year -old logged concession, which was unexpected as it was higher than in the primary forest (1.7 individuals/km^2). The Great Hornbill was not recorded in any of the post-logged concessions. The Black and White-crowned Hornbills were present in the three- to four-year-old and above logged forests. The Wrinkled Hornbill was hardly detected in primary and logged forests.

In Terengganu, six hornbill species (Black, Bushy-crested, Wreathed, Wrinkled, Rhinoceros, and Helmeted) were detected in a wildlife assessment of nine forest compartments of three different age groups (virgin, newly logged, and old logged) (WWFM 1998). Hornbill density estimates were unsurprisingly highest in virgin compartments, ranging between 2.2 – 6.5 individuals/km^2. Newly logged compartments reported between 0.8 – 2.4 individuals/km^2. Old logged compartments supported between 1.6 – 2.3 individuals/km^2, indicating perhaps Helmeted Hornbills returning to these regenerated compartments.

In Sarawak, Mohd-Azlan *et al.* (2023) reported similar findings, using relative abundance rather than density. Primary forests, or treated as future logging coupes in their surveys, supported seven of the eight hornbill species found in Borneo. The Wreathed Hornbill was not detected. In the current and recently logged coupes, the number of hornbills detected dropped (31 – 33 detections) compared to the future logging coupe (36 detections). Generally, hornbills can survive in post-logged forests as shown by several studies but most populations do not recover fully (Meijaard *et al.* 2005). This situation is exacerbated when hunting or poaching occurs in logging concessions, further suppressing hornbill population numbers (Datta 1998).

THREATS TO HORNBILLS

Forest loss and fragmentation is undoubtedly the single most destructive threat to hornbills in south-east Asia, including Malaysia (Lambert and Collar 2002). Much of the plains-level forests (<150 m a.s.l.) have been logged or cleared for rubber and oil palm cultivation which would have deprived hornbill populations of nesting trees and food resources. Forest fragmentation has many impacts: reduced patch size, increased edge, reduced ratio of undisturbed core to disturbed fringes, greater travel distances for hornbills across non-forest food-poor environments, and greater chances of human intrusion. There might also be greater susceptibility of small forest patches to droughts, greater drying leading to greater fire risks, wind exposure, all leading to impacts on tall emergent forest trees, lesser tree species diversity, and food shortages such as elimination of fig species which fruit asynchronously and in intact forests, fill in seasonal food gaps (Lambert and Collar 2002). Hornbill-rich habitats, primarily extreme lowland dipterocarp and peat/freshwater swamp forests, are now a fraction of their former size. Remaining forests continue to be subjected to further pressures of being converted into timber plantations of fast-growing exotic species, durian plantations, infrastructure projects, and rare earth element (REE) prospecting and mining.

Although fragmented forest habitats could still support some hornbills, the diversity and population size are expected to be much reduced (Sodhi 2002; Atikah *et al.* 2025). Smaller hornbills such as Oriental Pied and Bushy-crested Hornbills could continue to persist in reasonably-sized fragments. Large hornbills such as the Rhinoceros, Great, and

Helmeted Hornbills would most certainly perish in forest fragments over time, with remnant birds or post-breeding dispersers from other areas giving a misleading impression of continued survival. Wreathed Hornbills, which are nomadic by nature, are likely to move between forest landscapes and fragments. In a citizen science project carried out in 2009 and 2010 by the MNS Perak Branch, birdwatchers recorded only three hornbill species in small-sized forests (1,000 – 9,999 ha) and only encountered six species in large-sized forests (≥10,000 ha) (MNS Hornbill Conservation Project, unpublished data). The most commonly encountered hornbill species were the Oriental Pied and Rhinoceros.

Poaching and hunting are affecting several hornbill species in southeast Asia. The Helmeted Hornbills crisis which erupted in 2016 has decimated populations in Indonesia (Beastall *et al.* 2016). Demands for luxury trinkets and jewelry and ornamental objects of carved Helmeted Hornbills from East Asian markets fueled the trade. There were concerns if (or when) the demand grew, Malaysia could be targeted as the next 'source country'. Two cases of Helmeted Hornbill seizures have been reported to date and are under investigation. In those cases, the casques were likely to have originated from Indonesia (Anon. 2016). However, Malaysian authorities have seized several live juvenile hornbills from Kuala Lumpur International Airport, most of which were Rhinoceros and a single Helmeted (Anon. 2021). In Peninsular Malaysia there are anecdotes of soliciting mobile phone photographs of nesting hornbills, for a small cash reward: the reward is indeed paid, but metadata (e.g., date, location) are then potentially available to the one receiving the photograph (G.W.H. Davison, pers. obs.).

Climate change is also predicted to impact wildlife movements and their ecology over time. Predictive modeling of climate change impacts on hornbill species in India showed that shifts in their distribution were possible (Sarkar and Talukdar 2023). This could arise due to the changes in the forest phenology when the normal patterns are disrupted. The disruption could affect the hornbills' breeding period. Malaysia is now experiencing changing weather patterns at the local level in recent years (Abdul Rahman 2009). The intensity of El Niño and La Niña events is increasing which has resulted in longer dry seasons (or droughts) and heavier rainfall during monsoonal months in parts of the country (Hashim and Ibrahim 2025). The potential impact of weather disruptions on hornbill ecology in Malaysia remains unclear for the time being, which necessitates long-term monitoring of hornbills in our forests, but may result in scarcer or more unpredictable food sources, and potentially altitudinal shifts.

Birdwatching tourism is a growing industry globally and in Malaysia (Tourism Malaysia 2021). The desire to "tick off" or photograph iconic birds in birdwatching sites has led to undesirable behaviour in the birdwatching and photography communities. The use of playbacks or the creation of bird feeding 'ports' to attract birds is now common practice. Playback is often used to lure birds into the open for better photo opportunities. The Helmeted Hornbill is regarded as a 'star bird'. One incident in Fraser's Hill highlighted the lengths that photographers go to capture the perfect photo of the Helmeted Hornbill pair (Macaranga 2022). Yang *et al.* (2025) have shown that the use of call playback could be fatal to territorial birds, especially during sensitive periods such as breeding.

Another unhealthy practice is hornbill feeding as a tourism activity. In Pangkor Island, several tourism operators have advertised Oriental Pied Hornbill feeding as a tourist attraction (Syamil 2020). Foods provided are sometimes suitable (e.g., banana, papaya) and sometimes not (e.g., bread, buns). For both call playback and feeding, wildlife laws are unable to stop these practices as the hornbills (or any bird species) are not physically harmed, nor are their nesting sites damaged. However, hornbill feeding could potentially lead to human-hornbill conflicts in future, as shown on several occasions in Singapore (Yahya *et al.* 2024).

HORNBILL CONSERVATION IN MALAYSIA

The conservation of Malaysian hornbills is tightly linked to their distribution and dependence on large forest areas (Table 1) with distinctions in their preferred vegetation and elevation (Table 2), and the presence of large trees carrying suitable natural cavities for nesting (Table 4). Breeding cycles show annual but prolonged patterns (Table 3), probably influenced by weather, day length and food availability. Figs, however, are irregular and largely aseasonal sources of food, proving reliable only through their abundance in large forest tracts and with multiple species producing fruit at differing times. These characteristics make figs a keystone resource.

Policy support and species action plans

National and State biodiversity-related policies generally do not contain explicit prescriptions on hornbill conservation. However, national and state-level policies such as the National Policy on Biological Diversity and Sabah Biodiversity Policy, respectively, have outlined several key goals and activities that directly and indirectly impact hornbills and their habitats. At the site level, the Royal Belum Special Area Plan in Peninsular Malaysia has also explicitly outlined hornbills as the protected area's natural asset and recommended regular monitoring of hornbill populations. In Sabah, the state government is developing a Hornbill Action Plan with assistance from local NGOs (Vanar 2023). Regionally, the Helmeted Hornbill species action plan has been developed, but adoption and implementation by range countries were poor (Jain *et al.* 2018).

Legal protection of hornbills

Hornbills are relatively well protected under Malaysia's laws. Hornbills are classified as "Totally Protected" under the Wildlife Conservation Act 2010 [Act 716] in Peninsular Malaysia and the Wildlife Protection Ordinance 1998 in Sarawak. In Sabah they are classified as "Protected" under the Wildlife Conservation Enactment 1997. Under this enactment, hunting is permitted with a license, but no such application has been made to date (Sabah Wildlife Department, pers. comm.). Additionally, the International Trade in Endangered Species Act 2008 [Act 686], which enforces the resolutions of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) decisions, protects hornbill species in Malaysia from being traded.

Site prioritisation for hornbill conservation

The future survival of hornbills in Malaysia depends entirely on the preservation of remaining forest landscapes. The Malaysian Nature Society developed the Important Hornbill Landscape (IHL) concept to help policy and decision-makers and site managers identify and prioritise forest sites for the best chance of survival for hornbills based on four selection criteria. A total of 17 IHLs were identified for Peninsular Malaysia (Yeap *et al.* 2023), and eight in Sarawak (Wee *et al.* 2024). No IHL has been identified for Sabah currently, but several well-known protected/conservation areas, e.g. DaMaI (Danum Valley, Maliau Basin, Imbak Canyon), Tabin and Kinabatangan Wildlife Reserves, and Tawau Hills Park are considered as hornbill strongholds (Koid *et al.* 2021; Nur Syamimi *et al*. 2025).

Use of artificial nest boxes

Artificial nest boxes are an important tool in hornbill conservation, especially for sites where the forest habitat has been fragmented, causing shortages of suitable nest trees and cavities (Kaur *et al.* 2018; Vercoe *et al.* 2021). The Kinabatangan region is a prime example of this situation. Despite supporting high levels of wildlife diversity, including eight hornbill species, the shortage of nesting trees has prevented hornbills from breeding. The use of nest boxes to assist hornbill pairs to breed has shown some success. The Rhinoceros and Bushy-crested Hornbills have used nest boxes and produced chicks (Kaur *et al.* 2018). However, the provision of nest boxes should be carefully considered due to several factors,

e.g. high maintenance cost (manpower and money), competition from other cavity users, poaching pressures in the area etc (Zhang *et al.* 2023). In some cases, hornbill pairs investigated the artificial nest boxes provided but did not attempt to use it thereafter (Lee and Rombang 2011). The preservation of intact forest landscapes should always be treated as the priority prescription as much as possible before attempting to install artificial nest boxes.

Hornbill and forest guardianship by local communities and indigenous peoples

Indigenous and local communities that live near or in forest landscapes where hornbills are recognised as important stakeholders in conserving hornbills and forests, as proven in other countries e.g., India, Thailand, Indonesia (Poonswad *et al.* 2005; Teampanpong *et al.* 2024; Anon. 2026). MNS has engaged with the local Jahai Orang Asli in BTFC and trained them as hornbill guardians (Yeap *et al.* 2021). They have been instrumental in bridging the knowledge gaps on hornbill ecology in BTFC. In Kinabatangan, local communities and NGOs rallied together to provide artificial nest boxes and even repair natural cavities to enable hornbills to breed (Vercoe *et al*. 2021). Additionally, they also monitor hornbill nests and restore degraded habitats.

Restoring degraded lands and forests for hornbills (and other wildlife)

Figs are currently being actively propagated and used as one of the primary plant groups for restoration projects in Sabah (Parry and Cheema 2021). Five species, i.e. *Ficus subcordata*, *F. cucurbitina*, *F. benjamina*, *F. racemosa* and *F. dubia*, were identified for trial planting that would benefit the eight hornbill species and other wildlife found in Tawau Hills Park. In BTFC, Orang Asli Jahai women in Kampung Chuweh have trialled germinating non-fig hornbill food plants, e.g. *Polyalthia* sp., collected from hornbill middens for the possible use of rehabilitating degraded areas in the landscape (The Habitat Foundation 2025).

Communication, education, and public awareness (CEPA)

The appreciation for hornbills in Malaysia is increasing, as seen on various social media platforms. They are also being featured more in locally published children's storybooks. MNS has conducted several school camps in BTFC, reaching more than 500 school kids and educators, to raise awareness about hornbills and forest conservation. In 2025, Malaysia officially adopted 10 November as its National Hornbill Day (Koshy 2025), elevating its status and spurring more CEPA actions. The Rhinoceros Hornbill is also featured on Malaysia's RM5 banknote, which enables every Malaysian to champion hornbill conservation by using it as a CEPA tool.

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CHAPTER 3

The state of raptors in Malaysia

CHONG LEONG PUAN[1,2]*, KIM CHYE LIM[2,3], MENG-YONG NG[3], SIEW TECK YEO[3] and JIA JIE NG[3]

Abstract: In Malaysia, 69 raptor species have been recorded, comprising 47 diurnal and 22 nocturnal species, including two near-endemics and about 20 migratory species. Among these, one is Endangered, four are Vulnerable, and 11 are Near Threatened. Recent taxonomic revisions, such as those involving the Collared Scops-owl (*Otus lettia*), Sunda Owlet (*Taenioptynx sylvaticus*) and Eastern Barn-owl (*Tyto javanica*), have refined species classification and distribution. Over the past three decades, 79 journal articles on Malaysian raptors have focused on behaviour, species assemblages, and anthropogenic threats, with increasing emphasis in the past 15 years on nocturnal species. Citizen science initiatives have provided valuable insights into the natural history, behaviour, and ecological interactions of local residents, including the Peregrine Falcon (*Falco peregrinus ernesti*), Black-thighed Falconet (*Microhierax fringillarius*), Grey-headed Fish-Eagle (*Ichthyophaga ichthyaetus*), Crested Honey-buzzard (*Pernis ptilorhynchus torquatus*) and Rufous-bellied Eagle (*Lophotriorchis kienerii*). Most of these records are available in the Malaysian Bird Report, with earlier reports also appearing in Suara Enggang, now temporarily halted. A 2024 survey documented 39 confirmed and suspected breeding sites of the Peregrine Falcon on limestone hills in Peninsular Malaysia. Tanjung Tuan, Melaka, serves as the only long -term migration count site, and nearly full-season counts at Tanjung Tuan (northbound) and Taiping (southbound) in 2009 and 2010 revealed differing patterns among the Crested Honey-buzzard (*P. ptilorhynchus orientalis*), Black Baza (*Aviceda leuphotes*), and Chinese Sparrowhawk (*Tachyspiza soloensis*). Gaps remain in long-term monitoring and threat assessments, with most research concentrated in Peninsular Malaysia. Major threats include habitat loss, secondary poisoning from agricultural chemicals, poaching, and illegal pet trade facilitated by social media. Strengthening conservation through renewed local collaborations, such as the Raptor Study Group (halted in 2018), and regional initiatives under the Asian Raptor Research and Conservation Network (ARRCN) is crucial. Future research should prioritise integrated monitoring, migration flyway protection, habitat conservation, and citizen science to ensure the long-term survival of Malaysian raptors, particularly poorly studied species.

INTRODUCTION

Raptors are an integral component of both terrestrial and aquatic ecosystems, functioning as apex predators, mesopredators, and scavengers across different trophic levels. Through predation, raptors regulate populations of small mammals, birds, reptiles, amphibians, fish, and large invertebrates, thereby contributing to food-web stability and ecosystem regulation (Sergio *et al.* 2008). For these reasons, raptors are widely recognised as suitable indicators of ecosystem health (Sergio *et al*., 2008; McClure *et al.* 2018), in addition to serving as biological control agents in agricultural landscapes (Ravindran *et al.* 2022). Raptors also play important roles in human culture, including mythology, religion, and national identity. Updating their status and distribution is therefore essential for conservation planning and biodiversity assessment in Malaysia.

[1] Faculty of Forestry and Environment, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia.
[2] Asian Raptor Research and Conservation Network.
[3] Malaysian Nature Society, JKR 641, Jalan Kelantan, Bukit Persekutuan, 50480 Kuala Lumpur, Malaysia.
***Corresponding author: chongleong@upm.edu.my**

The raptor assemblage in Malaysia is ecologically diverse, occupying various niches and comprising both habitat specialists and generalist species that vary in their tolerance to environmental disturbance. Generalist raptors are frequently associated with human-modified landscapes such as agricultural areas, plantations, rural and urban environments where they exploit predictable food resources and open foraging habitats (Ferguson-Lees and Christie 2001). These species often persist in fragmented landscapes and may increase in abundance with moderate levels of land-use change.

On the other hand, specialist raptors are closely associated with specific habitat features and ecological conditions. Forest-dependent species rely on structurally complex lowland and montane forests (Concepcion and Puan 2025), particularly pristine ones (Puan *et al.* 2015), while others are restricted to freshwater wetlands, peat swamps, mangroves, coastal ecosystems, or limestone karst formations (Kéry *et al.* 2025). Such specialisation increases vulnerability to habitat loss and degradation, which are widespread in Malaysia due to deforestation, agricultural expansion, and infrastructure development (Thiollay 1998; Wells 1999; Concepcion and Puan 2025).

Raptors of Malaysia

Located within the Sundaland biodiversity hotspot, Malaysia supports a rich assemblage of resident and migratory raptors across both Peninsular Malaysia and Malaysian Borneo (Wells 1999; Puan *et al.* 2020). This diversity reflects the country's wide range of habitats across altitudinal, landscape and local gradients as well as its position along major migratory flyways linking East Asia and Australasia, with Malaysia serving as wintering and staging sites.

To date, a total of 69 raptor species have been recorded in Malaysia, comprising 47 diurnal and 22 nocturnal species. Diurnal raptors are represented by one species in the family Pandionidae, 39 species in Accipitridae, and seven species in Falconidae, while nocturnal raptors include three species in Tytonidae and 19 species in Strigidae. This assemblage includes two near-endemic species and approximately 20 migratory species that occur seasonally during passage or wintering periods. In terms of conservation status, one species is classified as Endangered, four as Vulnerable, and 11 as Near Threatened according to the IUCN Red List of Threatened Species.

Recent taxonomic revisions have refined species limits and clarified distributional patterns of several raptor taxa in Malaysia, with important implications for conservation planning. These include the recognition of the Collared Scops-owl (*Otus lettia*) in Peninsular Malaysia, while the Sunda Scops-owl (*Otus lempiji*) is now considered its counterpart in eastern Malaysia (Borneo) (Wu and Rheindt 2023). Similarly, the Collared Owlet (*Taenioptynx brodiei*) occurring in Peninsular Malaysia has been taxonomically separated from the Sunda Owlet (*Taenioptynx sylvaticus*) in eastern Malaysia (Gwee *et al.* 2019). Revisions involving the Eastern Barn-owl (*Tyto javanica*) have also clarified its species status and regional distribution.

At higher taxonomic levels, revisions within the family Accipitridae have resulted in the reassignment of several species formerly placed in the genus *Accipiter* to the genera *Tachyspiza* and *Lophospiza* (Catanach *et al.* 2024). Likewise, eagle-owls in Malaysia previously classified under *Bubo* are now placed in the genus *Ketupa*. These taxonomic updates reflect advances in molecular, morphological, and vocalisation studies, and highlight the importance of accurate taxonomy for assessing species distributions and conservation status, as well as for guiding conservation planning in the country.

Raptor research in last 30 years

Over the past three decades, raptor research in Malaysia has grown steadily, with at least 79 peer-reviewed journal articles addressing various aspects of raptor ecology and conservation. Early studies were largely descriptive, focusing on species occurrence, behaviour, and assemblage composition, particularly in forested and coastal habitats. More recent research has increasingly examined anthropogenic threats, including habitat loss, land-use change, persecution and disturbance associated with development. Notably, there has been a marked increase in studies on nocturnal raptors over the past 15 years (Yahya *et al.* 2020), reflecting improved survey techniques and growing recognition of the conservation importance of owl species, many of which are forest-dependent and poorly understood (Puan *et al.* 2015; Atikah *et al.* 2019).

Citizen science initiatives have made substantial contributions to raptor research in Malaysia, particularly in documenting natural history, breeding behaviour, and ecological interactions of resident species. Observations submitted by birdwatchers and local raptor enthusiasts have generated valuable data on species such as the Peregrine Falcon (*Falco peregrinus ernesti*), Black-thighed Falconet (*Microhierax fringillarius*; Khoo *et al.* 2024), Grey-headed Fish-eagle (*Ichthyophaga ichthyaetus*; Lim 2015), Crested Honey-buzzard (*Pernis ptilorhynchus torquatus*; Chiu 2024), and Rufous-bellied Eagle (*Lophotriorchis kienerii*; McAfee 2025). Much of this information has been published in the Malaysian Bird Report (www.malaysianbird.report), with earlier records also published in *Suara Enggang*, which is currently inactive. These citizen-generated data have been particularly important for species that were difficult to monitor in the past.

Targeted research efforts have also yielded important conservation-relevant findings. A recent survey in 2024 documented 39 confirmed and suspected breeding sites of the Peregrine Falcon on limestone hills, which may not be occupied annually, in Peninsular Malaysia (Kéry *et al.* 2025), with the national estimate of 60 – 70 pairs and a potential decline in the West Malaysian population over the last five years. This highlights the significance of limestone karst landscapes as breeding habitats and the vulnerability of these sites to quarrying and other forms of anthropogenic development. Tanjung Tuan, Melaka, remains Malaysia's only long-term and systematic raptor migration count site. Nearly full-season counts conducted in 2009 and 2010 at both Tanjung Tuan (northbound migration; Puan *et al.* 2014) and Taiping, Perak (southbound migration; Lim *et al.* 2022) revealed distinct migration patterns among key species such as the Crested Honey-buzzard (*P. p. orientalis*), Black Baza (*Aviceda leuphotes*) and Chinese Sparrowhawk (*Tachyspiza soloensis*). Since 2016, shorter migration counts of approximately two weeks have continued annually at Tanjung Tuan. Taiping represents the second most extensively surveyed site, with sustained autumn migration counts from 2000 to 2014 and additional shorter monitoring periods in 2020 and 2021. The site supported records of 13 species during these counts, compared to 11 species recorded at Tanjung Tuan.

Other locations across Peninsular Malaysia, including Perlis State Park (Perlis), Bedong (Kedah), Lakum (Pahang), Pulau Tioman (Pahang), Bukit Kepong (Johor) and Pulau Babi Tengah (Johor), have been subject to only short-term or single-year surveys, often focusing on either spring or autumn migration seasons (Table 1). These migration counts have been exploratory in nature, aimed at identifying potential long-term survey sites. In Malaysian Borneo, short-duration surveys were conducted at selected locations, such as Kudat, Semporna and Tanjung Datu, as well as in broader areas of Sabah and western Sarawak. However, none of these efforts have been maintained over extended periods. Despite their limited duration, these surveys still provide valuable baseline data on migratory raptor movements in eastern Malaysia where long-term monitoring remains scarce.

Table 1. Raptor migration counts conducted in Malaysia (2000 – 2025).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Perlis State Park, Perlis									↓																	
Bedong, Kedah													↓	↓												
Taiping, Perak	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓						↓	↓				
Lakum, Pahang				↑																						
Pulau Tioman, Pahang													↓													
Tanjung Tuan, Melaka							↑	↑	↑	↑	↑	↑	↑	↑	↑	↑	↑↓	↑	↑	↑	↑	↑	↑	↑	↑	↑
Bukit Kepong, Johor																	↓									
Pulau Babi Tengah, Johor												↓														
Semporna, Sabah														↓												
Kudat, Sabah			↓																							
Tanjung Datu, Sarawak			↓																							
Sabah & western Sarawak											↑	↓														

↑ northbound migration ↓ southbound migration

Raptor conservation

Raptors in Malaysia face a wide range of conservation challenges due to rapid environmental change and increasing human pressures. Major threats include habitat loss and degradation caused by deforestation, agricultural expansion, infrastructure development and quarrying, particularly in forested (Atikah *et al.* 2019) and limestone karst ecosystems (Kéry *et al.* 2025). Secondary poisoning from agricultural chemicals, including rodenticides and pesticides, poses additional risks to both diurnal and nocturnal raptors through bioaccumulation (Ravindran *et al.* 2022). Collisions with vehicles, feeding of unnatural food, and intentional or accidental trapping by farmers and fishermen further exacerbate these threats (Puan 2023). Poaching (Shepherd and Shepherd 2009) and the illegal pet trade, particularly for falconry or exotic pet markets, have become more prominent with the rise of online platforms and social media.

Between 2008 and 2009, Malaysian authorities uncovered the largest recorded illegal owl trade in the country, with a total of 1,519 owl carcasses seized alongside other protected wildlife during multiple raids in Johor and Pahang (Shepherd and Shepherd 2009). These seizures revealed a previously unknown trafficking network, as there had been no local signs of owl consumption or trade before. Most of the confiscated owls were Eastern Barn-owls, a species common in plantations, raising concerns that some birds may have been taken directly from nest boxes or captured using nets. The full extent of the trade remains unclear; it remains unknown whether illegal owl trade continues today or if these cases were isolated.

Effective raptor conservation in Malaysia requires a combination of species- and habitat-focused approaches. Habitat specialists, including forest-dependent and limestone -associated species (Kéry *et al.* 2025), are especially vulnerable to landscape alteration and require targeted protection of key breeding and foraging sites (McClure *et al.* 2018). At the same time, species such as the Brahminy Kite (*Haliastur indus*) demonstrate ecological flexibility, occurring in coastal habitats as well as inland along rivers and in human -dominated landscapes (Wells 1999). While such adaptability may confer resilience to moderate disturbance, these species are still susceptible to threats such as pollution, human-wildlife conflict and persecution (Shepherd and Shepherd 2009). The same applies to plantations adjacent to forests, where some owl species can adapt, but others, such as Brown Boobook (*Ninox scutulata*), Dusky Eagle-owl (*Ketupa coromanda*), and Barred Eagle-owl (*Ketupa sumatrana*), likely rely primarily on forests and use plantations only as suboptimal habitat (Atikah *et al.* 2019).

Collaborative networks play a vital role in advancing raptor conservation in Malaysia and throughout Asia. At the national level, revitalising local partnerships, such as the Raptor Study Group, which halted in 2018, could greatly enhance research coordination, long-term monitoring, and capacity building among conservation stakeholders. Regionally, the Asian Raptor Research and Conservation Network (ARRCN) serves as a crucial platform for data sharing, training, and transboundary conservation planning. Strengthening engagement at both local and regional scales is essential to address shared threats, close knowledge gaps, and ensure the long-term survival of raptors in Malaysia. Public education and outreach remain priorities, with ARRCN highlighting local conservation efforts, conducting workshops, and engaging communities to raise awareness and promote effective conservation actions.

Biennial ARRCN symposia provide an important forum for exchanging research findings and conservation strategies. Malaysian raptor research has been featured at many of these events. Notably, Malaysia hosted the 4th symposium in 2005 in Taiping, Perak, and the 12th symposium as a virtual meeting in 2022. Contributions from Malaysian researchers have enriched regional dialogues on raptor ecology and conservation challenges, fostering strong cross-border collaborations that are crucial for tackling threats that transcend national boundaries.

Conclusion and recommendations

Over 40% of Malaysian raptor species remain understudied, particularly forest-dependent and threatened species, highlighting the urgent need to fill critical knowledge gaps. Research over the past 30 years has expanded, with growing attention to nocturnal species, yet most studies remain concentrated in Peninsular Malaysia and in agricultural landscapes (Yahya *et al*. 2020), particularly the Eastern Barn-owl (Lim 2015). Major gaps persist in long-term monitoring and threat assessments, making Tanjung Tuan, Malaysia's only long-term migration count site, a key effort of the Malaysian Nature Society. Citizen science continues to provide essential complementary data on raptor ecology, behaviour and distribution.

Future priorities should focus on integrated monitoring, protection of migratory flyways, conservation of key habitats, and expansion of citizen-science initiatives. Effective conservation will also require stronger local and regional collaboration, sustained capacity building, and increased support from government agencies and research institutions (Puan 2023). By addressing these research and conservation priorities, Malaysia can promote more informed management and safeguard the long-term survival of its diverse raptor populations.

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CHAPTER 4

State of waterbirds in Malaysia

CHOON MIN SEE[1]*, CHIN-AIK YEAP [1], CHOO ENG TAN[2] and DING LI YONG[3]

Abstract: Natural and man-made wetlands provide crucial habitats and resources to many resident and migratory waterbird species globally. In Malaysia, at least 14 waterbird families, dominated by Scolopacidae, Charadriidae, Laridae, Ardeidae and Anatidae, depend on coastal and freshwater wetlands such as the intertidal mudflat, peat swamp forest and others throughout the country. Waterbird populations and wetlands in Malaysia are monitored primarily and consistently through the Asian Waterbird Census (AWC) since 1989, currently coordinated nationally by the Malaysian Nature Society (MNS) with the support from Department of Wildlife and National Parks (PERHILITAN) Peninsular Malaysia, Sarawak Forestry Corporation and Sabah Wildlife Department. Accumulated long-term AWC data showed that intertidal coastal mudflats on the west coast of Peninsular Malaysia and western Sarawak including the Bako-Buntal Bay, North-Central Selangor Coast (NCSC) and Teluk Air Tawar-Kuala Muda (TAT-KM) Coast are important wintering/staging sites for migratory waterbirds and several globally threatened and near-threatened species. Resident waterbird population trends in the country vary, and few species such as the White-winged Duck (*Asarcornis scutulata*) and Sarus Crane (*Antigone antigone*) have been locally extirpated. The Lesser Adjutants (*Leptoptilos javanicus*) are still present in their stronghold sites, but fewer sightings of Storm's Stork (*Ciconia stormi*) in Peninsular Malaysia have been reported indicating a possible decline. Colonial waterbirds including the migratory Asian Openbill (*Anastomus oscitans*) and the introduced Painted Stork (*Mycteria leucocephala*) have colonised Malaysia in recent years and expanded its distribution range and even breeding in Peninsular Malaysia. In terms of waterbird research, local universities and researchers are showing increasing interest, culminating in more dissertations and published papers on short-term surveys, feeding ecology and behaviour. Waterbirds and wetlands continue to be threatened by habitat loss and degradation, pollution, hunting and trapping, and climate change in Asia affecting many waterbird species and sites along the East Asian-Australasian Flyway (EAAF). The Curlew Sandpiper (*Calidris ferruginea*), a 'common' shorebird which was formerly listed as Least Concern (2012), has been upgraded to Vulnerable (2024) in the Red List within a decade. Conservation actions on waterbirds and wetlands are now actively pursued within the ambit of the East Asian-Australasian Flyway Partnership (EAAFP) and the ASEAN Flyway Network (AFN) Programme to prevent their further decline.

INTRODUCTION

Malaysia's natural wetlands span across a significant area of approximately 5.1 million hectares (Ismail *et al.* 2021). The documentation of wetlands in Malaysia has revealed 90 major lakes and approximately 100 river systems from 31 types of wetlands in Malaysia. Both natural and man-made wetlands in Malaysia are recognised as crucial habitats in providing resources and shelters to many resident and migratory waterbird species. In the 1980s, the implementation of the INTERWADER programme set in motion Malaysia's first

[1] Malaysian Nature Society, JKR 641, Jalan Kelantan, Bukit Persekutuan, 50480 Kuala Lumpur., Malaysia.
[2] MNS-Bird Conservation Council, Malaysian Nature Society, JKR 641, Jalan Kelantan, Bukit Persekutuan, 50480 Kuala Lumpur, Malaysia.
[3] BirdLife International (Asia Division), 354 Tanglin Road, #01-16/17, Tanglin International Centre, Singapore 247672
***Corresponding author: flyway@mns.org.my**

Malaysia's first comprehensive wetland and waterbirds surveys (Yeap 2020). The programme has provided a foundation of our best understanding of the waterbird population trends, distribution and utilization across the wetlands in Malaysia.

Wetlands from the coasts and floodplains of Malaysia support a significant number of waterbird species. Coastal wetlands including the intertidal mudflat and mangrove forest are known to provide more than 30 species of migratory shorebirds, terns and stork species. Waterbird populations and wetlands in Malaysia are monitored primarily and consistently through the AWC since 1989, currently coordinated nationally by MNS with support from PERHILITAN, Sarawak Forestry Corporation and Sabah Wildlife Department.

The last comprehensive review of waterbird species in Malaysia by Li *et al.* (2009) recorded a total of 106 waterbird species between 1987 to 2007, and ten globally threatened species recorded. Since then, the AWC result in Malaysia compiled by See *et al.* (2026) continue to record 150 waterbird species in Malaysia with 14 waterbird families dominated by the sandpipers (Scolopacidae), plovers (Charadriidae), terns (Laridae) and herons (Ardeidae) (Figure 1).

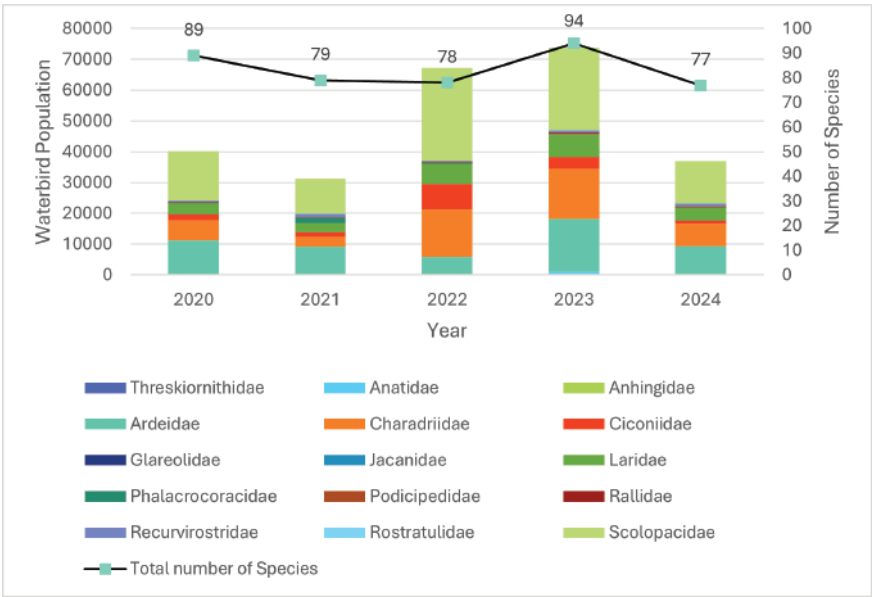

Figure 1. Waterbird population in Malaysia between 2020 to 2024 based on Asian Waterbird Census monitoring results.

Across Malaysia, the migratory waterbirds rely on coastal intertidal mudflat as foraging habitat and adjacent man-made wetlands including the aquaculture ponds and ash ponds as high tide roosts (Yong *et al.* 2022). Among 150 waterbird species recorded in wetlands of Malaysia, three species are Critically Endangered, five species are Endangered, and six species are Vulnerable (IUCN 2025). Due to differences in species community and diversity, the number of species that are globally threatened vary across Peninsular Malaysia and Malaysian Borneo (MNS-Bird Conservational Council 2021), and the breakdown of the species list summarised in Table 2.

Among the two largest groups of waterbirds monitored, shorebirds are represented by at least 24 species, including four that are globally threatened (Table 2). Notably, the Nordmann's Greenshank (*Tringa guttifer*), Great Knot (*Calidris tenuirostris*), and Far Eastern Curlew (*Numenius madagascariensis*) which was all classified as Endangered are

known to regularly winter in Malaysia. The species status review by Li *et al.* (2009) concluded that shorebird populations (families Scolocipadae and Charadriidae) in Malaysia have declined by 22.4%. The AWC data showed worrying trends for populations of Vulnerable species such the Curlew Sandpiper (*Calidris ferruginea*), Grey Plover (*Pluvialis squatarola*), and Chinese Egret (*Egretta eulophotes*) which are continuously declining (Langendoen *et al.* 2021).

Table 2. Global conservation status of threatened waterbird species in Malaysia. Species denoted with an asterisk (*) are currently considered extirpated from the regions where they were formerly recorded.

Conservation Status (IUCN 2025)	Common Name	Species Name	Peninsular Malaysia	Sarawak	Sabah
Critically Endangered (CR)	Masked Finfoot	*Heliopais personatus*	√	√	
	Spoon-billed Sandpiper	*Calidris pygmea*	√	√	
	Chinese Crested Tern	*Thalasseus bernsteini*		√	√
	White-winged Duck*	*Asarcornis scutulata*	-		
	White-shouldered Ibis*	*Pseudibis davisoni*		-	
Endangered (EN)	Storm's Stork	*Ciconia stormi*	√	√	√
	Nordmann's Greenshank	*Tringa guttifer*	√	√	√
	Far Eastern Curlew	*Numenius madagascariensis*	√	√	√
	Great Knot	*Calidris tenuirostris*	√	√	√
	Siberian Sand Plover	*Anarhynchus mongolus*		√	√
	Milky Stork*	*Mycteria cinerea*	-		
Vulnerable (VU)	Chinese Egret	*Egretta eulophotes*	√	√	√
	Christmas Island Frigatebird	*Fregata andrewsi*	√	√	√
	Grey Plover	*Pluvialis squatarola*	√	√	√
	Broad-billed Sandpiper	*Calidris falcinellus*	√	√	√
	Curlew Sandpiper	*Calidris ferruginea*	√	√	√
	Aleutian Tern	*Onychoprion aleuticus*	√	√	√
	Sarus Crane*	*Antigone antigone*	-		
Near Threatened (NT)	Beach Stone-curlew*	*Esacus magnirostris*	-		

In 2024, both the Grey Plover and the Curlew Sandpiper were uplisted from Least Concern to Vulnerable due to significant global population declines (IUCN 2025). While the globally flyway population of the Curlew Sandpiper has decreased by 12% (Langendoen *et al.* 2021), Malaysia appears to maintain a steady wintering population (Yeap 2020; See *et al.* 2026) as shown in Figure 2. Conversely, the Grey Plover maintains a steady global population and wintering population in Malaysia (Figure 3). However, Chinese Egret has experienced the most critical situation with 9% flyway population decline over the last 16 years and the declining trend is projected to reach 17% (Figure 4). Malaysia continues to support 30 to 50% of the wintering Chinese Egret population.

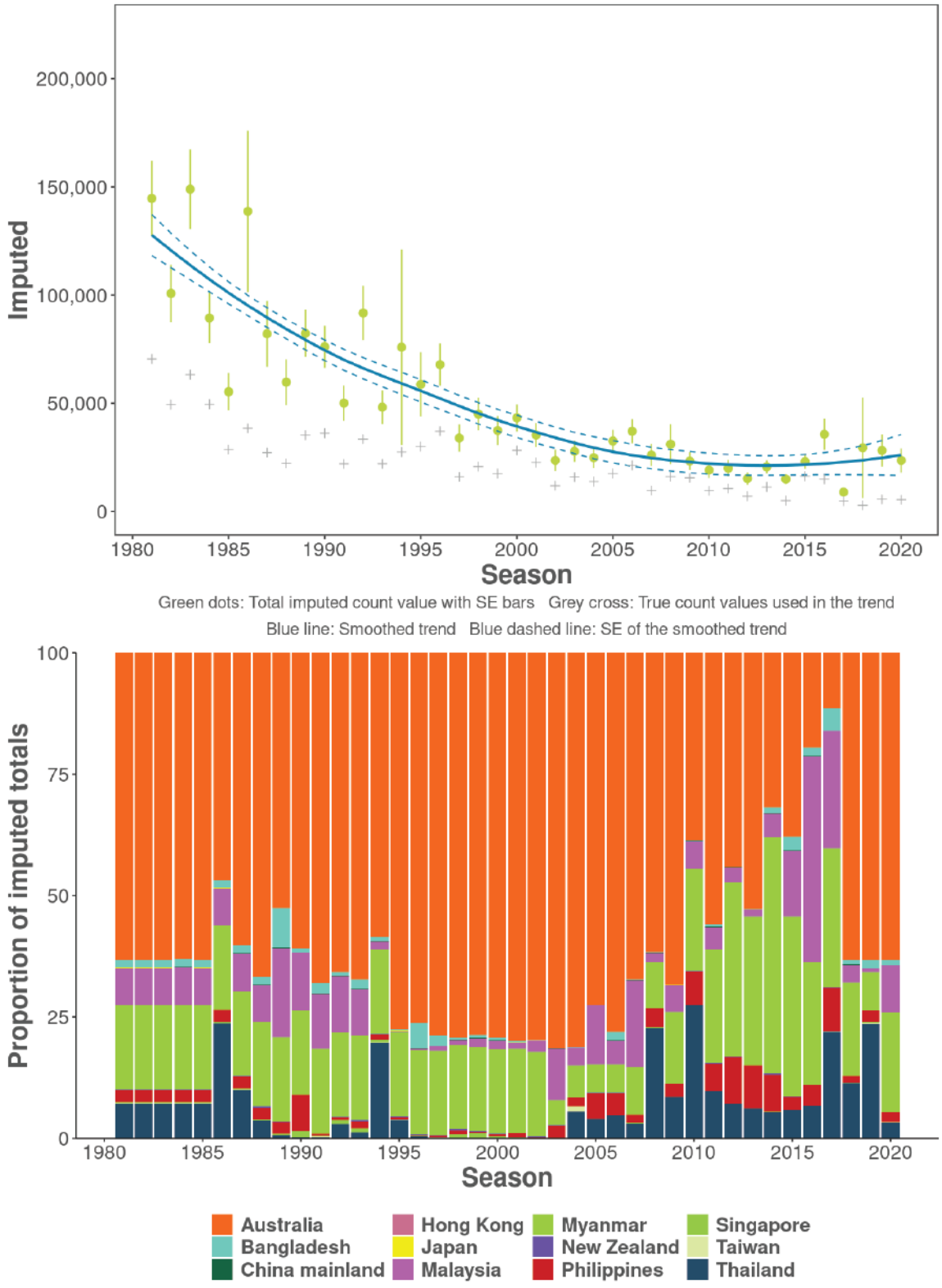

Figure 2. Population trend of Curlew Sandpiper from 1960 to 2020 based on Asian Waterbird Census data (Langendoen *et al.* 2021).

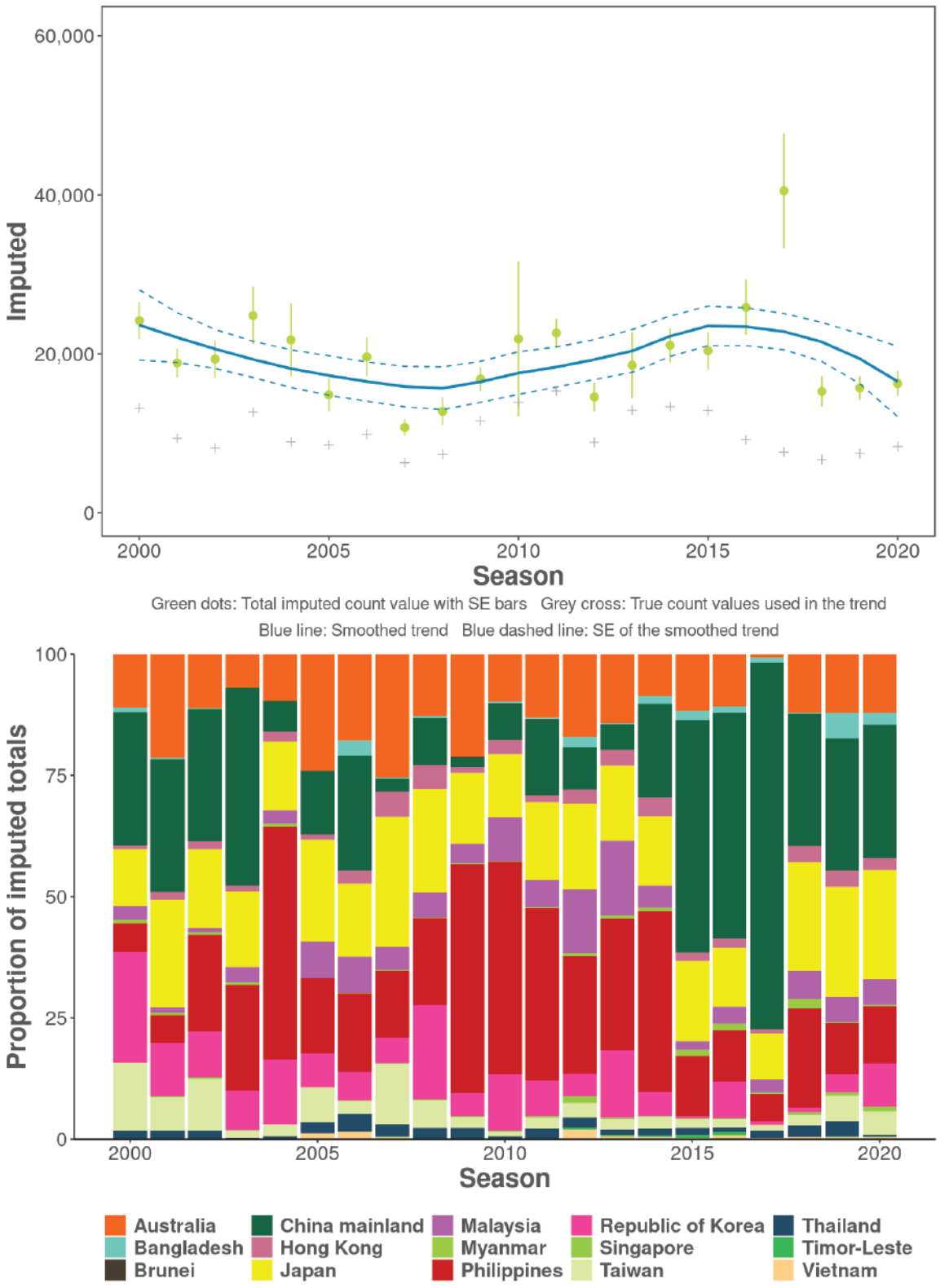

Figure 3. Population trend of Grey Plover from 1960 to 2020 based on Asian Waterbird Census data (Langendoen *et al.* 2021).

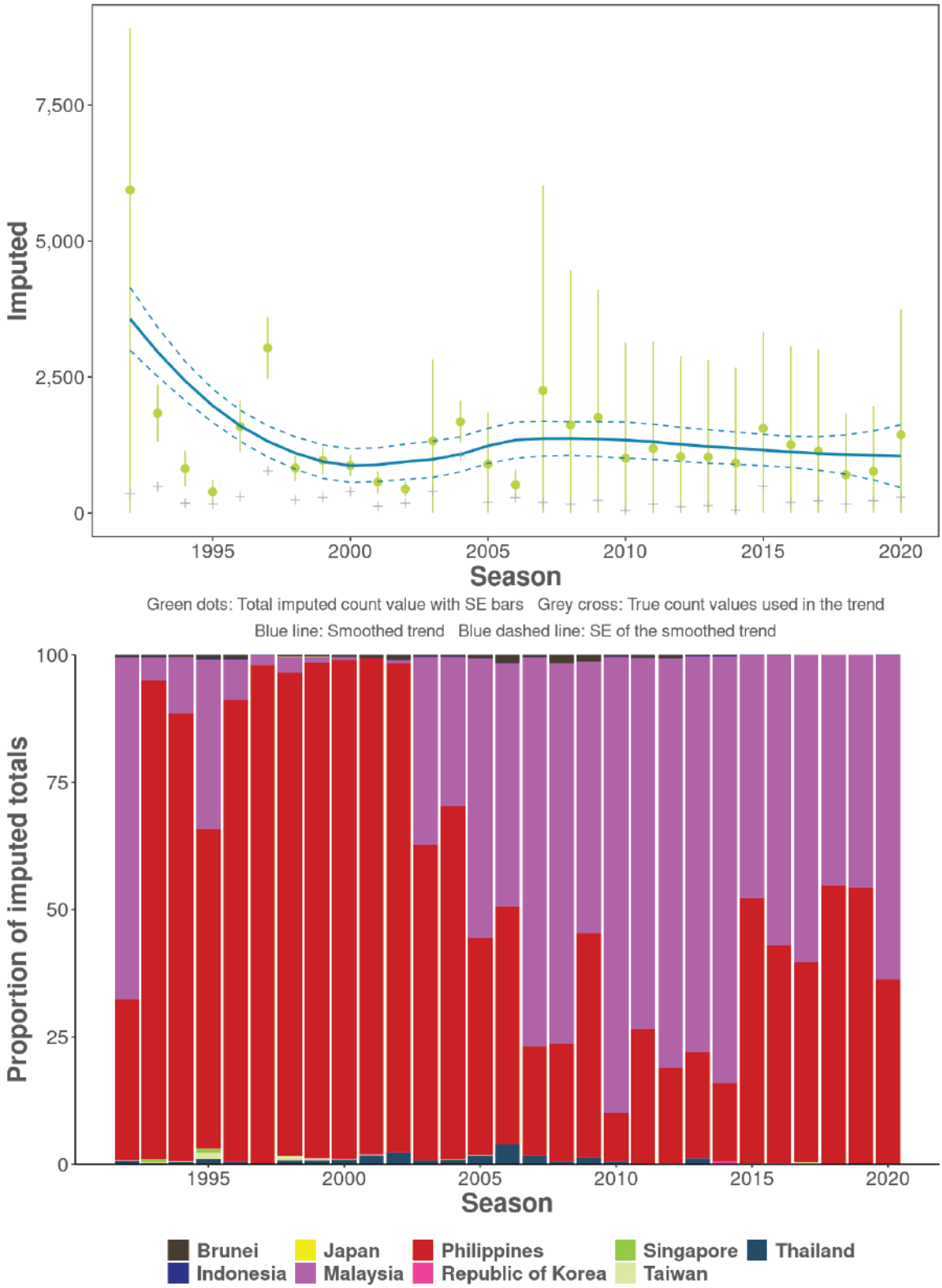

Figure 2. Population trend of Chinese Egret from 1960 to 2020 based on Asian Waterbird Census data (Langendoen *et al.* 2021).

WATERBIRDS IN PENINSULAR MALAYSIA

The coastline on the west coast of Peninsular Malaysia holds extensive areas of mangroves and intertidal mudflat which support a significant wintering congregation of terns (Laridae), sandpipers (Scolopacidae), and plovers (Charadriidae), which constitute the more than half of the waterbird population monitored in Asian Waterbird Census (See *et al.* 2026). Recent surveys continue to confirm the regional importance of key coastal Important Bird and Biodiversity Areas (IBA) along this coastline, specifically the Teluk Air Tawar–Kuala Muda Coast (TAT-KM) in Penang (Effendi *et al.* 2025) and the North-Central Selangor Coast in Selangor (Bakewell 2009; Chin and Khoo 2018; Yeap, 2020; See *et al.* 2026). These sites serve as a global wintering stronghold for the Nordmann's Greenshank with more than 5% of its total flyway population wintering in these sites (Crosby *et al.* 2025).

The broader landscape of wetlands in Peninsular Malaysia has witnessed significant shifts in the spatial distributions of several species of larger waterbirds. The Asian Openbill (*Anastomus oscitans*) was first recorded in northern states of Malaysia (first in Perlis and Penang) with its distribution expanding southward rapidly in recent years (Kamaruddin *et al.* 2015; Kamaruddin *et al.* 2017; Amzah *et al.* 2025), with new breeding colonies established. The expansion of the Asian Openbill was believed to be closely associated with the abundance of golden apple snails (*Pomacea canaliculate*) in paddy fields and other freshwater habitats in Malaysia (Amzah *et al.* 2025). The distribution maps generated from species occurrence map in Global Biodiversity Information Facility (GBIF) indicates that the species has expanded its range since 2008 (Figure 5) and has established breeding colonies in Northern states of Malaysia (Amzah *et al.* 2025).

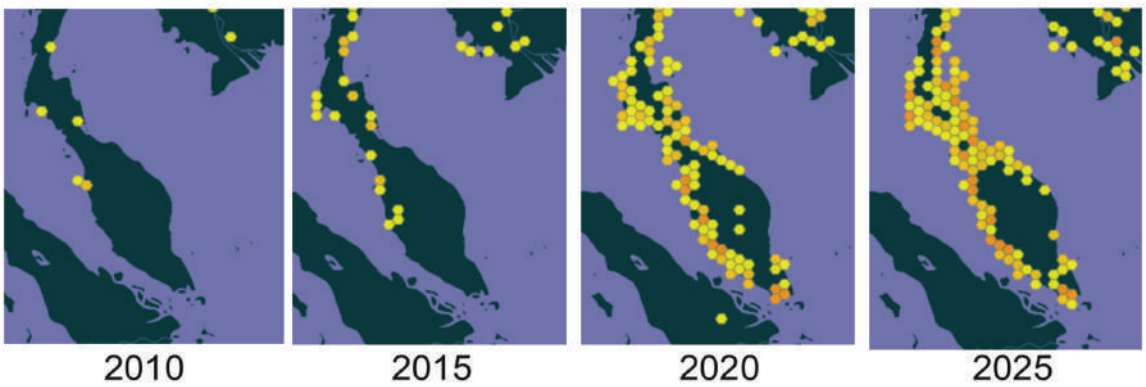

Figure 5. Spatiotemporal distribution of the Asian Openbill occurrence at five-year interval from 2010 to 2025 (GBIF Secretariat 2023a).

In contrast to the rapid expansion of the Asian Openbill in Peninsular Malaysia, the status of other resident storks in Malaysia is more complex. While listed globally as Endangered (IUCN 2026), the Milk Stork (*Mycteria cinerea*) is widely regarded by practitioners as extinct in the wild within Malaysia, as the contemporary records are mainly limited to captive or hybrid individuals (Ismail and Rahman 2012). The only known (wild) breeding colony of the species in Kuala Gula has undergone a sustained population decline for more than 90% (Li *et al.* 2006) with only five wild individuals recorded in 2009 and the wild population was expected to face extinction if the declining trend persists (Ismail and Rahman 2021). In Malaysia, the Matang Forest Reserve remains as the last stronghold for the species with Department of Wildlife and National Parks (PERHILITAN) Peninsular Malaysia leading the reintroduction program. However, the long terms success of the conservation efforts is threatened by the genetic hybridisation with the Painted Stork and mixing with free-flying individuals' collections in Perak, Selangor and Johor which has apparently established small breeding populations (Yee *et al*. 2013; Baveja *et al.* 2019; Tolohah *et al.* 2023).

The Painted Stork (*Mycteria leucocephala*) was first recorded in northern states of Malaysia including Kedah as vagrant (Wells 1999). In 1965, the Painted Stork was brought into Zoo Negara for captive breeding program, and the species was introduced to Malaysia after being released from captivity (Zakaria and Shukor 2019). Since then, the population of the Painted Stork monitored has increased by almost 10% to 13% every year (Zakaria *et al.* 2023) with the rapid species distribution expansion (Figure 6). The expansion of the Painted Stork species distribution is believed to increase habitat overlap with the native Endangered Milk Stork and increase the competition for resources (Zakaria *et al.* 2023) and hybridisation risk (Baveja *et al.* 2019).

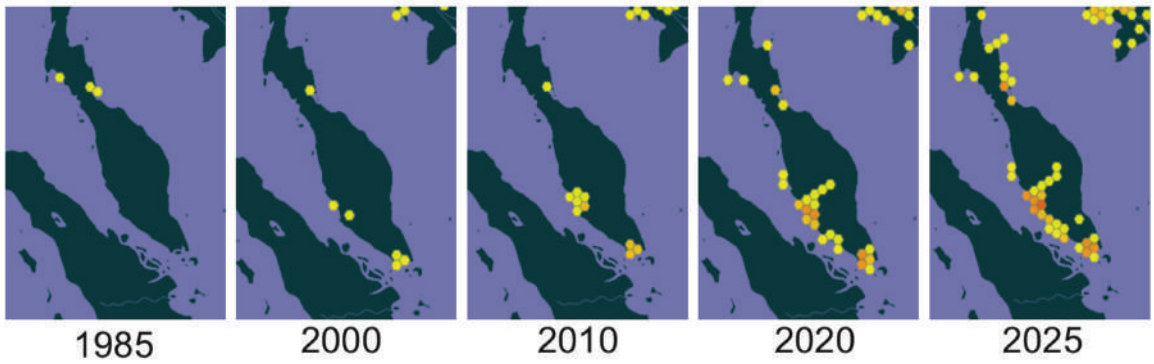

Figure 6. Spatiotemporal distribution of the Painted Stork occurrence at five-year interval from 2010 to 2025 (GBIF Secretariat 2023b).

WATERBIRDS IN SABAH AND SARAWAK

The western Sarawak coastline remains as one of Malaysia's most significant wintering grounds for the migratory waterbirds and hosts the country's current and only designated Flyway Network Site (FNS), Bako Buntal Bay. A comprehensive survey was conducted along the Sarawak coast and has recorded a minimum of 71,347 birds from 63 species (Bakewell *et al.* 2017). The Flyway Network Site, Buntal Bay and the adjacent Sejingkat ash ponds are documented to support at least 1% of the global population of the Far Eastern Curlew (*Numenius madagascariensis*) (Teepol *et al.* 2021). Additionally, the recent discoveries of the Critically Endangered species, the Spoon-billed Sandpiper (*Calidris pygmaea*) and the Chinese Crested Tern (*Thalasseus bernsteini*), in Sarawak highlighted the need to reassess its coastline (Teepol *et al.* 2023; J.J. Ng, per comms, 2025; D. Bakewell, per comms, 2026).

The coastal regions of Sabah remain the most under surveyed in Malaysia. Recent surveys have shown that some sites possess significant conservation value (Makbul *et al.*, in review). The Marudu Bay and Tawau coastline were found to support notable Far Eastern Curlew numbers. The Chinese Crested Tern was discovered wintering in Sabah with five individuals recorded in 2025 (J. Bakar, pers comms, 2026). This species was once thought to be extinct without confirmed records in Malaysia since the 1900s, but global population assessment now estimates 100 to 150 individuals remain with recent discoveries along the Bornean coast. These significant findings indicate that the conservation value of the Malaysian Bornean coast remains largely under discovery, and further studies are essential to fully understand the importance of the coast for the migratory waterbirds.

THREATS AND CONSERVATION

The primary drivers of the waterbird population decline in Malaysia are habitat loss, degradation, and fragmentation (Wells 1999; MacKinnon *et al*. 2012). The coasts of Johor, Selangor, and Pulau Pinang have undergone rapid changes, where coastal aquaculture, infrastructure and residential development have reduced mangrove coverage in these states (Yeap 2020; Crosby *et al.* 2025). These changes have reduced the foraging and roosting grounds for the migratory waterbirds (Yeap 2020) and essential nesting habitats for the resident waterbirds (See *et al.* 2025).

In 1995, the Malaysia government joined the Convention on Wetlands on Wetlands of International Importance Especially as Waterfowl Habitat (or the Ramsar Convention in short) to iterate its commitment to the conservation and wise use of the wetlands. In 2005, the East Asian-Australasian Flyway Partnership (EAAFP) was adopted as a Ramsar Regional Initiative, thus further strengthening wetland and waterbird conservation in Asia. The EAAFP has a strong focus on conservation of waterbirds, their associated habitats and community whoselivelihood depends on. Malaysia officially joined the EAAFP in 2012 marking a major commitment to migratory waterbird conservation. Soon after, the Bako Buntal Bay (EAAF 112) in Sarawak was accepted as Malaysia's first Flyway Network Site. Since, waterbirds and wetlands are monitored annually through AWC has led to identification and prioritisation of monitoring efforts of eight sites of importance to migratory waterbirds (Figure 7).

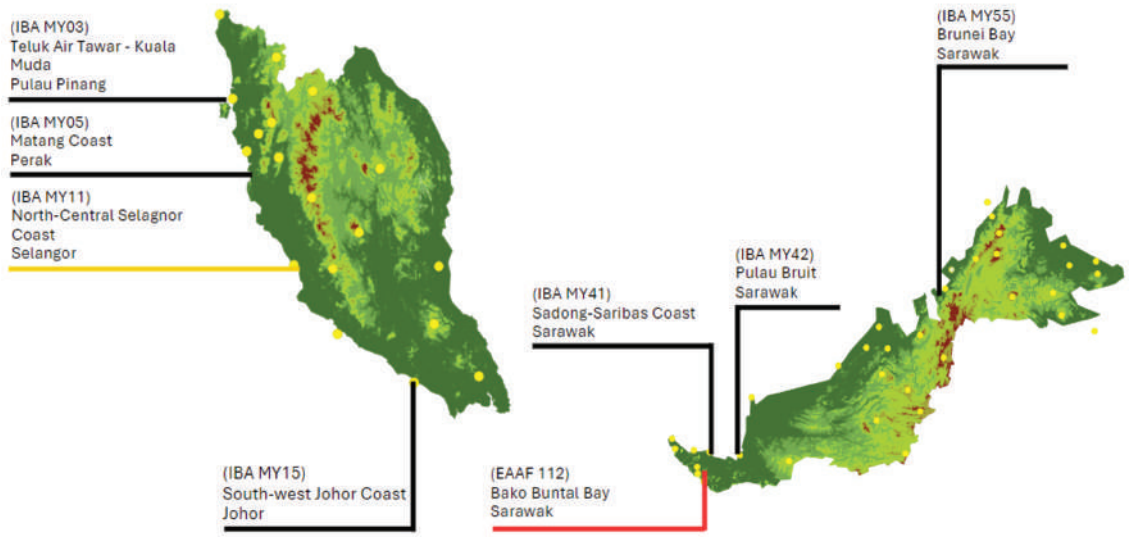

Figure 7. Priority sites of conservation importance for waterbirds monitored by the Asian Waterbird Census.

A recent assessment by BirdLife International identified seven coastal sites of importance to migratory waterbirds in Malaysia of which the Kuala Muda–Teluk Air Tawar coast and North-Central Selangor Coast received the highest priority (Crosby *et al.* 2025). MNS and PERHILITAN are currently advocating the NCSC as the next FNS after Bako Buntal Bay under the EAAFP. Parallel to this effort, the Malaysian government is also supporting the ASEAN Centre for Biodiversity (ACB) programme in identifying ASEAN Flyway Network (AFN) sites as part of a regional effort among ASEAN member states.

RECOMMENDATIONS AND CONCLUSION

Based on the current conservation status of waterbird in Malaysia, there are several priority interventions required to advance the waterbird conservation in Malaysia, and the key recommendations are summarised as below.

Strengthen transboundary and regional conservation networks
While wetlands of ornithological and conservation importance have been identified in Malaysia under several initiatives (e.g. IBAs, EAAFP Flyway Sites), there is a significant disparity between our national inventory and our internally recognised FNS. To bridge this gap, it is important to elevate the conservation status of our important wetlands (Figure 7), strengthen the current wetland site management to be more inclusive of waterbird needs, and advocate for site nomination of the high priority coastlines (including nomination of sites as FNS or Ramsar Sites) as a strategic requirement to ensure that the conservation of wetlands and waterbirds are fully integrated into regional and national conservation framework.

Plan for targeted conservation action for species of conservation concern
Many waterbird species including the Milky Stork, Sarus Crane or Storm's Stork have extirpated or are on the brink of being extirpated, and yet, Malaysia lacks a systematic framework to track this status. A national red list assessment is essential to document the local conservation status of the waterbirds, allowing for timely conservation intervention before more species vanish unnoticed.

While regional single species action plans already exists for priority species such as the Spoon-billed Sandpiper, Chinese Crested Tern, and Far Eastern Curlew, there are limitations. These plans outline the regional and national level for key actions and the stakeholders involved in implementing them, but there is still a need to further develop these strategies into tangible and site-specific actions at the local level. Other species that are experiencing critical decline that currently lack formal conservation frameworks, such as the Chinese Egret, require further attention for targeted conservation interventions on the grounds.

Foster community-led conservation and ethical outreach
Community-based conservation that integrates local knowledge, socio-cultural practices and participatory governance with the Indigenous People and Local Communities (IPLCs) foster greater environmental accountability and long-term success. Important wetlands (Figure 7) often overlap with the livelihood of local fishermen or traditional settlements, such as the Orang Asli Mah Meri in NCSC or the Orang Asli Kuala in the South-west Johor Coast. Integrating Free, Prior, and Informed Consent (FPIC) into all conservation projects and management plans is essential to ensure inclusive and socially equitable outcomes.

Communication, Education and Public Awareness (CEPA) strategies are key for building local stewardship and bridging the gaps between holistic conservation goals and reality on the ground. CEPA empowers the IPCLs to transition from passive supporters to active guardians of their natural heritage. This includes promoting ethical nature-based tourism, to mitigate anthropogenic disturbances to the habitats, such as wildlife feeding and other unethical ecotourism practices.

Conduct systematic surveys in data-poor regions or understudied waterbird group/species
Prioritising conservation actions for waterbirds is currently hindered by the geographical and taxonomic "blind spots", or knowledge gaps essentially. The importance of the coastline of Malaysia Borneo was validated by recent records of the Critically Endangered Chinese Crested Tern and the Endangered Far Eastern Curlew from ongoing studies and citizen science. Consequently, the launching of a systematic, and multi-season surveys across the little-known coastlines of Sabah and Sarawak is very important to identify or reassess previously undocumented sites of international importance. Additionally, for colonial breeding species such as seabirds and resident colonial waterbirds, specialised surveys for colony monitoring will be required to address the gaps in conventional Asian Waterbird Census methods for more meaningful population estimation for each waterbird group.

Advance movement ecology study to understand local movement of waterbirds
While AWC remains as essential tools on understanding local population abundance of most waterbird species, it offers limited insight into how waterbirds utilise the complex mosaic landscape of Malaysia intertidal landscape as foraging, roosting and stopover sites on daily or seasonal basis. To support evidence-based conservation for site conservation, targeted studies to understand the local movement ecology, which can be taxa-specific, allows us to have better understanding on the daily and seasonal movements of the waterbirds between different habitats.

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CHAPTER 5

Edible-nest swiftlets of Malaysia: Conservation outlook

LIM CHAN KOON*

Abstract: Edible-nest swiftlets are small-sized cavernicolous birds (Family Apodidae), comprising four species of swiftlets that construct nests of commercial value. This paper provides some insights into g the positive and negative aspects of human-swiftlet relationship; one which caused its demise on one hand, while another provides a safe haven in the form of swiftlet houses. Causes of swiftlet populations decline and breakdown of century-old traditional harvesting schemes driven by human greed in the 1980's and 1990's are deliberated. Comprehensive studies on the ecology of swiftlets in 1999 – 2000 greatly increase our understanding on the reproductive strategies of these intriguing birds, which enable formulation of sustainable harvesting plans. Three successful conservation initiatives are presented. Finally, the emergence of the swiftlet farming industry in Malaysia is chronologically outlined. Its overall effect on the birds' nest trade is briefly discussed.

INTRODUCTION

Swiftlets (*Aerodramus* spp. and *Collocalia* spp.) are small-sized swifts (Family Apodidae) from Indo-Pacific region that roost and nest in caves or cavern-like places (Chantler and Driessens 1995; Lim and Cranbrook 1999, 2014). Swiftlets nest in colonies, preferring remote and inaccessible areas such as vertical cave walls or ledges on overhang. Different species select different nesting sites; this choice is influenced by the ability to echolocate, or the nature of their nesting saliva. Swiftlets' nest is a cup-shaped structure supported and held together by salivary nest cement secreted from a pair of sub-lingua glands (Medway 1962a). This hardened nest cement is the edible part—the basic ingredient of bird's nest soup.

Amongst the 24 species of swiftlets in the world, only a few species produce nests of commercial interest. The bulk of edible birds' nests (EBN) traded worldwide comes from four exploited species: (i) coastal cave-dwelling Grey-rumped Swiftlets (*Aerodramus inexpectatus*), (ii) Brown-rumped Swiftlets (*A. fuciphagus*), (iii) Black-nest Swiftlets (*A. maximus*) and (iv) Glossy Swiftlets (*Collocalia esculenta*). The swiftlets that occupy man-made structures are a subspecies of Brown-rumped Swiftlets (*A. fuciphagus fuciphagus*).

The so-called "white-nest" produced by *A. fuciphagus* and *A. inexpectatus* are the most highly prized because their nests are made entirely of pure nest cement (hardened saliva of the swiftlets). Only very few small contour feathers of the swiftlet's plumage are incorporated. *Aerodramus inexpectatus* is confined to coastal caves (e.g. Tioman, Satang Islands, Mantanani and Berhala Islands). Majority of "white-nest" comes from *A. fuciphagus*, in which *A. fuciphagus* vestitus is only found in inland limestone caves (e.g. caves in middle Baram, Sarawak and Gomantong Cave, Sabah). The sub-species *A. fuciphagus fuciphagus* can be considered semi-domesticated swiftlets, whereby they readily occupy man-made structures, or purposely build bird-houses in the swiftlet farming industry. At present, nests from the swiftlet farming industry supply almost entirely the global demand for EBN.

More abundant throughout its distribution range, especially in Borneo, is the builder of the commercially inferior "black-nest", produced by the Black-nest Swiftlet. During nest building, the birds undertake frequent bouts of preening, by which they obtain the feathers

Kuala Lumpur, Malaysia
***Corresponding author: limchankoon2@yahoo.com**

of salivary nest cement. Each nest may contain up to 700 feathers of various sizes, hence require extensive cleaning before they can warrant for sale. The cleaned edible fractions, in the form of separated strains of nest cement, are then molded into oval-shaped bird nest chips.

At the height of the ENB industry, starting from the early 1990's, there was also a market for mossy nests constructed by Glossy Swiftlets. Nests of this species are also cup-shaped. The self-supporting mossy nest is attached to the cave wall by a basal attachment made of nest cement. At present, swiftlet farming provides a constant supply of higher grade EBN, and hence, exploitation of Glossy Swiftlets has ceased. Perhaps this is a blessing in disguise.

CONSERVATION ISSUES – DECLINING YIELD AND CONCERNS

In the past 30 to 40 years, production of EBN from caves in Sarawak has fallen dramatically because of a sharp decline in wild swiftlet populations. One major factor that caused this decline is unsustainable harvesting practices. The surge of demand from Hong Kong and skyrocketed prices in the mid-1980s' triggered frenzy harvesting by the local communities that otherwise followed a well-established traditional sustainable harvesting regime.

Consequently, the swiftlets' nests are being harvested more frequently. As a result, species that had withstood traditional exploitation for more than a century began to diminish rapidly because of short-term monetary gain. Countless numbers of eggs and nestlings are destroyed in the process. The interval between harvests is too short to permit any nestlings to fledge, thereby denying the recruitment of young swiftlets into the old and dying populations.

One example with a long recorded history of edible bird nest harvesting is Niah Caves in Sarawak. It used to be a major producer of "black-nest" in the 1980's. In 1935, the swiftlet population at Niah was calculated to be in the range of 1.7 million individuals (Banks 1935). Sixty years later in 1995, surveys placed the population at around 200,000 birds, or 88% decline (Sarawak Wildlife Master Plan 1996). Elsewhere in middle Baram, the Brown-rumped Swiftlet population also suffered a 69% reduction between 1948 and 1997 (Lim 1999).

Prior to 1997, there is not much information available on the breeding periodicity of the swiftlets. Main references then are the works done by the Earl of Cranbrook at Niah Caves in the late 1950's and early 1960's (Medway 1962b,1962c). Acting upon the recommendations from the 1996 Surabaya CITES Technical Workshop, the Sarawak Government incorporated the conservation of the edible-nest swiftlets into its Wildlife Master Plan. Subsequently, a comprehensive 12-month study on the annual breeding periodicity of Brown-rumped Swiftlet was conducted at middle Baram, Sarawak (Lim 1999). A similar study was also conducted on the Black-nest Swiftlet at Bukit Sarang in 2000 (Lim 2000). Both studies produced a tremendous amount of practical information with significant management implications.

Swiftlets annual breeding periodicity

The annual breeding season of the Brown-rumped Swiftlet and Black-nest Swiftlet is a protracted event, lasting at least nine months from August to March. There are three breeding bouts within this period (Figure 1). One breeding bout is defined as the first nest deposition until completion of the nest, followed by laying, incubation, and brooding until the nestlings are strong enough to fledge. Each breeding bout lasts between 86 and 116 days (30 days of nest building, 19 – 32 days incubation, 37 – 54 days brooding to fledging), or roughly 4 months.

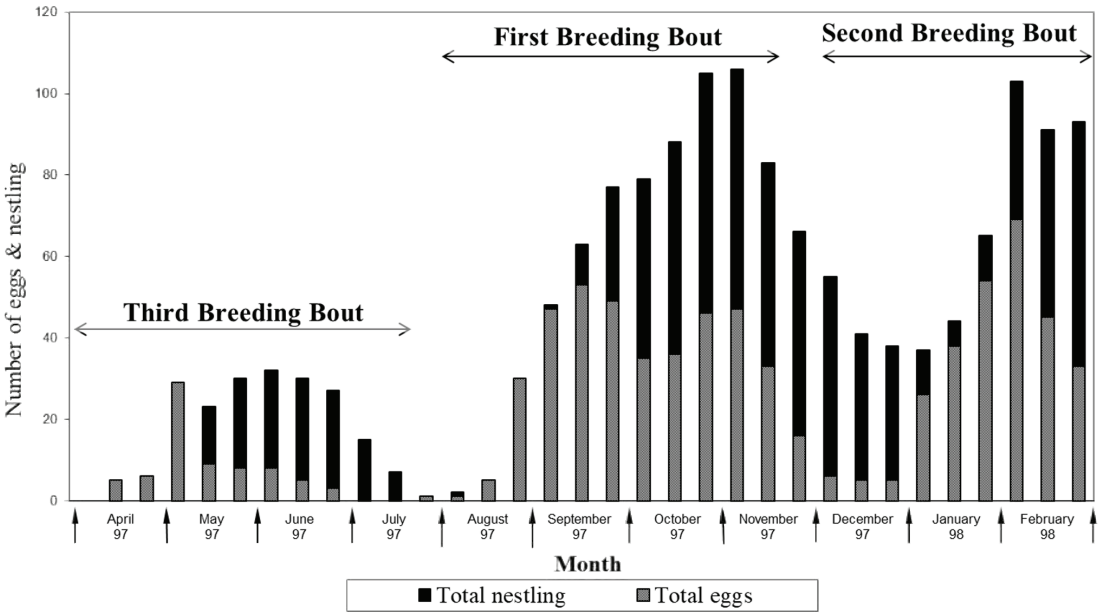

Figure 1. Three distinctive peaks represent three breeding bouts of Brown-rumped Swiftlets (*A. fuciphagus vestitus*) at Lubang Salai, middle Baram, Sarawak.

If the nest is not collected after the nestlings have fledged, or deteriorated due to damp surrounding, the same pair will re-use it. If the nest is removed, another replacement nest will be built on the same site. If eggs are lost during incubation, another replacement clutch will be laid. If breeding is successful and the nestlings have fledged, the parent will produce a subsequent clutch.

All species of Aerodramus lay a 2-egg clutch, except for the Black-nest Swiftlet that produces a single egg clutch. Swiftlets employ a multi-brooded reproductive strategy, meaning they will attempt to produce as many clutches and raise as many young as possible within the favorable breeding season. On average, with three breeding bouts, each pair of Brown-rump Swiftlet and Black-nest Swiftlet can produce three and two nestlings per year, respectively.

Successful conservation stories

A thorough understanding of the swiftlets' breeding biology is crucial in formulating sustainable harvesting practices that strike a balance between nest exploitation and conservation. The scientific basis for sustainable harvest, applicable to both species, dictates a mandatory 4-month no-harvesting period every year to allow each pair to raise one brood of nestlings. There are three examples of how declining swiftlet populations were reversed years after sustainable harvest was implemented.

The first example is a well-documented cave, i.e. Lubang Salai, in middle Baram, Sarawak. This cave is inhabited by the subspecies of Brown-rumped Swiftlet (*A. fuciphagus vestitus*). After sustainable harvest was adopted in 1998, the swiftlet population increased over the years as shown in Table 1. This government endorsed sustainable harvesting plan calls for a compulsory closed season from January to April every year. This 4-month closure is sufficient to achieve a full breeding cycle. Thereafter, the local communities are allowed up to five nest harvests per year.

Table 1. Data showing increase in the Brown-rumped Swiftlet populations in Lubang Salai, middle Baram Sarawak after sustainable harvest was implemented in 1998.

Year	Population Size	Increment
1997	1,398	–
1998	1,339	– 4 %
1999	1,524	+ 9 %
2000	1,976	+ 41 %
2001	2,400	+ 72 %
2002	3,240	+ 132 %
Fast forward to 2019		
2019	8,366	+ 498 %

The story of exploitation and conservation of Black-nest Swiftlets is more complicated because of anthropological issues. Outright total ban on harvesting is pointless when an area could not be effectively guarded. Illegal harvesting easily defeats any conservation efforts. Furthermore, it also fails to address the social-economical plights of the local communities. In Sarawak, most of the caves inhabited by Black-nest Swiftlets are communally shared. As such, tragedy of the common sets in.

A new concept of managing communal caves, where the traditional system has failed, was introduced at Bukit Sarang, Bintulu Division (Lim 2000), and at Niah National Park (Lim and Haidar 2003). The appointmentemergence of a cave manager under a unified group consolidates control, overseeing several areas combined under a larger, stronger and more efficient management. Only then can sustainable harvest be implemented. The outcome is a win-win situation for all parties, including the swiftlets. Swiftlets populations at these two locations have increased significantly over the years after a sustainable harvest regime was implemented as shownshowed in the Table 2 and Table 3 below.

Table 2. Data showing significant increase of Black-nest Swiftlet populations at Bukit Sarang, Bintulu Division, Sarawak (sustainable harvest implemented in 2000).

Year	Population Size	Increment
2000	8,528	–
2001	8,905	+ 4 %
2002	9,356	+ 10 %
2003	10,000	+ 17 %
2004	12,000	+ 41 %
2005	13,400	+ 57 %
2006	14,000	+ 64 %
2007	15,800	+ 85 %

Table 3. Recovery of Black-nest Swiftlet populations at Lubang Perintah, Niah National Park over a period of 21 years.

Year	Population Size	Increment
2002	2,974	–
2003	3,056	+ 3 %
2004	3,122	+ 5 %
2005	3,526	+ 20 %
2006	3,594	+ 23 %
2007	3,814	+ 30 %
Fast forward to 2023		
2023	9,174	+ 208 %

It is safe to state that at least some edible-nest swiftlets populations in Sarawak are sustainably managed and conserved. More importantly, the local communities having rights to these swiftlet colonies continue to derive livelihood from this valuable wildlife resource in a sustainable manner. In addition, Gomantong Cave in Sabah, where both Black-nest Swiftlets and Brown-rumped Swiftlets occur, is also reportedly being sustainably managed. Finally, a once balanced human-swiftlet relationship that was wrecked by human greed is now restored in few places.

Historical development of swiftlet farming industry

Swiftlet farming is similar to apiculture but instead of hives, humans build specially designed buildings that imitate cave-like environments to lure swiftlets to roost and nest. Indonesia is the birthplace of this industry, where the first of such houses was reported in Sedayu, East Java, in 1880 (Mardiastuti 1996). The initial approach was passive colonisation of buildings by the swiftlets. Nothing is done to improve the conditions within these houses.

As the price of EBN appreciated in the 1980's, people started to modify any buildings occupied by the swiftlets to make them more conducive for these wealth-creating inhabitants. Fundamental techniques and innovative modifications to emulate a cave-like atmosphere, as we see today in the swiftlet farming industry, were developed. The modern swiftlet farming era is epitomised by acoustic manipulation of swiftlets' social vocalisations associated with colonial nesting or courtship behavior. Play-back of swiftlet calls are used to excite and entice or lure the swiftlet into newly constructed buildings specifically designed for this purpose.

Spontaneous colonisation of old shop-houses by *A. fuciphagus fuciphagus* throughout Peninsular Malaysia occurred as early as 1940's and 50's (Cranbrook *et al.* 2013). The earliest published record of a swiftlet house in Malaysia is in Penang (Langham 1980). Intensive swiftlet farming only started around 1995/96, and truly took off during the Asian financial crisis in 1997/98, because so many completed shop-houses remain unsold, sitting empty unutilised. Many took this opportunity to convert them into swiftlet houses. About the same time, detached swiftlet houses erected on agricultural land also began to mushroom across sub-urban and rural areas across Peninsular Malaysia.

Prior to the Asian financial crisis, it was estimated that there were only roughly 150 or so swiftlet houses throughout Peninsular Malaysia. By 2000, the number had increased to about 800 houses, and between 5,000 to 8,000 houses in 2003. By 2006, this number had exceeded the tens of thousands mark. The rapid expansion of swiftlet farming in Malaysia also coincides with the rise of China's economic boom. The rise of affluent and middle classes in China pushed the demand for EBN to a new level. However, the peak of this industry was from 2010 to 2015, thereafter the swiftlet populations in houses also started to decline.

The EBN industry suffered a severe blow with the nitrite crisis in 2011, when China, the biggest EBN market, banned the import due to high levels of nitrite found in some nests. This crisis was partially resolved in 2012. The total ban was only lifted by the Chinese government in 2014. Although the export of EBN to China has resumed, the industry has been unable to attain export volumes compared to the golden-years era.

Kota Kinabalu

DILEMMA AND CHALLENGES AHEAD

One caveat for the success of conservation stories is that the caves must be able to be guarded effectively. As such, significantly more Black-nest Swiftlets caves across its distribution ranges are not so secured. Most populations are still being decimated by over-harvesting. One saving clause, however, is that with better quality EBN produced from swiftlet houses at comparable price, demand for "black-nest" almost come to a standstill in the last 2 years, with prices drop by almost 85%. Hopefully, this will provide some respite for the Black-nest Swiftlets.

The species that is currently in dire state is the Grey-rumped Swiftlets (*A. inexpectatus*). Its distribution in Peninsular Malaysia is mainly confined to the east coast islands of Terengganu-Pahang-Johor archipelago, e.g. Pulau Nyireh (Terengganu), Tioman (Pahang), Pulau Tinggi (Johor). In Sarawak, this species is found in Pulau Satang Island and Lakei, while in Sabah it has been recorded from Pulalu Mantanani off the coast of Kota Belud, and Pulau Berhala in Sandakan Bay. Repeated trips by Earl of Cranbrook in 2010's to these islands failed to spot any (pers. com.), suggesting our greatest fear of local extinction.

On the swiftlet farming front, it appears that populations of the semi-domesticated *A. fuciphagus fuciphagus* have been artificially increased by the countless number of bird houses constructed across Malaysia. No doubt the populations in swiftlet houses had exploded during the initial flourishing phase. Nonetheless, in recent years, overall EBN productions from swiftlet farming are also in the decline, but pose no immediate existential threat to this sub-species.

This leads to the next important question. What is the future outlook for edible bird's nest industry? Answer to this question will also provide insight into the future threat to the edible-nest swiftlets. China is the main consumer of EBN; intricately woven into the Chinese gastronomic ethos and beliefs. But will the younger Gen-Z embrace such indulgence? Or will EBN suffers similar demise as shark-fin soup? Rejected by personal conscious. Many say this is a sunset industry; already passed its golden era.

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CHAPTER 6

Sea turtle conservation in Peninsular Malaysia

MOHD UZAIR RUSLI[1]* and DIONYSIUS S. K. SHARMA[2]

Abstract: Sea turtle conservation in Peninsular Malaysia has undergone substantial changes since the publication of *The State of Nature Conservation in Malaysia* in 1991. This chapter critically examines developments in population status, scientific research, conservation investment, community participation and governance over the subsequent 35 years. Although sustained protection has coincided with encouraging increases in green turtle nesting, recovery remains uneven across species and regions. Long-term studies have revealed important changes in recruitment, body size and breeding periodicity, demonstrating that increasing nesting abundance does not necessarily reflect improvements in all aspects of population performance. In contrast, the near disappearance of Terengganu's leatherback turtles raises critical questions about whether scientific knowledge has been matched timely intervention and adequate conservation investment. Their unexpected return to nest in 2026, without successful embryonic development, further highlights unresolved reproductive uncertainties. Drawing on historical evidence, recent scientific findings and conservation experience, we argue for a stronger connection between research, strategic investment, institutional coordination and community stewardship. Future priorities should extend beyond protecting nests and producing hatchlings towards reducing mortality, safeguarding marine habitats and strengthening population viability. Ultimately, Malaysia's conservation progress must be judged not simply by the efforts undertaken, but by their measurable contribution to the long-term survival and recovery of sea turtle populations.

INTRODUCTION

Revisiting the conservation outlook

When Chan Eng Heng reviewed the state of sea turtle conservation in Malaysia in 1991, the outlook was troubling. Decades of egg harvesting, incidental capture in fishing gear, coastal development and poorly managed tourism had taken their toll. Terengganu's once-abundant leatherback turtles (*Dermochelys coriacea*) were already approaching local extinction, while green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and olive ridley (*Lepidochelys olivacea*) turtles faced mounting pressures (Chan 1991).

The recommendations were clear: strengthen legislation, protect nesting and marine habitats, improve hatchery management, sustain scientific monitoring and foster international cooperation. Much of this agenda remains relevant today. Malaysia has since made substantial progress. More nesting beaches receive protection, research programmes have produced increasingly sophisticated ecological knowledge, and conservation has attracted wider participation from communities, educational institutions and the private sector. Yet the outcomes have been far from uniform. Some nesting populations have increased considerably; others have dwindled to the point where even their reproductive future is uncertain.

[1] Sea Turtle Research Unit (SEATRU), Centre for Marine Conservation, Institute of Oceanography and Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
[2] Faculty of Science and Marine Environment, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
***Corresponding author: uzair@umt.edu.my**

This chapter examines what has changed in Peninsular Malaysia since the 1991 assessment, where conservation has made a difference and where persistent shortcomings deserve closer attention. Central to our assessment is whether scientific knowledge, conservation investment and institutional action have kept pace with the biological challenges facing different turtle populations.

Uneven progress across species and regions

The green turtle remains the most abundant and widely distributed nesting species in Peninsular Malaysia, with Terengganu providing its principal stronghold. Its global reclassification from Endangered to Least Concern in the 2025 IUCN Red List reflects encouraging recovery across numerous populations (Wallace and Broderick 2025). However, global improvement should not obscure the considerable differences among Malaysian nesting sites.

Boulven *et al.* (2024) analysed green turtle nesting records from 1996 to 2022 and found markedly different regional trends. Recorded nesting activity increased by an estimated 379% in Terengganu, with smaller positive trends in Pahang and Pulau Pinang. Perak, by contrast, experienced an estimated 62% decline, while Johor exhibited a slightly negative trend. Such differences caution against treating national nesting totals as a reliable account of every population's condition.

At Chagar Hutang Turtle Sanctuary, Redang Island, evidence of increasing nesting activity is particularly strong. Drawing on 32 years of monitoring (1993 – 2024) and records of 4,609 individually tagged green turtles, Tromp *et al*. (2026) reported a three- to fourfold increase in annual nesting abundance, from approximately 400 – 500 nests in the earlier years to 1,500 – 2,000 more recently ($R^2 = 0.52$, $p < 0.01$).

The underlying processes are revealing. Wenceslau *et al*. (2021) found that increasing nest abundance was associated with the recruitment of new nesting females ($R^2 = 0.516$, $p < 0.001$). Nesting fluctuations were also correlated with the El Niño–Southern Oscillation (ENSO) approximately 2.5 years earlier, suggesting that climatic conditions affecting distant foraging grounds may influence subsequent breeding activity.

More recent findings complicate the conventional picture of population recovery. From 18,707 carapace measurements, Hays *et al.* (2025) documented a decline in mean nesting female size from 100.8 cm in 2005 to 96.8 cm in 2022. The influx of smaller, first-time nesters partly explained this reduction, although neophytes themselves were also becoming smaller. Meanwhile, Tromp *et al*. (2026) analysed 1,399 breeding-interval records and found that the relative proportion of four-year versus three-year remigration intervals increased from 28% in 1997 – 2012 to 37% in 2013 – 2024. This shift was significantly associated with annual nest numbers ($R^2 = 0.23$, $p = 0.01$).

These observations raise an intriguing possibility: population growth may be accompanied by changes in reproductive performance. Density-dependent food limitation and changing environmental conditions are plausible explanations, although their relative contributions remain unresolved. Increased nesting is encouraging, but it does not necessarily imply that individual females are breeding more frequently or maintaining their former body size.

Elsewhere, the situation remains more precarious. Hawksbill nesting is comparatively restricted, with Melaka supporting an important aggregation along the west coast, while olive ridley nesting has become exceptionally rare across much of its historical range. Smaller nesting aggregations, including those in Perak, warrant protection despite their modest numbers.

The most severe loss, however, remains the collapse of Terengganu's leatherback population. Nesting became so infrequent that the historical aggregation was considered functionally extinct. After a single recorded nest in 2010 and two in 2017, no further nesting was documented until five events occurred in 2026. This unexpected reappearance offers a rare opportunity to investigate whether reproductive potential persists within or beyond the remnant population. It does not, by itself, indicate recovery.

THE EVOLUTION OF SEA TURTLE SCIENCE IN MALAYSIA

The development of Malaysian sea turtle science has changed not only what researchers know, but also the questions they can investigate. Early work by Hendrickson established a foundation for studies of nesting and movement, while the establishment of the Sea Turtle Research Unit (SEATRU) in 1984 strengthened systematic research, particularly on leatherbacks in Terengganu.

A notable advance came through incubation biology. Chan and Liew (1995) demonstrated that incubation temperature influenced leatherback hatchling sex ratios, revealing a consequence of hatchery management that could not be detected through hatching success alone. Research increasingly began to examine the biological quality of hatchlings rather than simply counting their production.

Experimental studies subsequently extended this approach. Rusli *et al.* (2015) showed that incubation methods could affect green turtle hatchlings' crawling and swimming performance. Further investigations demonstrated that synchronous digging reduces the energetic cost of escaping underground nests (Rusli *et al.* 2016). Acoustic monitoring later revealed changes in the coordination of digging activity before emergence, providing insight into behaviour previously hidden beneath the sand (Nishizawa *et al.* 2021).

These findings are relevant to practical conservation. A hatchling that emerges successfully has not necessarily experienced favourable developmental conditions or retained the energetic reserves needed for its initial journey offshore. Understanding these mechanisms allows hatchery practices to be assessed more critically.

Research has also followed turtles into their marine environment. Investigations at Chagar Hutang identified predation on hatchlings by juvenile blacktip reef sharks, illustrating the ecological pressures encountered shortly after entering the sea (Bashir *et al.* 2020). Satellite telemetry has revealed a different dimension of their lives. Pilcher *et al.* (2019) reviewed 104 transmitter deployments in Malaysia, with usable information from 102, documenting migrations that connect nesting sites with distant foraging areas across Southeast Asia.

The contrast between what is known on land and at sea remains striking. Nesting females have been studied intensively at several locations, yet demographic information concerning juveniles, males and survival in marine habitats is still limited. Genetic methods, remote sensing and digital monitoring offer ways to address these gaps, provided they are directed towards well-defined conservation questions.

We regard this progression as a considerable achievement. Malaysian research has moved from describing nesting activity towards explaining the physiological, behavioural and environmental processes that influence survival. Its next test is whether those explanations can improve management decisions, particularly where established approaches have proved insufficient.

Scientific investment and the leatherback conservation challenge

The value of scientific knowledge becomes most evident when conservation faces its greatest difficulties. Terengganu's leatherback history offers a sobering example of what can happen when recognised threats persist despite research, protection measures and public concern.

In 1956, the coastline supported an estimated 10,155 leatherback nests. By 1995, only 37 were recorded, equivalent to approximately 0.4% of the earlier abundance (Chan and Liew 1996). Egg exploitation, fisheries-related mortality, coastal disturbance and shortcomings in incubation practices contributed to this decline.

Many of these problems were understood before the population reached such critically low numbers. Research had documented the consequences of egg harvesting and fisheries interactions, while incubation studies identified concerns about hatchling production and sex ratios. Beyond Malaysia, stage-based population modelling demonstrated the importance of survival among larger juvenile turtles (Crouse *et al.* 1987). Frazer (1992) similarly warned that increasing hatchling production without addressing the causes of mortality could offer only a partial conservation solution.

The issue, therefore, extends beyond whether sufficient research had been conducted. It concerns the extent to which available knowledge was converted into timely intervention, supported by the resources, technical capacity and institutional commitment required to reduce threats.

Events in 2026 bring this question into sharper focus. Between 1 September and 10 October, five leatherback nesting events along the Terengganu coast produced 313 eggs. The intervals between nesting events suggested that the clutches may have originated from one female. Subsequent examinations found no detectable embryonic development, and all eggs failed to hatch (Bernama 2026a, 2026b).

These observations are biologically significant, but their interpretation requires care. The absence of observable embryonic development does not establish whether fertilisation failed or embryos died at a very early stage. Nor can nesting intervals alone confirm individual identity. Genetic analysis, reproductive diagnostics and appropriate embryological investigations are needed to distinguish these possibilities.

Other questions remain equally pressing. Does the returning female belong to the historical Terengganu population? Are breeding males present within the wider region? Where do surviving individuals spend their time between breeding seasons, and what threats do they encounter? Addressing such questions may require coordinated genetic sampling, satellite tracking, reproductive investigations and marine monitoring extending beyond Malaysian waters.

The difficulty is that opportunities to obtain this information have become exceptionally rare. Small populations can be scientifically demanding: individuals are difficult to locate, biological samples are scarce, and meaningful observations may occur years apart. Preparedness is therefore essential. Expertise, laboratory capacity, sampling protocols and financial resources must be available before an unusual nesting event occurs, not assembled only after the opportunity has passed.

This raises a broader question about the adequacy of conservation investment. We lack sufficiently consolidated historical financial data to quantify any funding shortfall or attribute the leatherback collapse specifically to inadequate expenditure. Nevertheless, the outcome warrants critical examination of whether investment was sustained, appropriately targeted and commensurate with the population's risk of disappearance.

The lesson is not that science failed to identify the problem. Rather, scientific knowledge alone could not secure the population. Effective conservation requires the ability to investigate remaining uncertainties while simultaneously reducing known threats.

Investment should therefore reflect more than the abundance of animals available for study. Extinction risk, biological uncertainty and the urgency of intervention are equally legitimate considerations. A species should not receive diminishing scientific attention simply because so few individuals remain.

FROM PUBLIC AWARENESS TO SHARED STEWARDSHIP

Scientific capacity is only one part of an effective conservation system. The protection of sea turtles also depends on people who live and work alongside their habitats, institutions with clear responsibilities, and economic activities compatible with conservation objectives.

Community initiatives in Terengganu illustrate how these relationships have developed. At Ma'Daerah, partnerships involving WWF-Malaysia, government agencies and residents supported nesting habitat protection and local conservation advocacy. The establishment of Persatuan Khazanah Rakyat Ma' Daerah (MEKAR) in 2005 provided a platform for community participation. In Setiu, Persatuan Wanita Kampung Mangkok Setiu (PEWANIS), formally registered in 2010, connected wetland conservation with women's participation, environmental education and alternative livelihood opportunities.

Chagar Hutang offers a complementary model as a living lab, where long-term research, conservation and education are brought together within a functioning sea turtle nesting sanctuary. Since 1998, SEATRU's volunteer programme has enabled members of the public to participate directly in nesting monitoring, habitat protection and field research, while its Outdoor Classroom provides opportunities for experiential environmental learning (Chan 2010). More importantly, Chagar Hutang demonstrates how a university-led conservation initiative can evolve into a shared platform for scientific discovery, public engagement and stewardship, extending its value beyond institutional boundaries while keeping the protection of nesting turtles at its core.

Such programmes contribute to public understanding and can develop future conservation advocates. Yet participation should not be mistaken for demonstrated behavioural change. Ting and Hassan (2025) reviewed publicly reported outreach activities of 18 Malaysian organisations during 2023 – 2024. All used knowledge dissemination, 17 incorporated hands-on activities, and only four included knowledge-application approaches. Their findings reveal the breadth of outreach provision, but do not establish whether these programmes produce lasting changes in behaviour.

Experience-based tourism is gaining prominence in sea turtle conservation, with activities such as swimming and diving with turtles, guided nesting experiences and hatchling release programmes attracting growing public interest. These experiences offer opportunities to strengthen environmental appreciation, support coastal livelihoods and generate conservation funding. However, increased participation also raises ethical and ecological concerns, particularly regarding disturbance to turtles in their natural habitats, inappropriate wildlife interactions and the handling or release of hatchlings. Clear, science-based guidelines are therefore essential to ensure that tourism activities prioritise animal welfare, minimise ecological impacts and deliver genuine conservation benefits rather than simply providing memorable visitor experiences.

Conservation must also be considered within wider coastal development decisions. A multidisciplinary assessment in Perak combined ecological surveys, local knowledge, habitat mapping and socioeconomic valuation to inform coastal planning. Its estimate of RM 1.34 billion in total economic value concerned the broader coastal and marine ecosystems assessed, not sea turtles alone. Community surveys also indicated support for conservation financing mechanisms, offering opportunities to link habitat protection with public benefits (Universiti Malaysia Terengganu *et al.* 2026).

Governance remains indispensable. Terengganu's 2021 amendment to the Turtles Enactment, which prohibited the sale of eggs from all turtle species from 1 June 2022, marked a significant legislative development (Bernama 2021). Its conservation value, however, depends on enforcement and the wider management of threats affecting turtles at sea and along developed coastlines. The next advance in community conservation should be judged by the durability of these arrangements: whether local people gain meaningful roles, whether environmentally harmful practices decline, and whether conservation continues when individual projects or funding agreements end.

THE WAY FORWARD

Malaysia now possesses an extensive body of research, practical experience and institutional knowledge (Table 1). The challenge is to organise these assets around a clearer set of conservation outcomes, with priorities reflecting the condition and needs of individual populations.

Table 1. Progress and remaining priorities in sea turtle conservation in Peninsular Malaysia.

Conservation priority in 1991	Progress by 2026	Remaining challenge
Reduce egg exploitation	Greater nesting beach protection; Terengganu became the last state in Peninsular Malaysia to prohibit the commercial sale of all sea turtle eggs in 2022	Enforcement effectiveness and differences in protection across jurisdictions
Improve hatchery management	Advances in incubation biology and hatchling performance research	Evaluating reproductive outcomes beyond hatching success
Protect critical habitats	Turtle sanctuaries established; migration and foraging habitats increasingly documented	Securing important habitats beyond nesting beaches
Reduce fisheries-related mortality	Greater recognition of marine threats and growing ecological knowledge	Limited population-specific mortality and intervention -effectiveness data
Strengthen scientific monitoring	Long-term tagging, reproductive studies, genetics and telemetry	Limited demographic information on juveniles, males and survival at sea
Improve institutional and international cooperation	Wider engagement among agencies, universities, NGOs and communities	Sustained coordination, shared data and long-term financing

Reliable population assessment is the starting point. Standardised nesting records should be linked, wherever feasible, with information on breeding females, recruitment, reproductive intervals, survival and population connectivity. The long-term findings from Chagar Hutang demonstrate the value of such monitoring, while differences among states show why consistent methods and interpretation matter.

Marine protection requires comparable attention. Nesting beaches are only one component of the habitat network used by sea turtles. Fisheries-related mortality, conditions at foraging grounds and the security of migration corridors can undermine gains achieved through egg protection. Tracking, habitat mapping and ecological models should therefore guide practical management measures and provide evidence for evaluating their effectiveness.

Research priorities also need to reflect population status. Relatively abundant green turtle aggregations permit detailed demographic investigation, whereas depleted leatherback and olive ridley turtle populations may require specialised, opportunistic and regionally coordinated approaches. Neither should be neglected. The appropriate scientific response depends on the questions that must be answered and the risks of leaving them unresolved.

We propose a coordinated national research and recovery framework built around existing government agencies, universities and conservation organisations. Shared monitoring standards, accessible databases, clearly assigned responsibilities and agreed research priorities would reduce fragmentation. Financing arrangements should provide continuity beyond individual project cycles and support periodic assessments of whether management interventions are achieving their intended results.

Community stewardship and economic planning should form part of this framework, with indicators extending beyond volunteer participation, education sessions or tourism income. Compliance, local conservation capacity, community benefits and improvements in habitat protection provide more meaningful evidence of social contribution.

Above all, the distinction between conservation activity and conservation success must be made explicit. Numbers of nests protected, hatchlings released, publications produced and people engaged describe what conservation programmes do. They are useful measures of effort, but they are not substitutes for evidence that mortality has declined, reproductive performance has improved, habitats remain secure or populations are becoming more viable.

Malaysia has demonstrated that sustained protection and research can coincide with substantial increases in sea turtle nesting. The loss of the historical leatherback aggregation shows, just as clearly, that effort and knowledge do not guarantee recovery. Both experiences should inform the country's next conservation priorities. The task ahead is not simply to do more for sea turtles, but to direct our scientific, financial and institutional resources towards the interventions most likely to secure their future.

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CHAPTER 7

Sea turtle conservation in Borneo: Malaysia's oldest and strongest conservation legacy

JUANITA JOSEPH[1]*, JAMES BALI[2], SALVIA SEMBAI[2],
SITI NUR'AIN AMPUAN ACHEH[3], MOHD. RAFIEE ZULHILMIE ASDARI[4],
SHAMIL ARIF MUHAMAD[1] and GAVIN JOLIS[5]

Abstract: Long-term conservation efforts in Sabah and Sarawak have contributed significantly to the protection of sea turtles in Malaysia. Protection of nesting beaches, hatchery management, enforcement, community participation, and research have supported positive conservation outcomes across the region. Recent advances in genetic studies, satellite tracking, and long-term monitoring have improved the understanding of turtle connectivity and strengthened conservation management. Despite these achievements, threats such as fisheries bycatch, habitat degradation, marine pollution, and climate change continue to challenge conservation efforts. Future conservation success will depend on sustained protection, science-based management, and strong collaboration among stakeholders.

INTRODUCTION

Sea turtle conservation represents one of the longest-standing and most well-established conservation successes in Malaysia, with Sabah and Sarawak forming the foundation of this national legacy (Joseph *et al*. 2021). Conservation initiatives in Borneo can be traced back to the early 20th century and have continued uninterrupted for decades through a combination of legal protection, hatchery management, sustained enforcement, scientific research, and increasing community involvement. Together, these long-term and coordinated efforts have positioned East Malaysia as a regional leader in sea turtle conservation in Southeast Asia (Joseph *et al*. 2021; Bali *et al*. 2023; Sabah Wildlife Department 2025).

This conservation legacy is supported by strong state-level legislative frameworks in Sabah and Sarawak (Bali *et al*. 2023; Sabah Wildlife Department 2025). In Sabah, sea turtles and their eggs are protected under the Sabah Wildlife Conservation Enactment 1997, while key nesting and foraging habitats are further safeguarded through the Parks Enactment 1984 (Amendment 2024). In Sarawak, protection is provided under the Sarawak Wild Life Protection Ordinance 1998. Together, these legislative frameworks prohibit the taking, possession, and trade of protected species while supporting the conservation and management of important habitats.

In Sabah and Sarawak, two species of sea turtle nest regularly (Bali *et al*. 2023; Jolis *et al.* 2023; Sabah Wildlife Department 2025), namely the green turtle (*Chelonia mydas*; local name: *penyu agar* or *penyu hijau*) and the hawksbill turtle (*Eretmochelys imbricata*; local name: *penyu karah* or *penyu sisik*). Olive ridley turtle (*Lepidochelys olivacea*;

[1] Institut Marin Borneo, Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, Malaysia.
[2] Sarawak Forestry Corporation, Lot 218, KCLD, Jalan Sungai Tapang, Kota Sentosa, 93250 Kuching, Sarawak, Malaysia.
[3] Sabah Wildlife Department, 5th Floor, B Block, Wisma Muis, 88100 Kota Kinabalu, Sabah, Malaysia.
[4] Sabah Parks, Block H, Level 1-5, Lot 45 & 46, Signature Office, KK Times Square, Kota Kinabalu, Sabah, Malaysia.
[5] WWF-Malaysia, 6th floor, CPC Tower, Centre Point Complex, No. 1, Jalan Centre Point, 88800 Kota Kinabalu, Sabah, Malaysia.
***Corresponding author: juanita@ums.edu.my**

local name: *penyu lipas*) continue to nest in the region, although nesting occurs at very low frequency and remains sporadic. The leatherback turtle (*Dermochelys coriacea*; local name: *penyu belimbing*) and loggerhead turtle (*Caretta caretta*; local name: *penyu tempayan*) were historically recorded nesting in Sarawak (Bali *et al*. 2023), but these records were limited to single, isolated nesting incidents and no longer occur today.

In contrast to the restricted nesting assemblage, the coastal and offshore waters of Sabah and Sarawak support foraging habitats for four sea turtle species: green turtles, hawksbill turtles, olive ridley turtles, and leatherback turtles (Nishizawa *et al.* 2016, 2018; Joseph *et al*. 2021). These waters function as important migratory corridors, temporary stopover sites, and in some cases, resident feeding grounds for turtles originating from multiple regional rookeries (Nishizawa *et al.* 2016, 2018; Joseph *et al*. 2021; Bali *et al*. 2023). Loggerhead turtles, while documented at foraging grounds in Peninsular Malaysia (Abdul Rahman *et al.* 2021), have not been recorded utilising foraging habitats in Sabah and Sarawak. Collectively, these patterns show the significance of Borneo not only as a regional nesting area for selected species, but more importantly as a critical feeding and transit zone within the broader Indo-Pacific seascape.

Recent global and regional assessments reflect the positive outcomes of sustained conservation efforts in the region. The green turtle has been downlisted to Least Concern on the IUCN Red List (IUCN 2026), with one of the key contributing factors being the recovery of major populations in the Sulu Sea. Nesting populations in this region have increased by approximately threefold over recent decades, with Turtle Islands Park alone now recording more than 20,000 nests annually (Joseph *et al*. 2021). This site represents one of the largest green turtle rookeries in the Indo-Pacific and provides strong evidence that long-term protection, effective hatchery management, and consistent enforcement can lead to population recovery on a scale.

Beyond formal protection and enforcement, sea turtle conservation in Sabah and Sarawak has been strengthened by active participation from local communities, non-governmental organisations (NGOs), and research institutions, many of which have worked in close partnership with state agencies over extended periods (Joseph *et al*. 2021; Sabah Wildlife Department 2025; NRES 2026). Community-led nesting monitoring, hatchery management, outreach programmes, and collaborative research initiatives have played an important role in sustaining conservation outcomes (Jolis *et al*. 2023). Importantly, conservation efforts in East Malaysia are supported by strong scientific capacity, with long-term monitoring, tagging (Joseph *et al*. 2021; Bali *et al*. 2023; Sabah Wildlife Department 2025) satellite tracking (Pilcher *et al*. 2019), and genetic studies (Nishizawa *et al*. 2016, 2018, 2024) providing the evidence needed to guide adaptive management and policy decisions.

Despite these achievements, recovery trends are not uniform across all species. Hawksbill turtle nesting remains low and vulnerable, while olive ridley nesting continues to be extremely rare (Joseph *et al.* 2021; Joseph 2017). Persistent threats, including egg poaching, fisheries bycatch, coastal development, marine pollution, and climate change continue to challenge conservation efforts (Joseph *et al.* 2021). Emerging pressures, such as increasing tourism pressure at key foraging sites, further complicate management across multiple habitats. Overall, the conservation outcomes observed in Sabah and Sarawak reflect the strengths of long-term protection, governance, and institutional commitment, while ongoing threats and uneven recovery among species highlight the need for adaptive, forward-looking conservation strategies.

CURRENT STATUS AND DISTRIBUTION

The current status and distribution of sea turtles in Sabah and Sarawak vary markedly across sites and species, reflecting differences in historical exploitation, protection intensity, and monitoring effort (Joseph *et al*. 2021; Bali *et al*. 2023; Sabah Wildlife Department 2025). Nesting activity is concentrated at a limited number of key locations, while foraging grounds are more extensive and widely distributed (Figure1).

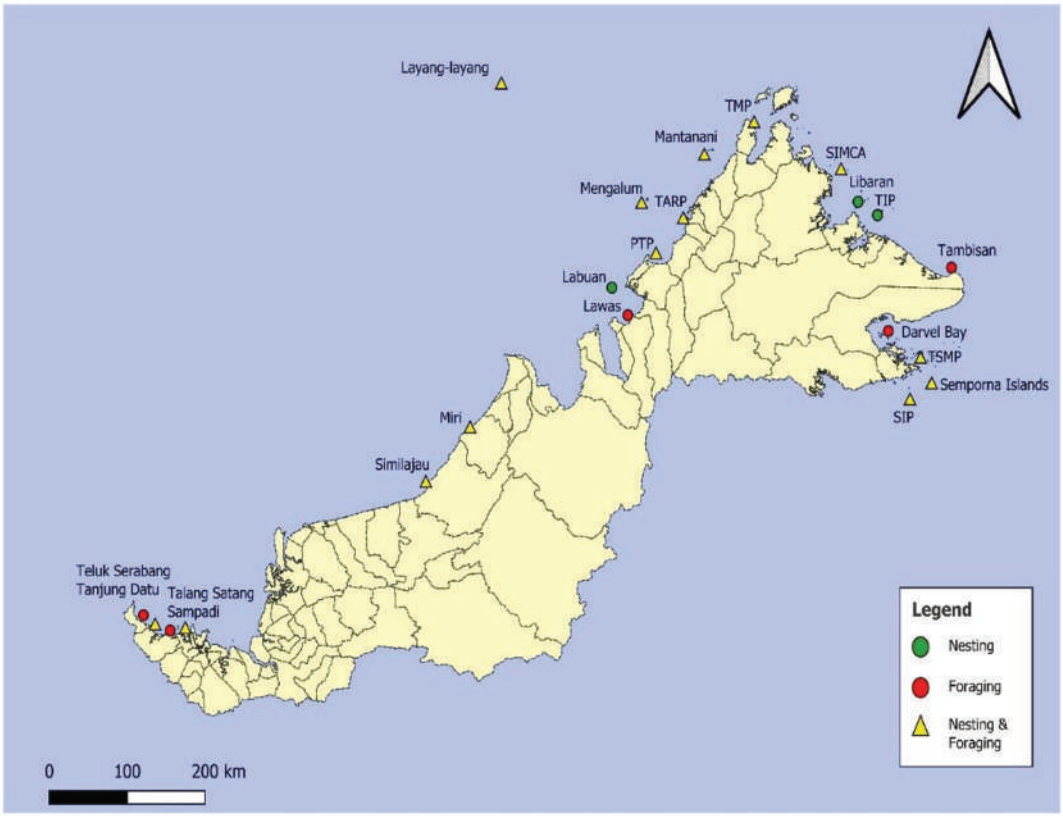

Figure 1. Distribution of sea turtle nesting and foraging areas across Sabah and Sarawak. (TIP – Turtle Islands Park; TMP – Tun Mustapha Park; SIMCA – Sugud Islands Marine Conservation Area, TSMP – Tun Sakaran Marine Park; TARP-Tunku Abdul Rahman Park; PTP – Pulau Tiga Park; SIP- Sipadan Island Park).

Sarawak: From historical decline to sustained protection and conservation gains

Long-term nesting records from Sarawak indicate a marked decline in sea turtle nesting since the early 1950s (Bali *et al*. 2023). Current nesting levels are estimated to be approximately 90% lower than those recorded in 1951 (Figure 2), reflecting the legacy of historical egg harvesting, coastal habitat loss, and prolonged exploitation prior to the implementation of comprehensive conservation measures.

Since the mid-1960s, nesting numbers have remained consistently low, fluctuating within a relatively narrow range. While this pattern reflects stabilisation at a depleted population level rather than population recovery, it also indicates that further declines have largely been prevented through sustained protection efforts. Nesting in Sarawak is dominated by green turtles, which account for approximately 95% of recorded nests (Bali *et al*. 2023). Hawksbill turtles contribute a smaller proportion (4%), while olive ridley nesting remains rare and irregular (Bali *et al*. 2023).

Despite the long-term reduction and stabilisation of nesting numbers, hatchling production in Sarawak has shown a clear and encouraging upward trend since the late 1970s. This increase coincides with gradual improvements in egg protection and hatchery management practices. Between 1980 and 1990, egg conservation efforts expanded substantially, resulting in a steady rise in hatchling output over this period. A major milestone in strengthening marine turtle protection occurred with the gazettement of the Wild Life Protection Ordinance in 1998. From 1999 onwards, the sale of turtle eggs from the Sarawak Turtle Islands to the public was fully discontinued. Instead, all eggs were systematically purchased and incubated under the coordinated management of the Sarawak Forestry Department, Sarawak Museum Department, and subsequently the Sarawak Forestry Corporation. These institutional arrangements marked a significant shift from exploitation to full conservation-oriented management.

As a result, hatchlings production continued to increase consistently through time, even in the absence of corresponding increases in nesting abundance (Figure 2). This pattern demonstrates that strengthened legal protection, improved hatchery infrastructure, and standardised egg management practices have substantially enhanced reproductive output and contributed meaningfully to the long-term conservation of sea turtles in Sarawak.

Beyond nesting beach protection, sea turtle conservation in Sarawak has progressively expanded to include habitat enhancement within coastal waters. Through the BEACON Project (Bali *et al*. 2023), reef ball (artificial reef) structures have been deployed at multiple locations along the Sarawak coastline to restore degraded marine habitats, discourage destructive fishing practices, and enhance overall marine biodiversity. Although these reef ball installations are not located directly on nesting beaches, they play an important role in improving nearshore habitats utilised by sea turtles during critical at-sea life stages. During inter-nesting periods and along coastal migration routes, turtles spend considerable time resting and foraging in coastal waters. By increasing habitat complexity and food availability, reef ball structures contribute to improved foraging conditions and help reduce exposure to anthropogenic threats such as fishing activities and accidental entanglement. Collectively, these long-term trends and integrated management approaches highlight Sarawak's transition from historical overexploitation to sustained protection, demonstrating the tangible conservation gains achieved through decades of commitment by the Sarawak Forestry Corporation and its partner agencies (Figure 3).

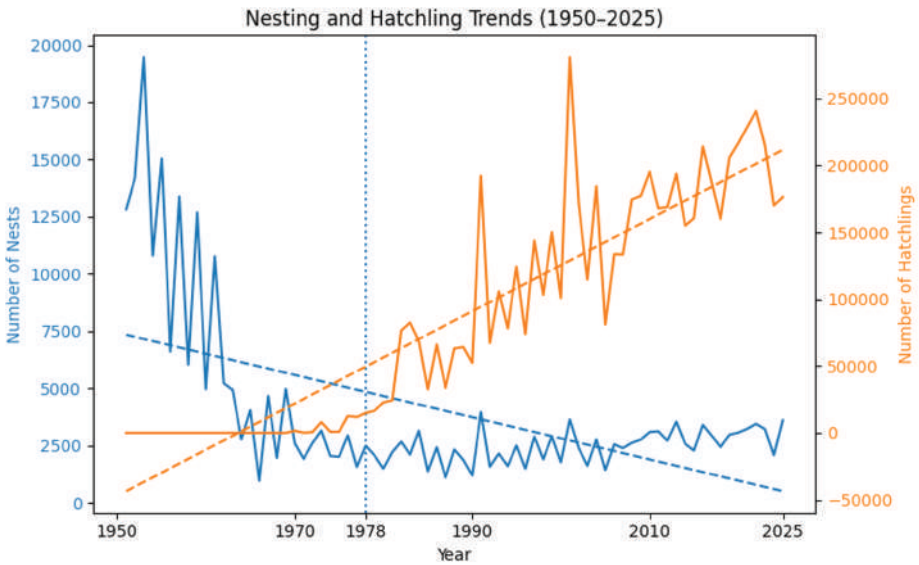

Figure 2. Long-term sea turtle nesting and hatching in Sarawak (1950 – 2025).



Figure 3. Sea turtle hatcheries in Sarawak under the management of the Sarawak Forestry Corporation.

Sabah: Conservation successes, adaptive management and community-led stewardship
One of the most successful sea turtle conservation programmes in Southeast Asia is found at the Turtle Islands Park (TIP), Sabah (Joseph *et al*. 2021; Sabah Wildlife Department 2025). TIP forms part of the Turtle Islands Heritage Protected Area (TIHPA), established in 1996 as the world's first transboundary protected area dedicated specifically to sea turtle conservation between Malaysia and the Philippines. The TIHPA comprises three islands under Sabah's jurisdiction and six islands under the Philippines, all designated primarily for conservation.

At TIP, continuous nest relocation, hatchery management, and strict enforcement have been implemented for over five decades (Joseph *et al*. 2021; Sabah Wildlife Department 2025). The islands are managed exclusively for conservation purposes, with no permanent local communities present. Eco-tourism is permitted only on Selingaan Island, where visitor numbers and activities are strictly controlled to minimise disturbance to nesting turtles. Revenue generated from this regulated eco-tourism is reinvested directly into conservation and park management.

Consistent with these management interventions, long-term monitoring data from TIP (Figure 4) demonstrates a clear and sustained increase in green turtle nesting from 1979 to 2023 (Joseph *et al*. 2021; Jolis *et al*. 2023). This trend reflects a strong positive population response under strict protection, systematic hatchery management, and consistent enforcement. In contrast, hawksbill turtle nesting at the same site shows a long-term declining trend over the same period (Joseph *et al*. 2021; Jolis *et al*. 2023). This divergence highlights species-specific differences in vulnerability and suggests that pressures operating outside nesting beaches, particularly at foraging grounds and along migratory routes, continue to disproportionately affect hawksbill populations.

Nesting trends at Sipadan Island Park (Joseph *et al*. 2021; Jolis *et al*. 2023) show high inter-annual variability (Figure 5), with no consistent long-term increase or declining pattern. Sipadan has a long history of protection, having been declared a bird sanctuary as early as 1933, reflecting early recognition of its ecological importance. In 2004, Sipadan was formally gazetted as a marine park, and all accommodation facilities on the island were subsequently closed to further safeguard its pristine natural environment.

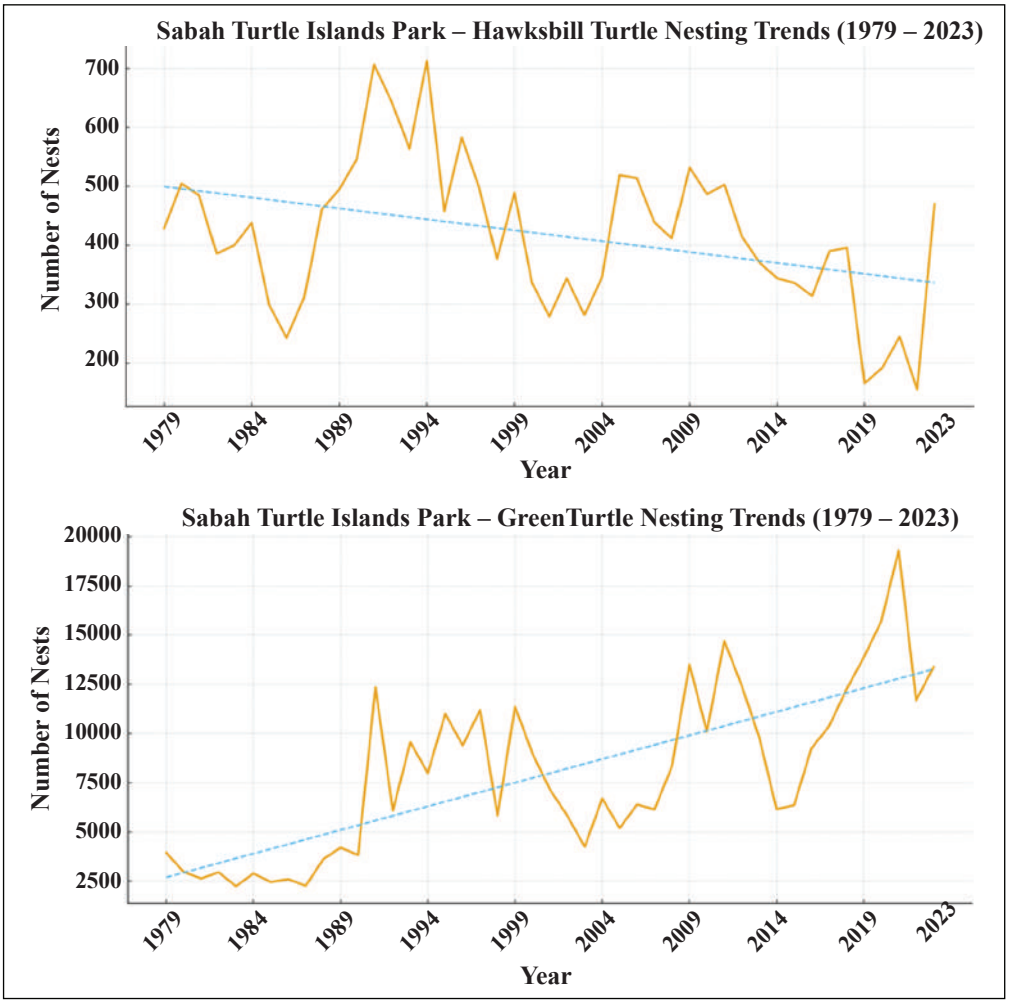

Figure 4. Long-term nesting trend for green and hawksbill turtles at Turtle Islands Park (1979 – 2023).

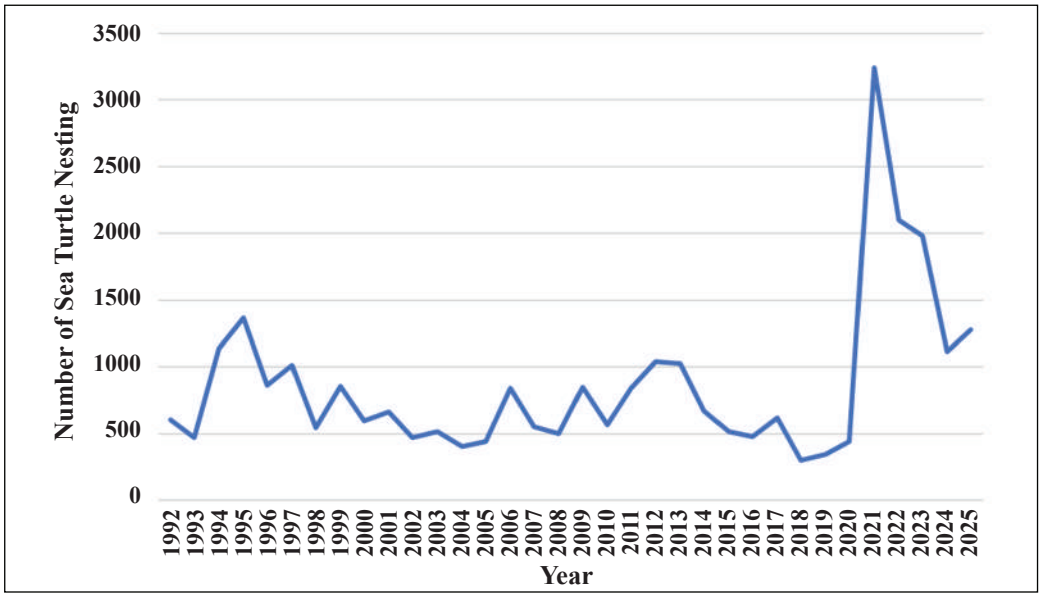

Figure 5. Long-term trends in sea turtle nesting at Sipadan Island Park.

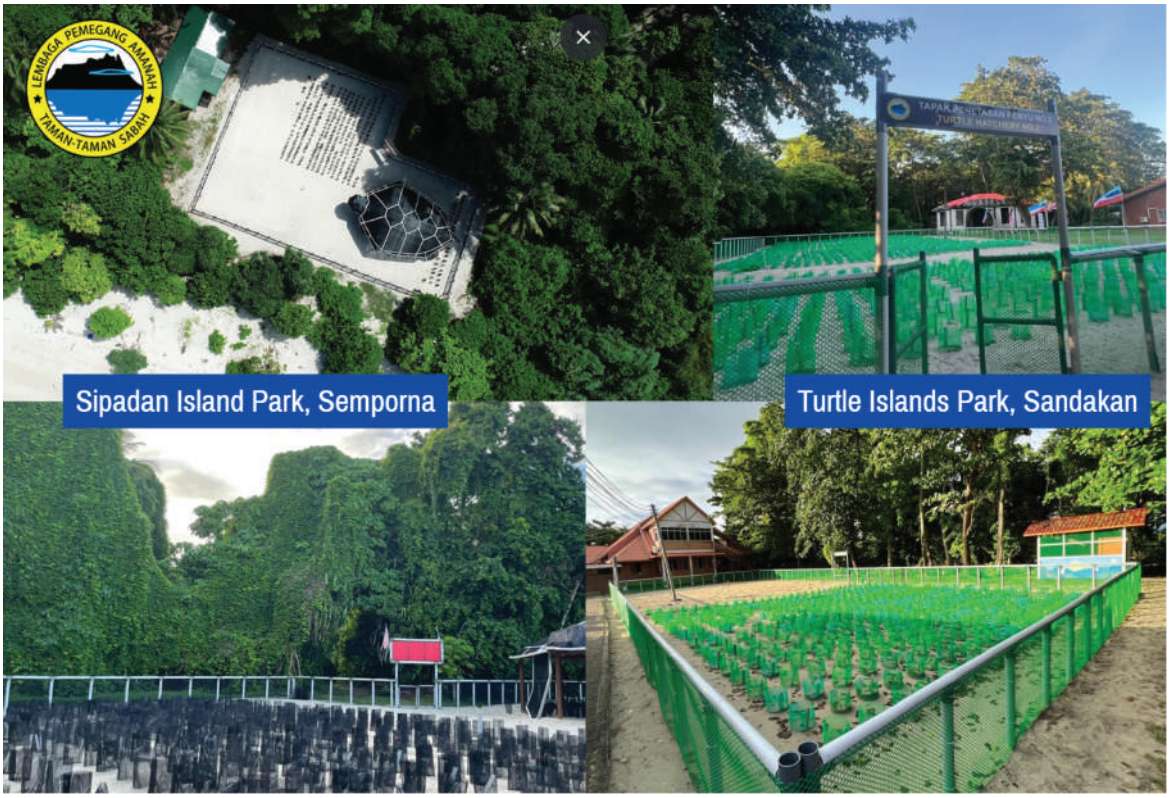

Figure 6. Sea turtle hatcheries in Sabah under Sabah Parks management.

The sharp increase in nesting records observed from 2021 onwards is therefore most likely associated with improvements in monitoring effort and nest detection, rather than a sudden biological increase in nesting activity. This distinction highlights the importance of accounting for changes in monitoring intensity when interpreting nesting trends at highly protected sites such as Sipadan, where management effectiveness has remained consistently high.

Beyond the main nesting strongholds, sea turtle nesting in Sabah also occurs at several additional sites with varying nesting intensity. Low-density nesting, typically involving fewer than 50 nests annually, is recorded at Tun Mustapha Park (Kudat), Pulau Mengalum, Pulau Mantanani, Pulau Tiga Park, and Tunku Abdul Rahman Park. Nesting sites located within gazetted marine parks, including Pulau Tiga Park, Tunku Abdul Rahman Park, and Tun Sakaran Marine Park are managed by Sabah Parks, where nest monitoring, protection, and egg management are carried out exclusively by parks rangers as part of the parks' conservation and enforcement mandate, except for Tun Mustapha Park which is led by local communities.

In eastern Sabah, the Semporna Islands and the Sugud Islands Marine Conservation Area (SIMCA) support moderate nesting activity, with approximately 200 – 1,000 nests recorded annually. These sites function as important secondary nesting areas. Here, nest monitoring and protection are largely conducted by local communities, NGOs, and resort operators who have undergone formal training and are appointed as Honorary Wildlife Wardens, working in close collaboration with Sabah Wildlife Department. The establishment of Priority Conservation Areas (PCAs) within Semporna has further strengthened the protection of important nesting and foraging habitats, while promoting sustainable ecotourism and community participation as complementary conservation strategies.

Community-based programmes in Kudat and Semporna represent some of the strongest success stories, demonstrating how local stewardship can be a replicative mode (Joseph *et al*. 2021) and can effectively complement state-led management, particularly areas with low or medium-density nestings, especially when enforcement and monitoring resources of government agencies are limited. Community involvement in night patrols, hatchery operations, volunteer programmes, and hatchling release activities has significantly strengthened nest protection and reduced poaching risk. At the same time, these initiatives have created opportunities for supplementary income through conservation-linked volunteering and nature-based tourism. This model highlights the dual benefits of community engagement and enhancing conservation outcomes while supporting sustainable livelihoods within Sabah's broader sea turtle conservation framework.

Foraging grounds and spatial patterns

Major foraging grounds for sea turtles have been identified along the coasts of Sabah and Sarawak (Figure 1), supporting large mixed-stock aggregations composed of individuals originating from multiple nesting rookeries across the region. These foraging habitats play a critical role in sustaining regional sea turtle populations, as turtles spend a substantial proportion of their life cycle feeding, growing and maturing in these areas.

The most extensive and well-studied foraging aggregation in Malaysia occurs in Lawas, Sarawak (Joseph *et al.* 2016, 2023), where large numbers of green turtles forage in seagrass-dominated habitats. Genetic mixed-stock analyses and satellite telemetry studies have demonstrated that turtles utilising this area originate from multiple rookeries (Nishizawa *et al.* 2018; Joseph *et al.* 2016), with major contributions from the Sulu Sea, Peninsular Malaysia, and Sarawak. Lawas (Brunei Bay) is therefore recognised as a key regional foraging and developmental habitat in South China Sea rather than a nesting area, highlighting its importance within the broader life cycle of sea turtles.

In Sabah, important foraging grounds have been identified in both eastern and northern waters, particularly around the Semporna Islands (Kirishnamoorthie 2023; Samsol *et al*. 2025) and Tun Mustapha Park, Kudat (Nishizawa *et al.* 2024). These areas support substantial foraging aggregations of green and hawksbill turtles and are considered among the largest and most significant foraging grounds in Southeast Asia. Foraging habitats in these areas are closely associated with coral reefs and seagrass beds, providing essential food resources and shelter. Ongoing research has highlighted their importance as residents and long-term feeding grounds for both juvenile and adult turtles (Jolis 2023).

Similar to Brunei Bay, turtles foraging in the Semporna Islands and Tun Mustapha Park originate from multiple rookeries, with strong genetic contributions from the Sulu Sea and Sarawak (Nishizawa *et al.* 2024). Notably, genetic evidence indicates that a proportion of green turtles foraging in Semporna originate from Micronesian rookeries (Nishizawa 2018), highlighting the international connectivity of these foraging grounds and their relevance to regional and transboundary conservation efforts. Foraging activity has also been recorded at Tambisan, although existing data remain limited due to small sample sizes. Further surveys and expanded genetic sampling are required to better characterise the population structure and conservation significance of this site.

The presence of large, mixed-stock foraging aggregations in Sabah and Sarawak highlights the importance of protecting foraging habitats alongside nesting beaches. As turtles from multiple rookeries converge at shared feeding grounds, localised exploitation or habitat degradation in these areas can have far-reaching impacts across regional populations. These findings reinforce the need for targeted management, spatial protection, and continued research to safeguard foraging habitats as integral components of effective, life-cycle-based sea turtle conservation.

CHALLENGES AND THREATS

Despite decades of conservation progress, sea turtles in Sabah and Sarawak continue to face mounting pressures driven by human activities and environmental change. While early conservation efforts understandably focused on nesting beaches, effective long-term conservation requires safeguarding sea turtles across all life stages, from eggs and hatchlings to juveniles, subadults, and breeding adults. The long lifespan and highly migratory nature of sea turtles expose them to multiple threats across diverse habitats, making life-cycle-based conservation both essential and challenging.

Egg poaching, illegal harvesting and direct take
Despite comprehensive legal protection, illegal egg collection, direct harvesting of turtles, and associated black-market trade continue to occur in some areas. Demand for turtle eggs for human consumption remains a key driver of illegal egg collection in certain localities, despite growing public awareness and strengthened enforcement efforts. These activities are now largely localised and sporadic, but remain of concern, particularly along transboundary routes within the Sulu–Sulawesi region, where enforcement is complex and cross-border coordination is required.

Bycatch in fishing gear
Incidental capture in fishing gear, particularly trawl nets and drift nets, remains a significant source of mortality for sea turtles. Trials of Turtle Excluder Devices (TEDs) in Sabah and Sarawak have demonstrated encouraging results, although wider adoption and consistent implementation remain key challenges.

Habitat degradation
Coastal development, artificial lighting, and shoreline erosion continue to reduce the quality and availability of suitable nesting habitats and disrupt natural nesting behaviour, particularly at low-density or fragmented nesting sites.

Marine debris and plastic pollution
Ingestion of plastics and entanglement in marine debris are increasingly reported, especially among juvenile and subadult turtles.

Climate change
Rising sand temperatures influence hatchling sex ratios, while sea-level rise and increasing storms intensity threaten the stability and persistence of nesting beaches, adding long-term uncertainty to conservation planning.

FUTURE DIRECTIONS AND RECOMMENDATIONS

To ensure the long-term conservation of sea turtles in Malaysia especially in Sabah and Sarawak, conservation efforts must continue to extend beyond nesting beaches to encompass all stages of the sea turtle life cycle. While protection of nesting sites remains essential, sea turtles spend most of their lives in offshore and coastal waters, and migrate across national boundaries, where they are exposed to a wide range of threats. As long-lived and highly migratory species, their effective conservation therefore requires coordinated action across habitats and jurisdictions.

Strengthening enforcement at high-risk nesting areas and along known illegal trade routes remain a priority. At the same time, reducing incidental capture in fisheries, through wider adoption of turtle-friendly fishing practices, including TEDs is important. Continued awareness and outreach programmes, coupled with incentives that encourage sustainable

fishing practices, could further strengthen industry participation and reduce turtle bycatch. Protection of key foraging grounds and migratory corridors should be further enhanced through integrated marine management approaches.

Continued research, long-term monitoring, and data sharing will be critical to improving understanding of sea turtle movements, population structure, and emerging threats. In this context, the ShellBank Malaysia represents an important advancement in conservation and enforcement. By integrating genetic data, satellite tracking, and traceability tools, ShellBank strengthens the ability to identify the origin of turtles and turtle products, supports investigations into illegal trade, and provides a scientific foundation for evidence -based management and regional collaboration.These efforts are further supported by the Sabah Wildlife Department Wildlife Health, Genetics and Forensics Laboratory, which is listed in the CITES Directory of Laboratories Conducting Wildlife Forensic Testing.

International and regional collaboration remains equally important, as many sea turtles that nest or forage in Malaysian waters originate from, or migrate through, neighbouring countries within the Coral Triangle and wider Indo-Pacific region. Effective conservation therefore depends on sustained cross-border cooperation, information exchange, and shared management responsibilities, particularly for species that utilise transboundary foraging grounds and migratory corridors.

Finally, the continued engagement of local communities, government agencies, research institutions, and non-governmental organisations will remain central to the success of sea turtle conservation in Malaysia. Community stewardship, capacity building, and partnerships with the private sector have already demonstrated tangible conservation gains in Sabah and Sarawak. By strengthening these collaborations and adopting an integrated, life-cycle-based approach supported by science and innovation, Malaysia is well positioned to further consolidate its role as a regional leader in sea turtle conservation.

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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**

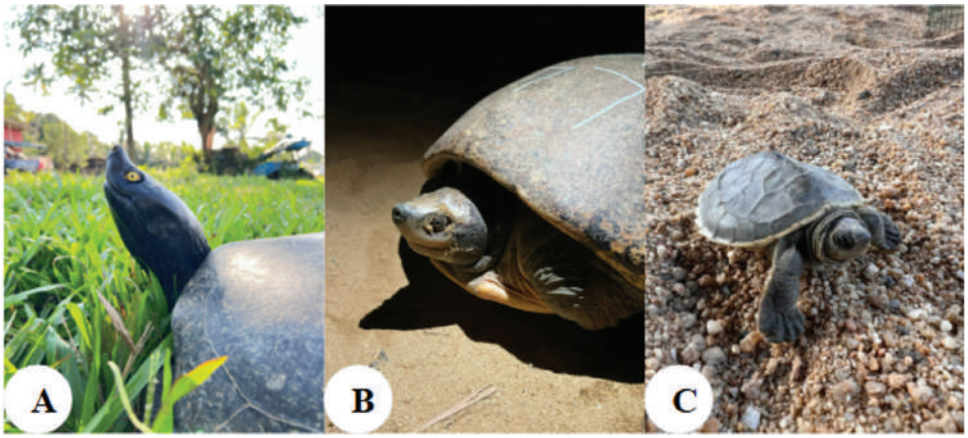

Figure 1. The critically endangered *Batagur affinis* in Malaysia.
(A) Adult male; **(B)** Adult female; **(C)** Hatchling.

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.

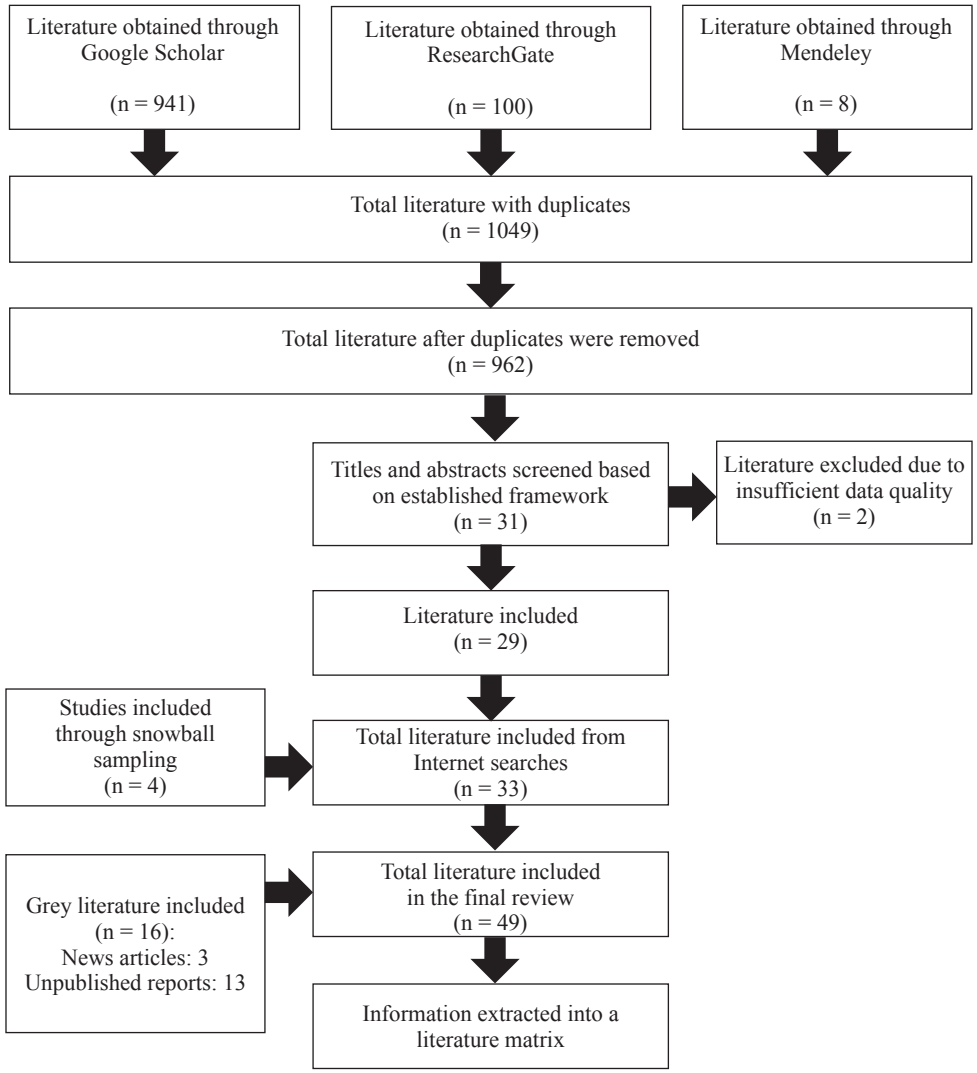

Figure 2. PRISMA workflow diagram of the literature review process for the studies of *Batagur affinis* in Malaysia.

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.

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CHAPTER 9

Technical report on the herpetofauna of Peninsular Malaysia

NORHAYATI AHMAD[1]*, DAICUS BELABUT[2] and KIN ONN CHAN[3]

Abstract: This technical report summarises the current taxonomy and IUCN Red List conservation status of amphibians, lizards and snakes in Peninsular Malaysia. Chelonians and crocodilians are not covered. The total fauna assessed comprises 430 species, and the report highlights that lizards face the most severe threat levels, with a high percentage of species at elevated risk, followed by amphibians, while snakes currently show the lowest overall threat proportion. A critical finding is that 10 species are critically endangered across all three groups, requiring immediate intervention, while a large number of species, particularly amphibians, are data deficient or not evaluated. Priority recommendations emphasise habitat protection, increased research to reduce knowledge gaps, and emergency action for the most imperilled species.

INTRODUCTION

Peninsular Malaysia harbours exceptional herpetofaunal diversity, reflecting the region's tropical climate, diverse topography, and varied habitats spanning lowland rainforests to montane environments. This report provides a comprehensive assessment of the region's amphibians, lizards, and snakes based on current taxonomic knowledge and IUCN Red List conservation status data (Figure 1). The analysis examines species richness, family-level composition, threat status, and conservation priorities to guide effective biodiversity management and research efforts. Understanding the conservation status of these groups is critical, as herpetofauna serve as indicators of ecosystem health, contribute to essential ecological processes including pest control and nutrient cycling (Hocking and Babbitt 2014), and represent unique evolutionary lineages of global significance.

DIVERSITY AND STATUS OF AMPHIBIANS

The amphibian fauna of Peninsular Malaysia comprises 121 species distributed across seven families. The fauna is dominated by frogs and toads (anurans), with only a few caecilians (gymnophionans). The amphibian fauna shows relatively balanced family-level diversity (Table 1).

Table 1. Family-level composition of Amphibia in Peninsular Malaysia.

Family	Number of Species	Percentage (%)
Microhylidae	25	20.7
Rhacophoridae	21	17.4
Dicroglossidae	21	17.4
Bufonidae	19	15.7
Ranidae	18	14.9
Megophryidae	11	9.1
Ichthyophiidae	6	5.0

[1] Department of Biological Science and Biotechnology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia.
[2] Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia.
[3] Department of Integrative Biology, Michigan State University, East Lansing, MI 48824, USA.
***Corresponding author: norhayatiahmad@ukm.edu.my**

This taxonomic composition reflects diverse ecological adaptations (Chan *et al.* 2010; Das *et al.* 2011; Ahmad 2017; Matsui 2019). Microhylids include many fossorial and terrestrial species associated with leaf litter and rotting logs. Rhacophorids are predominantly arboreal, with many species exhibiting foam nest construction and specialised reproductive behaviour. Dicroglossids and ranids occupy a range of aquatic and semi-aquatic habitats, from fast-flowing streams to stagnant ponds. Bufonids are largely terrestrial with explosive breeding aggregations at temporary water bodies. Megophryids are commonly associated with montane and submontane forest streams, often showing remarkable cryptic morphology. Caecilians (Ichthyophiidae) are fossorial, inhabiting moist soil and leaf litter in primary forests (Nishikawa *et al*. 2012).

Of the 121 amphibian species, 103 species (85.1%) have been formally assessed under IUCN Red List criteria, while 18 species (14.9%) are classified as Not Evaluated (NE) (IUCN 2025; Table 2). This relatively high assessment coverage provides a reasonably comprehensive understanding of conservation status, though the unassessed species require evaluation.

The majority of assessed amphibian species (69 species, 57.0%) are classified as being of least concern (LC). However, nine species (7.4%) are threatened, distributed across critically endangered (CR; n = 2; 1.7%), endangered (EN; n = 3; 2.5%), and vulnerable (VU; n = 4; 3.3%) categories (Table 2). An additional 8 species (6.6%) are near threatened, bringing the total number of species at elevated conservation risk to 17 (14.0% of the fauna).

Table 2. IUCN conservation status of the amphibians in Peninsular Malaysia.

IUCN Category	Number of Species	Percentage (%)
Least Concern (LC)	69	57.0
Not Evaluated (NE)	18	14.9
Data Deficient (DD)	17	14.0
Near Threatened (NT)	8	6.6
Vulnerable (VU)	4	3.3
Endangered (EN)	3	2.5
Critically Endangered (CR)	2	1.7

Conservation issues and knowledge gaps

A substantial proportion of species face knowledge gaps. Seventeen species (14.0%) are classified as data deficient, indicating insufficient information to properly assess extinction risk. Additionally, 18 species (14.9%) remain not evaluated under IUCN criteria. Combined, these 35 species (28.9% of the fauna) have uncertain conservation status, representing a major impediment to effective conservation planning. This high proportion of species with unknown status is concerning given that amphibians globally face severe threats from habitat loss, disease (particularly chytridiomycosis), and climate change.

The nine threatened amphibian species face multiple synergistic threats. Amphibians are particularly vulnerable to environmental changes due to their permeable skin, biphasic life cycles requiring both aquatic and terrestrial habitats, and limited dispersal abilities. The two critically endangered species (*Leptobrachella kecil* and *Kalophrynus yongi*) require immediate conservation intervention to prevent extinction. Priority actions include surveys to determine current population status, identification and protection of critical breeding sites, captive assurance colonies where appropriate, and disease monitoring programmes. For species classified as data deficient or not evaluated, targeted surveys focusing on taxonomic clarification and distribution mapping are essential to enable proper threat assessment.

DIVERSITY AND STATUS OF LIZARDS

The lizards of Peninsular Malaysia comprises 168 species distributed across eight families (Grismer 2011; Uetz 2025). This substantial diversity reflects the region's tropical biogeography and habitat heterogeneity, encompassing lowland rainforests, montane environments, limestone karst formations, and disturbed habitats. The distribution of species across the eight families is shown in Table 3.

Table 3. Family-level composition of Lacertilia in Peninsular Malaysia.

Family	Number of Species	Percentage (%)
Gekkonidae	82	48.8
Scincidae	42	25.0
Agamidae	33	19.6
Varanidae	4	2.4
Dibamidae	3	1.8
Leiolepididae	2	1.2
Eublepharidae	1	0.6
Lacertidae	1	0.6

The dominance of Gekkonidae, Scincidae, and Agamidae is characteristic of Southeast Asian lizard assemblages. Geckos exhibit remarkable ecological diversity, occupying arboreal, saxicolous, and terrestrial niches, with many species showing high degrees of microhabitat specialization and nocturnal activity patterns. Skinks are primarily terrestrial and fossorial, with several lineages adapted to leaf litter and subterranean environments. Agamids are largely diurnal and include both arboreal and terrestrial species, with several exhibiting elaborate social behaviors and color displays. The substantial representation of these families underscores their evolutionary success in the region's humid tropical conditions.

Of the 168 lizard species recorded from Peninsular Malaysia, 153 species (91.1%) have been formally assessed under the IUCN Red List criteria, while 15 species (8.9%) remain unassessed (Table 4). This high assessment coverage provides a comprehensive picture of the conservation status of the fauna, though the unassessed species warrant priority attention for future evaluation. The assessment reveals a concerning conservation picture for Peninsular Malaysia's lizard fauna. More species face a significantly higher proportion of threat than many other regional reptile faunas.

Table 4. IUCN conservation status of the lacertilians in Peninsular Malaysia.

IUCN Category	Number of Species	Percentage (%)
Least Concern (LC)	99	58.9
Not Evaluated (NE)	17	10.1
Data Deficient (DD)	15	8.9
Near Threatened (NT)	12	7.1
Vulnerable (VU)	12	7.1
Endangered (EN)	7	4.2
Critically Endangered (CR)	6	3.6

An additional 12 species (7.1%) are classified as near threatened (NT), indicating they are approaching threatened status or may qualify in the near future if current trends continue. When threatened and near-threatened categories are combined, 37 species (22.0% of the total fauna) are at elevated conservation risk. This proportion is substantially higher

than global reptile extinction risk patterns and represents a major conservation concern requiring urgent management intervention. The presence of six critically endangered species is particularly alarming, as these taxa face an extremely high risk of extinction in the wild. These species have severely restricted ranges and face acute habitat loss, requiring immediate conservation action to prevent extinction.

Seventeen species (10.1%) are classified as data deficient (DD), representing a significant knowledge gap in understanding the conservation status of the fauna. This designation indicates insufficient information to assess extinction risk, typically reflecting limited knowledge of species distributions, population trends, ecological requirements, or unresolved taxonomic uncertainties. The relatively high proportion of DD species is concerning because it may mask additional species at genuine extinction risk that cannot be identified without further data collection. These DD species should be prioritised for targeted field surveys, population studies, and taxonomic research to enable proper conservation assessment. Given the high proportion of threatened species already identified in the assessed fauna (16.3% of assessed species are threatened), it is plausible that several DD species may also be at risk once adequate data become available.

Fifteen species (8.9%) have not yet been assessed under IUCN Red List criteria. This gap in assessment coverage may reflect recently described species, recent taxonomic revisions splitting formerly recognised species, or species with poorly documented distributions. Given the ongoing discovery of cryptic diversity in Southeast Asian reptile faunas through molecular systematic techniques, some unassessed species may represent recently recognised taxa requiring urgent evaluation. A concerted effort to assess these 15 species would complete the conservation evaluation of Peninsular Malaysia's lizard fauna and enable more comprehensive conservation planning. Priority should be given to species with restricted distributions or those occurring in threatened habitats.

The 25 formally threatened species (14.9% of the fauna) represent the highest conservation priorities. The severity of threat is particularly concerning given the presence of six critically endangered (*Pseudocalotes flavigula*, *P. rhaegal*, *Cyrtodactylus jarakensis*, *C. guakanthanensis*, *Cnemaspis temiah*, *Larutia penangensis*) and seven endangered species (*Acanthosaura titiwangsaensis*, *Dibamus tiomanensis*, *Cyrtodactylus pulchellus*, *C. sworderi*, *C. trilatofasciatus*, *Hemiphyllodactylus titiwangsaensis*, and *Sphenomorphus cameronicus*). Effective conservation of threatened species requires immediate implementation of species-specific recovery plans incorporating habitat protection and restoration, population monitoring programmes, threat mitigation measures, and where appropriate, *ex situ* conservation in captive breeding facilities. The six critically endangered species require emergency intervention to prevent extinction. Near-threatened species should be monitored closely with proactive management to prevent further decline into threatened categories.

DIVERSITY AND STATUS OF SNAKES

The snake fauna of Peninsular Malaysia comprises 141 species distributed across 14 families (Table 5). The fauna includes representatives of all major snake lineages, from primitive burrowing snakes to highly derived venomous species.

Colubridae is overwhelmingly dominant, representing 83 species (58.9%) and encompassing the majority of snake diversity in the region. This family includes diverse ecological types from terrestrial to arboreal, fossorial, and semi-aquatic species, with varied feeding ecologies. Homalopsidae (mud snakes and water snakes) contributes 13 species (9.2%), all aquatic or semi-aquatic specialists. Elapidae (cobras, kraits, and coral snakes)

comprises 11 highly venomous species (7.8%), while Viperidae (pit vipers) accounts for ten venomous species (7.1%). Pareidae (slug snakes) is represented by seven specialised mollusk-eating species (5.0%), and Typhlopidae (blind snakes) includes six fossorial species (4.3%). The remaining eight families are represented by one or two species each, collectively accounting for 8.5% of the fauna.

Table 5. Family-level composition of Serpentine in Peninsular Malaysia.

Family	Number of Species	Percentage (%)
Colubridae	83	58.9
Homalopsidae	13	9.2
Elapidae	11	7.8
Viperidae	10	7.1
Pareidae	7	5.0
Typhlopidae	6	4.3
Pythonidae	2	1.4
Lamprophiidae	2	1.4
Acrochordidae	2	1.4
Anomochilidae	1	0.7
Cylindrophiidae	1	0.7
Xenodermidae	1	0.7
Xenopeltidae	1	0.7
Xenophidiidae	1	0.7

This taxonomic composition reflects remarkable ecological diversity. Colubrids occupy virtually all available niches from fossorial to highly arboreal, with specialised feeding ranging from generalist predators to specialists on frogs, lizards, birds, mammals, or eggs. Homalopsids are obligately aquatic, feeding primarily on fish and amphibians. Elapids and viperids are important predators of small mammals, birds, and reptiles, with sophisticated venom delivery systems. Pareids represent a unique evolutionary radiation of mollusk specialists. Typhlopids are fossorial, feeding primarily on ant and termite larvae. The presence of pythons, file snakes (Acrochordidae), and various primitive snake families highlights the region's significance for snake evolution and phylogenetic diversity.

Nearly all snake species (135 species, 95.7%) have been formally assessed under the IUCN Red List criteria, with only six species unassessed (based on their absence from evaluated categories). This exceptionally high level of assessment coverage provides comprehensive understanding of the conservation status of the snake fauna. The snake fauna shows a more favorable conservation status compared to amphibians and lizards. The majority of snakes (120 species, 85.1%) are classified as Least Concern. Only six species (4.3%) are threatened, comprising two Critically Endangered (1.4%) and four Vulnerable (2.8%) species. Notably, no species are currently classified as Endangered. An additional species is classified as Near Threatened, bringing the total number at elevated conservation risk to seven species (5.0% of the fauna).

Table 6. IUCN conservation status of the snakes in Peninsular Malaysia.

IUCN Category	Number of Species	Percentage (%)
Least Concern (LC)	120	85.1
Not Evaluated (NE)	8	5.7
Data Deficient (DD)	6	4.3
Near Threatened (NT)	4	2.8
Vulnerable (VU)	2	1.4
Endangered (EN)	1	0.7
Critically Endangered (CR)	0	0.0

The relatively low proportion of threatened snake species (4.3%) contrasts markedly with lizards (14.9%) and amphibians (7.4%), suggesting that snakes may be more resilient to habitat modification or face different threat profiles. However, this apparent resilience should not lead to complacency, as snake populations are harder to sample or may decline more slowly than other taxa, masking emerging conservation problems. Eight species (5.7%) are classified as data deficient, a relatively low proportion compared to amphibians (14.0%) and lizards (10.1%). These species likely have poorly documented distributions, uncertain taxonomic status, or insufficient population data. Priority should be given to resolving these knowledge gaps through targeted surveys and taxonomic research.

The six threatened snake species, while few in number, require conservation attention. The presence of two critically endangered species (*Gongylosoma mukutense* and *Oligodon booliati*) indicates that some taxa are at extreme risk of extinction and require immediate conservation action including population surveys, habitat protection, and threat mitigation. Given the low detection probability of many snake species (due to cryptic behavior, nocturnal activity, and low population densities), regular monitoring programmes using standardised protocols are essential to track population trends. Public education to reduce persecution of non-venomous species and promote coexistence with venomous species is also critical.

COMPARATIVE ANALYSIS

Species richness and assessment coverage

Comparing the three major herpetofaunal groups reveals important patterns. Lizards exhibit the highest species richness (S = 168), followed by snakes (S = 141) and amphibians (S = 121) (Figure 1 and Table 7). Assessment coverage is highest for snakes (95.7%), followed by lizards (91.1%) and amphibians (85.1%). The comprehensive assessment coverage across all groups provides a robust foundation for conservation planning.

Table 7. Conservation status comparison.

Taxon	Total Species	Threatened (%)	At Risk (%)	Data Deficient / Not Evaluated(%)
Amphibians	121	14.0	14.0	28.9
Lizards	168	22.0	22.0	19.0
Snakes	141	5.0	5.0	5.7

The differential threat profiles likely reflect differences in ecological vulnerability and threat exposure. Lizards, with many species, endemic to specific mountain ranges or limestone karst formations, often have restricted ranges making them highly vulnerable to localized habitat loss. Many lizard species are also diurnal and conspicuous, increasing vulnerability to collection for the pet trade. Amphibians face unique threats from emerging infectious diseases and are highly sensitive to changes in moisture and temperature regimes. Snakes may be more resilient to moderate habitat modification and some can persist in agricultural landscapes, though they face persecution pressures.

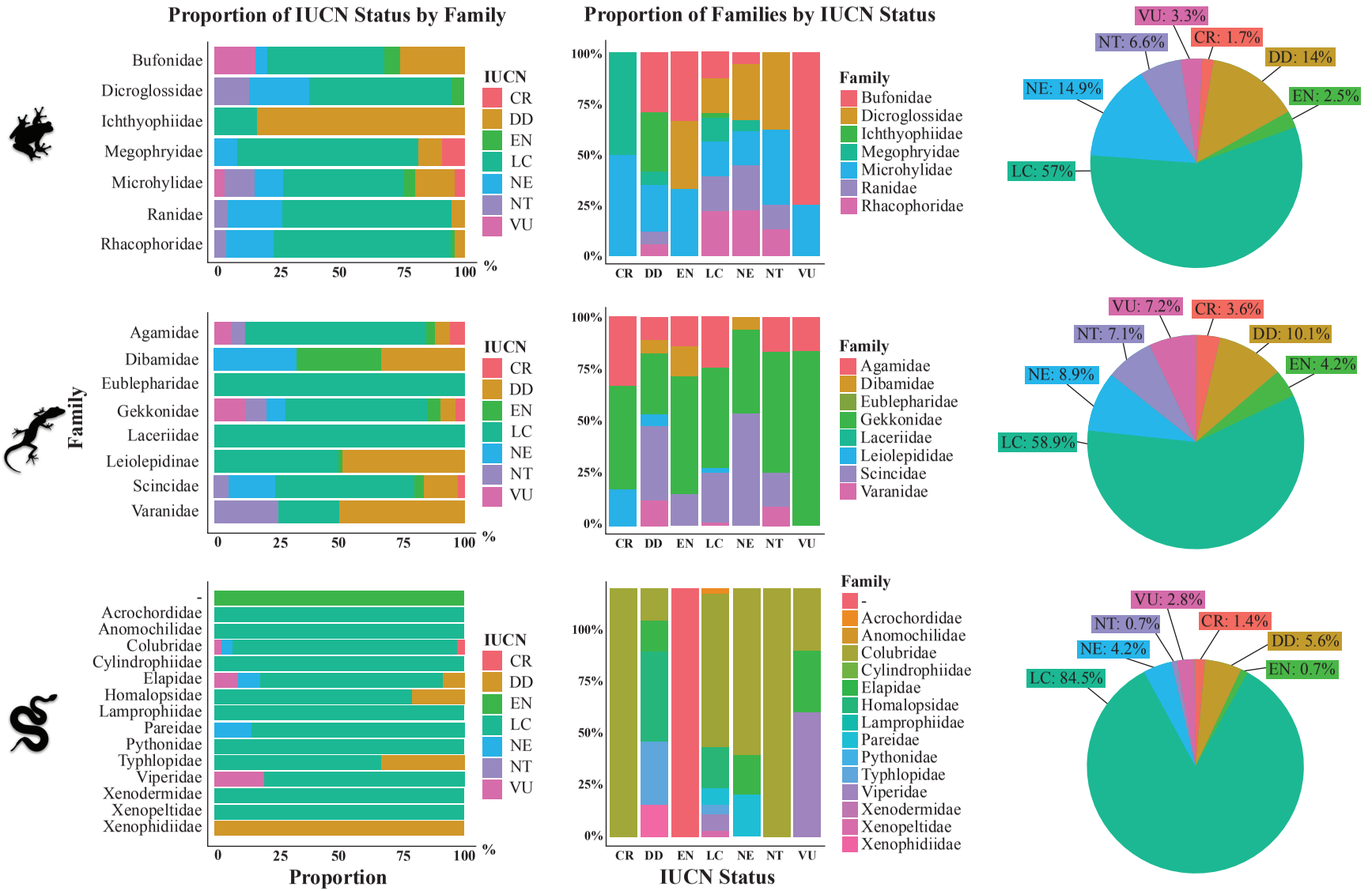

Figure 1. Comparative analysis of IUCN conservation status across the three major herpetofauna groups in Peninsular Malaysia.

CONCLUSION AND RECOMMENDATIONS

The herpetofauna of Peninsular Malaysia exhibits exceptional diversity, with 430 species comprising 121 amphibians across seven families, 168 lizards across eight families, and 141 snakes across 14 families. However, conservation status assessments reveal significant concerns, particularly for lizards where 14.9% are threatened and 22.0% are at elevated risk. Across all three groups, 40 species are formally threatened (9.3% of the total fauna), including ten critically endangered species facing imminent extinction risk. The presence of critically endangered species in all three taxonomic groups (two amphibians, six lizards, and two snakes) indicates that immediate emergency intervention is required to prevent extinctions. Additionally, substantial knowledge gaps persist, particularly for amphibians where nearly 29% of species have uncertain conservation status. These gaps hinder comprehensive conservation planning and may mask additional threatened species. The primary threats driving population declines are habitat loss and degradation from deforestation and agricultural expansion, direct persecution (particularly of snakes), collection for international trade, emerging infectious diseases (amphibians), and climate change impacts. Many threatened species are range-restricted endemics associated with specialised habitats such as montane forests or limestone karst, making them particularly vulnerable to localised threats.

Priority recommendations

Emergency intervention for Critically Endangered species

The ten CR species (two amphibians, six lizards, and two snakes) require immediate action including population surveys, habitat protection, threat assessment, and development of emergency recovery plans. *Ex situ* conservation measures should be considered for the most imperiled taxa to prevent further population declines and potential extinction.

Habitat protection and restoration

Expand and improve management of protected areas to encompass critical habitats for threatened species. Priority should be given to the protection and restoration of primary forests, montane environments, limestone karst systems, and wetlands. Ecological corridors should be established and maintained to enhance connectivity between isolated populations and facilitate species movement across fragmented landscapes.

Resolution of knowledge gaps

Systematic assessment of the 60 species (14% of fauna) with uncertain conservation status (DD or NE) should be undertaken to address the knowledge gaps. Modern survey techniques should be incorporated to improve the detection of rare and elusive species. This includes the use of environmental DNA. Priority should be given to species with restricted distributions or those occurring in threatened habitats.

Species-specific recovery plans

Develop and implement recovery plans for all 40 threatened species, incorporating population monitoring, threat mitigation, habitat management, and adaptive management strategies. Priority actions should be identified to support the population recovery and ensure the long-term survival of these species.

Disease surveillance for amphibians

Amphibians are particularly vulnerable to diseases such as chytridiomycosis and ranavirus, thus requiring monitoring programmes to be implemented to control disease outbreaks. Disease-free assurance populations should be established, especially for threatened species, alongside research on disease ecology, transmission, and management.

Reduction of human-wildlife conflict
Species affected by human-wildlife conflict, such as snakes, require targeted interventions, including public education programmes to reduce the persecution of snakes and promote coexistence with venomous species. Rescue and relocation programmes should be established and managed in urban areas.

Climate change adaptation
Climate vulnerability assessments should be conducted for threatened and range-restricted species to identify those most at risk from changing environmental condition. Priority should be given to the identification and protection of climate refugia, while ecological corridors shold be established to facilitate range shifts.

Trade regulation and enforcement
Species vulnerable to collection and trade require strengthened protection through enhanced monitoring and enforcement of wildlife trade regulations. Increased penalties for illegal collection should be considered to deter collection of these species. Populations of species targeted by collectors need to be regularly monitored.

Long-term monitoring programmes
All three taxa require long-term monitoring programmes to track the population trends. Standardised monitoring protocols should be established at representative sites spanning elevational and habitat gradients to ensure consistent assessment over time for more robust tracking of their populations.

Capacity building and community engagement
Effective conservation of herpetofauna requires increased capacity and public participation. More herpetologists should be trained in survey and conservation techniques. Accurate and informative identification guides can be developed to aid in the monitoring of herpetofauna populations. Local communities should also be engaged through citizen science and economic incentive programmes.

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CHAPTER 10

The herpetofauna of East Malaysia

INDRANEIL DAS[1] and EVAN S.H. QUAH[2,3]*

Abstract: The herpetofauna of the tropical island of Borneo, comprising the East Malaysian States of Sabah and Sarawak, together with Brunei Darussalam and the multiple provinces of Kalimantan, Indonesia, comprises 229 species of amphibians and 324 species of reptiles. These figures, current as of end of the year 2025, include invasive species from both groups (three and six, respectively). We review the known diversity of amphibians and reptiles of Borneo, and assess their conservation status particularly of the East Malaysian states. An analysis of species accretion pattern suggests that additional species are to be expected in the current and next several decades, particularly when new areas are explored, or if contemporary field, lab, and analytical technologies are employed. Of the known and sometimes familiar taxa, a large number remain unassessed for conservation status. In terms of on-the-ground protection and management, several endemic and therefore potentially threatened species occur exclusively in areas that are outside of the protected areas system. Gaps in present knowledge relevant to conservation of Borneo's amphibians and reptiles are summarised. These include oftentimes dated conservation assessments, starting with Red Listing, of species currently in the Not Evaluated or Data Deficient categories, identification of endemic and threatened populations that are outside of National Parks and Sanctuaries, particularly, the development of resources for emergency action for emerging threats, identification of unprotected areas harbouring microendemics, and enhancement of research efforts to understand causes of endangerment of the local species of amphibians and reptiles of Borneo.

INTRODUCTION

Borneo, one of four major islands of the Indo-Malayan Archipelago, is situated towards the eastern portion of the Sunda Shelf. It stretches between coordinates 04ºS to 07ºN and from 109 to 119ºE, and is the second largest tropical island in the world (after New Guinea), covering a land area of approximately 743,380 km^2. The seas around Borneo are shallow (< 200 m), except for the deep Makasar Strait (> 2,000 m). While the present chapter is an attempt to review the conservation status of the herpetofauna of East Malaysia, including Sarawak (124,450 km^2) and Sabah (73,620 km^2), one has to be mindful that a major part of the island falls in the Indonesian part of Kalimantan (539,460 km^2), and also, the Sultanate of Negara Brunei Darussalam (5,760 km^2). Nonetheless, numerous contacts, most recently over the Pleistocene glaciation phases, when sea levels fell between 120 – 200 m below current levels, facilitated movements of biota into and out of the island. At 4,101 m, Low's Peak in Mount Kinabalu, northern Sabah, is the highest point on the island (Malkmus *et al.* 2002). The Kinabalu Range itself comprises Tertiary sedimentary rocks, constituted of sandstone and shale. The highest mountain in Sarawak is Mount Murud, at 2,423 m asl. Cave systems on Borneo comprise isolated limestone outcrops located primarily in coastal Sarawak, north-western Sabah and south-eastern Kalimantan. A number of large rivers flow

[1] Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[2] Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Jalan UMS, 88400, Kota Kinabalu, Sabah, Malaysia
[3] Lee Kong Chian Natural History Museum, National University of Singapore, 2 Conservatory Drive, Singapore 117377
***Corresponding author: evanquah@ums.edu.my**

through Borneo, some forming important biogeographic limits. All of Sarawak's rivers drain into the South China Sea. The important rivers of Sabah include the Segama and the Kinabatangan. Kalimantan's great rivers include the Kapuas, Barito, Kahayan, Kayan, and Mahakam. Many of the coastal segments of rivers are broad and meandering, the Kapuas for example dropping only 50 m between Putussibau, ca. 900 km inland, and the sea.

Borneo lies within the tropics and the equator crosses the island approximately over the city of Pontianak in Kalimantan Barat. Consequently, the island is characterised by high, equitable temperature and heavy rainfall spread throughout the year. The relatively wetter periods are observed during the passage of the Northeast Monsoons (November to April), although the Southwest Monsoons (April to August) also bring rainfall to the area. Within Borneo, the western and central parts are wetter than the eastern ones. Daytime temperatures in most parts of the low-lying areas are 30 – 32ºC, and humidity is typically above 70%. On the other hand, temperatures in the highlands, such as Mount Kinabalu, can be low. Annual precipitation is typically 4,000 – 5,000 mm (Davies 2022).

The plant life of Borneo is characterised by high species diversity and endemism, especially in the highlands. The richest forests of south-east Asia are in north-western Borneo, encompassing the north-east portion of Sarawak, Brunei and the south-western lowlands of Sabah, an area that has been suggested to be a Pleistocene refugium (de Bruyn *et al.* 2014).

Nonetheless, rates of deforestation for timber in the lowlands are high in East Malaysia, translating to the near elimination of old growth dipterocarps forests outside of the protected areas. Secondary causes of forest loss include an enormous project of settling people from densely populated Indonesian islands of Java and Madura into Kalimantan, the opening up of forest land for settlement and plantations of oil palm and other crops, and forest fires. Most of Borneo's herpetofauna being linked to primary hill dipterocarp forests (exceptions being coastal and riparian assemblages), loss of forest cover may be considered the primary threat to the island's amphibians and reptiles (Inger and Tan 1996; Gaveau *et al.* 2019). Other factors more specific to poikilothermous groups include the change of thermal and hydric qualities of landscapes, as a result of climate change (Bickford *et al*. 2010; McAlpine *et al.* 2018; Davies 2022; Davies-Barnard *et al.* 2023).

CONSERVATION STATUS

Temporal aspects of discovery

Figure 1 shows the chronology of species descriptions of Bornean amphibians and reptiles. The earliest (pre-mid-1800s) records of reptiles and amphibians from Borneo do not have an explicit type locality and may have been obtained from other parts of south-east Asia (Das 2023). Explorations started around the mid-19th century with the arrival of European, chiefly British and Dutch, administrators, naturalists, and explorers. For amphibians, a major peak is evident during the late 1800s to early 1900s, corresponding to the activity of George Boulenger, Keeper of Zoology at the British Museum (Natural History) in London. Other peaks include the 1920s decade, when collections and descriptions were made by curators of the Sarawak Museum and others, and particularly, in the 1960s – 1970s, and 1990s to the first decade of the 2000s, primarily reflecting the work of Robert Inger, Curator of Amphibians and Reptiles of the Field Museum of Natural History, Chicago. The trend line for discovery of reptiles shows a somewhat similar pattern, with additional peaks of discovery in the 1830s – 1840s and 1860s – 1890s, with the publishing activities of John Gray and his successor at the British Museum (Natural History), Albert Günther, respectively.

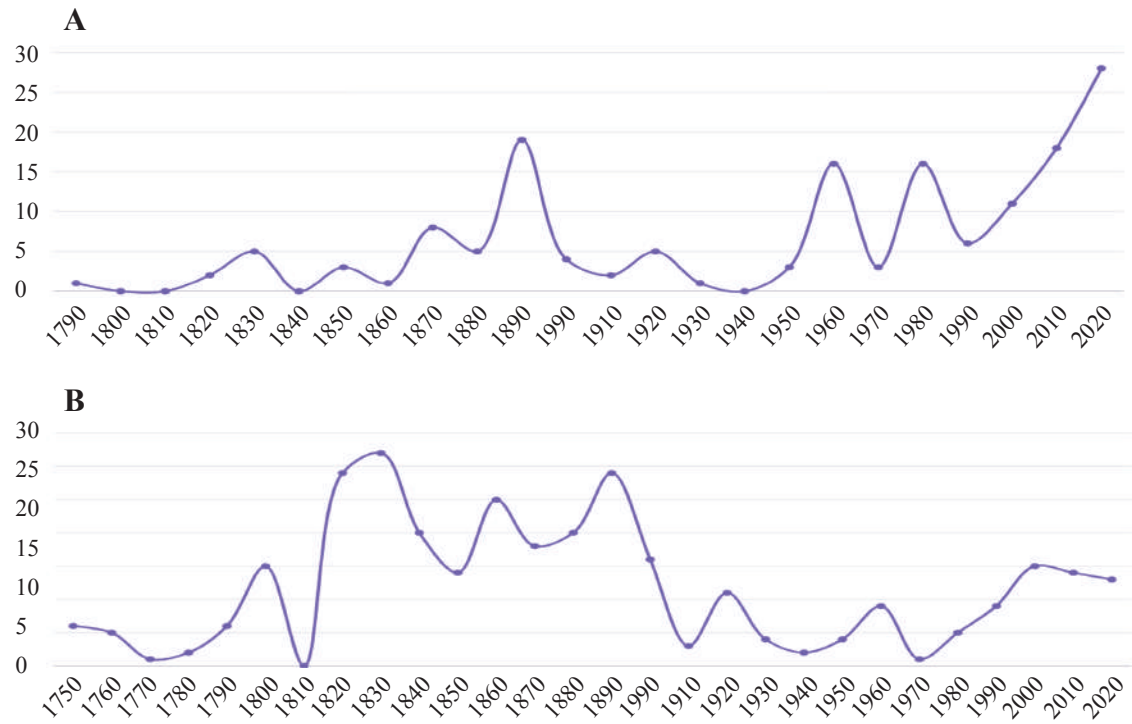

Figure 1. Description of **(A)** Bornean amphibian and **(B)** reptile species by decades.

For both taxonomic groups, cessation of studies during the War decades (World War I and II) are noticeable. Also obvious is the uptick in species discovery in the present decade, starting from the year 2020, where the first half of the decade produced nearly a third more species than the entire previous decade. The rapid increase in species can be explained by multiple, independent researchers, better access to once remote field sites, and contemporary analytical techniques, from field and lab tools to software, and above all, quicker communications and collaboration. The result has been the collection of 'all-new' species as well as the discovery of species complexes, the latter resulting in the naming of multiple species from what was once thought to be a single biological species (see for instance, Quah *et al*. 2019, 2020, 2021; Dehling *et al*. 2025).

Lineage diversity

By the end of 2025, a total of 229 species of amphibians and 324 species of reptiles had been recorded from Borneo (AmphibiaWeb 2025; Das 2025; Frost 2025; Uetz *et al.* 2025). These included invasive species, including three amphibians (*Aquarana catesbeiana*, *Hoplobatrachus chinensis*, and *Microhyla heymonsi*) and six reptiles (*Trachemys scripta*, *Pelodiscus sinensis*, *Calotes versicolor*, *Iguana iguana*, *Lycodon capucinus*, and *Naja kaouthia*) (Bauer and Das 2024; Quah *et al*. 2025).

As expected of a landmass that is continental with a recent history of land connection with the continent, higher level endemicity is low. The Lanthanotidae, unique to Borneo, is represented by a single species, *Lanthanotus borneensis*. Endemic genera too are rare for both amphibians (*Huia*, monotypic; *Sabahphrynus*, monotypic; *Sarawakiphrys*, monotypic; *Meristogenys*, 13 species) and reptiles (*Pelturagonia*, five species; *Complicitus*, monotypic, *Hypsicalotes*, monotypic) (Figure 2; AmphibiaWeb 2025; Frost 2025; Uetz *et al.* 2025).

Nonetheless, a number of lineages are more speciose on the island than elsewhere, for both amphibians (*Ansonia*, 16 species; *Pelophryne*, nine species; *Limnonectes*, 34 species; *Philautus*, 22 species) and reptiles (*Dibamus*, three species; *Cnemaspis*, 10 species; *Dasia*, five species; *Sphenomorphus*, 14 species; *Tropidophorus*, seven species; *Calamaria*, 21 species; *Asthenodipsas*, six species) (Figure 2; AmphibiaWeb 2025; Das 2025; Frost 2025; Quah and Grismer 2025; Uetz *et al.* 2025).

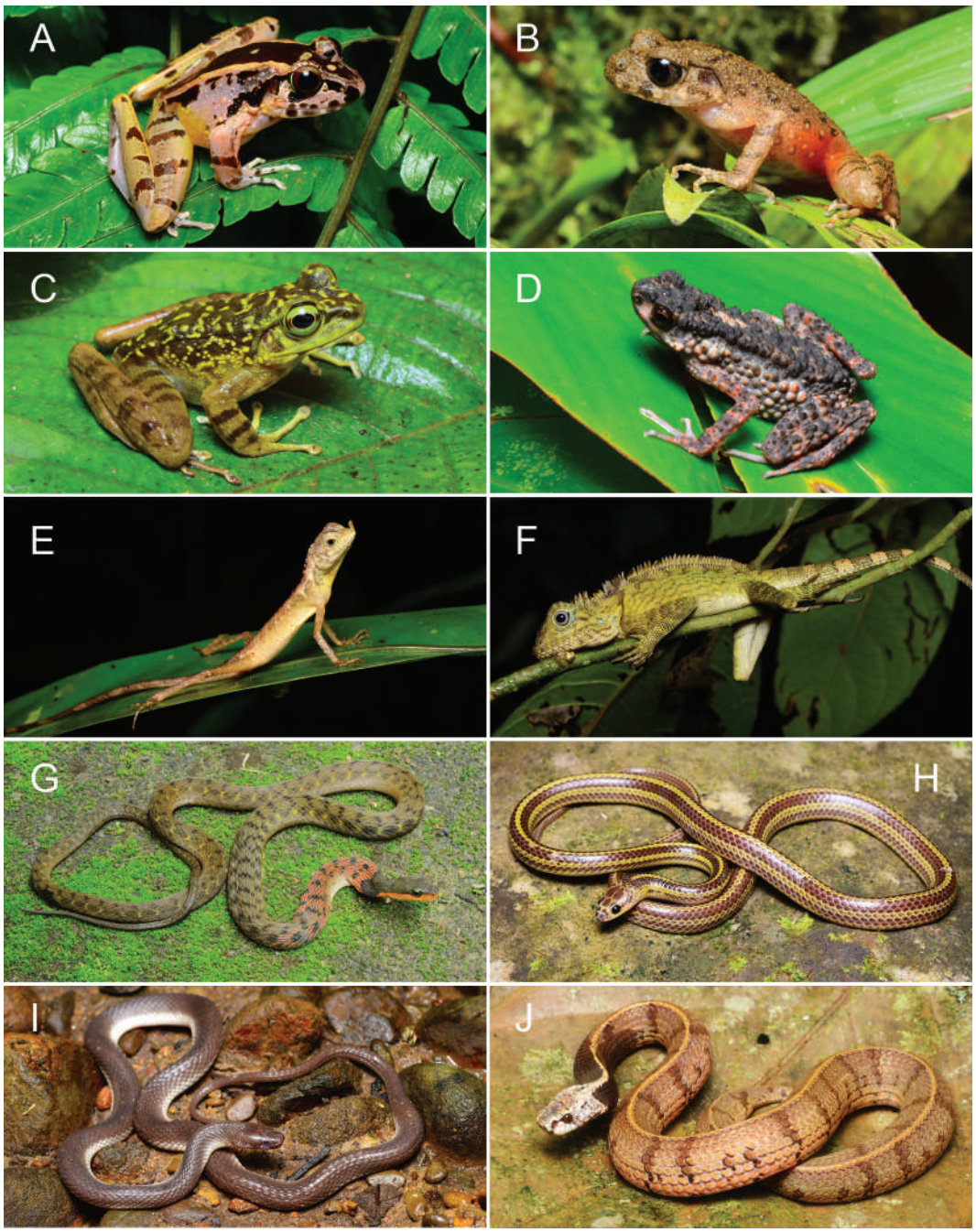

Figure 2. Representative species of amphibians and reptiles of Borneo. **A.** *Huia cavitympanum*, **B.** *Leptobrachella arayai*, **C.** *Meristogenys kinabaluensis*, **D.** *Ansonia spinulifer*, **E.** *Aphaniotis ornata*, **F.** *Gonocephalus borneensis*, **G.** *Rhabdophis murudensis*, **H.** *Dryocalamus tristrigatus*, **I.** *Hydrablabes typicus*, **J.** *Asthenodipsas borneensis*.

Conservation issues

We looked at the species recorded (until 31 December 2025) from Borneo, against those listed in the IUCN Red List of Threatened Species (version 2025.2; see www.iucnredlist.org), adopting the global threat categories therein. Species counts for amphibians and reptiles were considered separately. Figure 3 shows the distribution of species from these two groups under each of the threat categories.

Apart from the 34 (14.8%) amphibian species and 29 (9.0%) reptile species that are in the Not Evaluated (NE) categories, and 15 (6.6%) and 61 (18.8%) in the Data Deficient (DD) categories for the two groups, respectively, one sees slight and perhaps no significant difference in proportional representation in the threatened categories.

Of a smaller (229 species) fauna, six amphibians (2.6%) are Critically Endangered (CR), as against the larger (324 species) group comprising reptiles, whose equivalent figure is nine (2.8%). In the next highest threat category (Endangered, EN) are 13 (5.7%) amphibians and four (1.2%) reptiles. A total of nine (3.9%) amphibians are Vulnerable (VU), while the number of reptiles in this category is eight (2.5%). A total of 26 (11.4%) of amphibians and four (1.2%) reptiles are Near Threatened (NT). Finally, a majority of amphibians (126 species or 55.0%) and reptiles (209 species or 64.5%) are in the Least Concern (LC) category, that are currently not threatened, but may move to one of the threatened categories with one or more increased or novel threats in the future. Excluding the NE and DD categories, well over half of all recognised species are therefore in the threatened (Red Data List) species list of the IUCN.

The high number of species in the NE category (14.8% and 9.0% for amphibians and reptiles, respectively) is due to the recent discovery of many species, mostly in the current decade. On the other hand, the Red List assessment process itself is a lengthy, peer-reviewed activity, requiring considerable resources, volunteer effort, and coordination. Nonetheless, for a majority (> 95%) of all species enumerated, loss of forest cover, and for several CR species, unrepresented populations in the region's protected areas systems, are major drivers of extinction threat or endangerment.

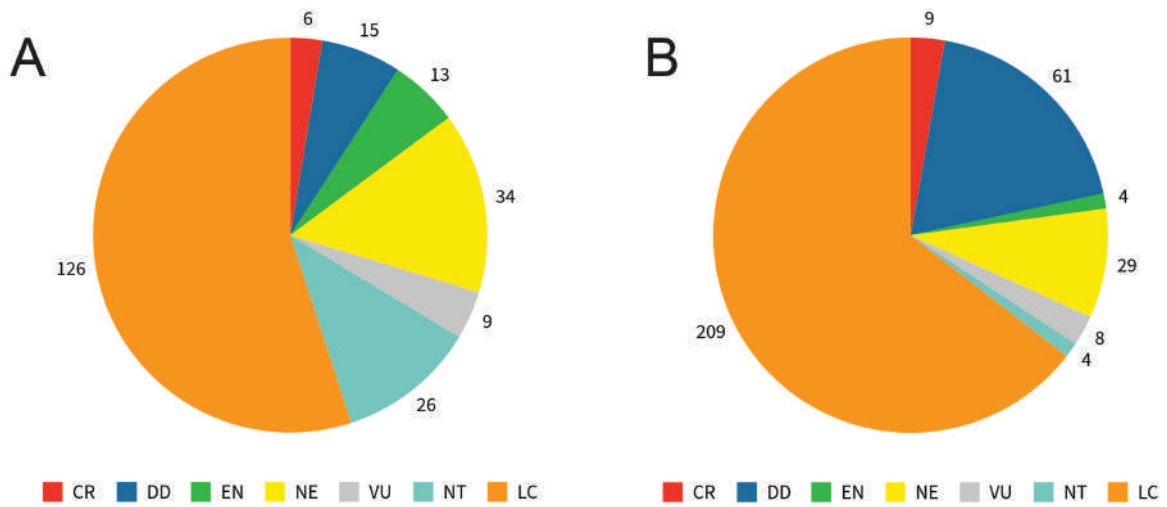

Figure 3. Conservation status of **(A)** amphibians and **(B)** reptiles of Borneo. Threat categories from the IUCN Red List of Threatened Species (version 2025.2).

KNOWLEDGE GAPS AND SUGGESTIONS FOR THE FUTURE

A priority is naturally to assess the conservation status of species that remain unassessed. These tend to be recently described taxa or those that are widespread. While the reasons for the absence from the threat categories of the former are obvious (IUCN Red List assessments and revisions take place about twice a decade, sometimes much longer), the shortage of time and expertise often place restrictions on the assessment teams. Examples include the Bornean species of *Cnemaspis*, a gekkonid lineage that tends to be specialist rock-dwelling microendemics, with over half of the known species described in the past half decade, and seven of these are in either the Data Deficient or Not Evaluated categories (Kurita *et al*. 2017, 2024; Nashriq *et al.* 2022). All are restricted to single, often spatially restricted sites of karst, and threatened with mining and other forms of quarrying. More resources therefore need to be freed up for conservation assessment activities, these perhaps moving at least partially online, as well as for follow-up action, such as emergency financial resources for species whose continued existence requires immediate intervention.

Another concern is the protection of species recognised as threatened that do not occur within any protected areas. For both jurisdictions (Sabah and Sarawak), legal instruments do not cover amphibians or all except the largest reptile species (such as marine and freshwater turtles, crocodilians, and large snakes) explicitly. Nonetheless, they are generally protected as components of the respective region's biological diversity. A cursory look at the IUCN Red List for East Malaysian species shows that several threatened species have populations entirely outside of the protected areas systems. Among amphibians, these include the Endangered *Ansonia latidisca*, *Limnonnectes cintalubang*, *Meristogenys penrissenensis*, and *Philautus erythtophthalmus*, and the Critically Endangered *Leptobrachium kantonishikawai*. The list is nearly equivalent for reptiles, and includes the Endangered *Tomistoma schlegelii* and *Siebenrockiella crassicollis*, and the Critically Endangered *Orlitia borneensis*, *Pelochelys cantorii*, and *Calamaria prakkei*, all species that find no space within parks and other protected areas of the two States. Studies have revealed there is value in protecting even secondary and non-forest habitats for the conservation of herpetofauna (Gillespie *et al.* 2012). Identification of sites with the known occurrence of multiple point endemics, therefore, is an urgent and immediate task, following taxon-focused surveys, using field methods, and where appropriate, emerging technologies such as the use of eDNA.

The utilisation of emerging technologies is also crucial for the management of threat -specific conservation action such as the monitoring of the spread of chytrid in amphibians (McLeod *et al.* 2020) and establishments of protocols for the detection of other emerging or future diseases. Similarly, technologies such as eDNA could also be deployed for the detection and management of invasive species. Concerted effort from all relevant stakeholders is key to curb the spread of invasive amphibians and reptiles in Borneo and presents an opportunity for citizen science and local conservation action.

Much remains to be learnt from the herpetofauna of East Malaysian Borneo. Areas for the expansion of fundamental research including the life histories of threatened species and physiological studies such as thermal tolerance, niche partitioning and habitat use, which are especially pertinent in the face of climate change. Past research has been dominated by faunistic studies, including inventories and systematics (Chan and Grismer 2021; Chan *et al.* 2022). While these are essential for understanding the diversity of local faunas in a given area, studies more directly pertaining to conservation have lagged behind. We recommend such research be given priority, not least because of the tendency of herpetofaunas to be microendemics but also as surrogates of poikilothermous vertebrates and a large component of the nation's biological diversity.

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CHAPTER 11

Freshwater fish of Malaysian Borneo

JONGKAR GRINANG[1]*, LEE NYANTI[2] and TAN HEOK HUI[3]

Abstract: This chapter focuses on taxonomic richness of freshwater fish of Malaysian Borneo which include endemism, research status, conservation effort, and investment needs. Freshwater ecosystems in Borneo support one of Southeast Asia's most distinctive fish assemblages, influenced by ancient geology, diverse habitats, and long-term river isolation. In Sarawak and Sabah, over 300 valid freshwater fish species are recorded, with high species richness from the order Cypriniformes, Siluriformes, Anabantiformes, and Gobiiformes. Endemism is a defining feature, with many lineages occurring in only a single basin or habitat, particularly peat swamps and elevated headwater streams, and most members of the family Gastromyzontidae occur nowhere else. The earliest freshwater fish collections from Borneo date to the 1820s, and the number of species described from the island has since increased from just over a hundred to more than 600 species today, driven by a steady rise in new species descriptions over the past decade. Yet major gaps persist, as peat swamps remain undersampled, upstream watersheds lack long-term datasets, and many historical type localities have been altered by land-use change. The continual discovery of new taxa indicates that true species richness is still underestimated and reinforces the importance of integrative taxonomy that combines morphology, genetics, and ecological data. Conservation needs are urgent since freshwater habitats are threatened by land conversion, river modification, presence of invasive species, and habitat impoundment. Peat swamps are particularly threatened, which affects narrow-ranged species such as *Paedocypris micromegethes*, and *Betta chini*. Ongoing efforts involve protected areas, riparian buffers, captive breeding and community-managed *Tagang* systems, however implementation has not been consistent in the region. To improve the conservation of freshwater fish in the future, basin-wide biodiversity surveys and updated Red List assessments are needed, as well as the identification and protection of important peat swamp habitats, headwater streams, molecular reference libraries for eDNA and building capacity with local researchers and communities. In the future, trans-border co-operation with Indonesian Kalimantan and Brunei Darussalam will also increase knowledge of inter-watershed connectivity. Malaysian Borneo retains its reputation for freshwater fish diversity, and the conservation of this part of natural heritage requires science integration, sound management, and continued commitment.

INTRODUCTION

Malaysian Borneo, comprising Sarawak and Sabah, is often celebrated for its towering dipterocarp forests, charismatic wildlife, and vast river systems. Yet beneath the surface of its rivers, streams, and peat swamps lies a lesser-known, but equally remarkable world: an extraordinary diversity of freshwater fish. These aquatic communities, shaped by millions of years of geological events and ecological isolation, represent one of Southeast Asia's most distinctive biological treasures. Today, this diversity faces mounting pressure from rapid environmental change. Understanding the richness, uniqueness, and vulnerability of Malaysian Borneo's freshwater fish is therefore essential not only for scientists, but also for policymakers, conservationists, and the public.

[1] Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia.
[2] Lorong G3, BDC, 93350 Kuching, Sarawak, Malaysia.
[3] Lee Kong Chian Natural History Museum, National University of Singapore, 2 Conservatory Drive, Singapore 117377
***Corresponding author: gjongkar@unimas.my**

The diversity of freshwater fish in Malaysian Borneo is deeply rooted in its geological and ecological history. The island's rivers have evolved across ancient landscapes marked by shifting tectonic plates, fluctuating sea levels, and long periods of isolation. These processes have divided river systems into distinct basins (e.g., Rajang, Baram and Kinabatangan), limiting connectivity and allowing species to evolve independently over time. As a result, Malaysian Borneo is recognised as an evolutionary hotspot, with freshwater systems ranging from blackwater peat swamps to fast-flowing hill streams and large meandering lowland rivers. Each habitat supports specialised fish communities adapted to unique environmental conditions. Peat swamp forests, for instance, are characterised by acidic, tannin-stained waters with low nutrient and oxygen levels. In contrast, highland streams are cool, oxygen-rich, and structurally complex (Figure 1). This environmental heterogeneity is a key driver of species diversity, enabling a wide range of ecological niches to coexist.

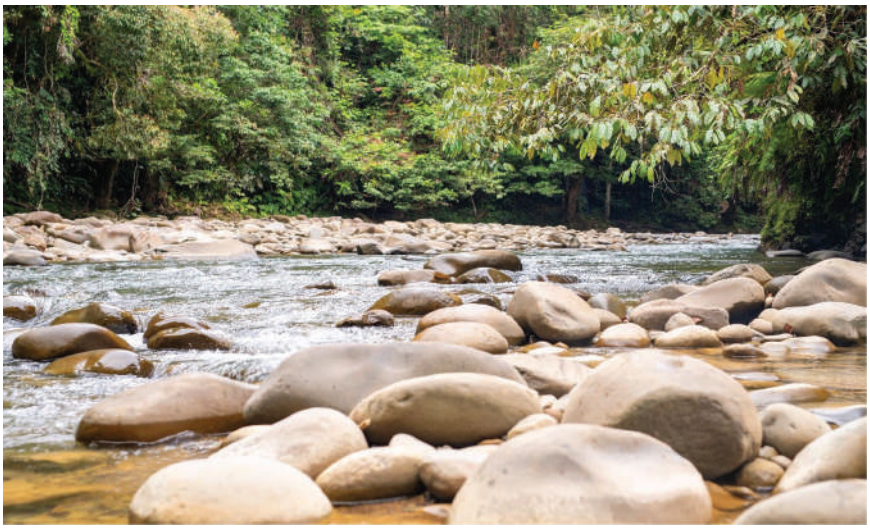

Figure 1. Typical habitat of upper river reaches, characterised by fast-flowing, well-oxygenated streams associated with hillstream loaches.

Richness Beneath the Surface and endemism

More than 300 valid freshwater fish species have been recorded in Malaysian Borneo, with Cypriniformes (carps and minnows) dominating the assemblage, followed by Siluriformes (catfishes), Anabantiformes (gouramies), and Gobiiformes (gobies) (see fishbase.org; Kottelat *et al.* 1993; Inger and Chin 2002). When considering the entire island of Borneo, the number exceeds 600 species, and continues to grow as new taxa are described. This diversity is not merely numerical, it reflects a wide array of ecological roles and adaptations. Some species, such as hillstream loaches (especially Gastromyzontidae) (Figure 2), possess dorso-ventrally flattened bodies with enlarged pectoral and pelvic fins that allow them to cling to rocks in fast-flowing waters. Others, like labyrinth fishes, have evolved accessory breathing organs to survive in oxygen-poor environments. Recent decades have seen a surge in species discoveries, with approximately 70 new species described from Borneo in the past 15 years alone. Advances in sampling techniques and molecular tools have revealed cryptic diversity, species that are morphologically similar but genetically distinct, highlighting how much remains unknown.

One of the most striking characteristics of Malaysian Borneo's freshwater fish fauna is its high level of endemism. Many species are restricted to a single river basin, or even to specific microhabitats within a basin. This pattern reflects the long-term isolation of river systems and the limited dispersal ability of freshwater fishes. Peat swamp ecosystems

are particularly notable for hosting stenotopic species (Figure 3). The miniature fish *Paedocypris micromegethes* (Figure 4), among the smallest vertebrates in the world, is confined to acidic blackwater habitats that may span only a few square kilometres. Similarly, several species of *Betta* and *Parosphromenus* are restricted to highly specific environmental conditions. Highland streams also harbour endemic species, particularly among loaches and cyprinids, often confined to headwaters of major basins such as the Rajang, Baram, and Kinabatangan. In some cases, closely related species occur in adjacent basins but nowhere else, illustrating the role of geographic isolation in driving speciation. Such restricted distributions make these species inherently vulnerable. The loss of a single habitat can result in the extinction of an entire lineage.



Figure 2. The hillstream loach, *Gastromyzon fasciatus*, serves as a useful indicator of the disappearance of high-quality habitats in the upper reaches of many river systems.



Figure 3. Oxbow lake is a common feature in downstream areas of Baram River in Sarawak.



Figure 4. One of the smallest freshwater fishes, *Paedocypris micromegethes*, reaches a maximum length of only about 10 mm.

A legacy of exploration

The study of freshwater fish in Borneo dates back to the early 19th century, when naturalists such as Pieter Bleeker and Albert Günther began documenting the island's biodiversity. Early collections gradually expanded knowledge on freshwater fish diversity, from just over 100 species to the more than 600 recognised (unpublished data) today for the entire island. Modern ichthyological research has accelerated since the 1990s, driven by collaborations among regional and international institutions. Researchers have increasingly focused on previously under-explored habitats, such as upland streams and peat swamps, leading to significant taxonomic advances. Despite this progress, major knowledge gaps remain. Many peat swamp systems are still poorly sampled, and long-term ecological data for upper watersheds are scarce. Furthermore, some historical type localities have been altered or degraded, complicating efforts to reassess species distributions.

The freshwater ecosystems of Malaysian Borneo are still undergoing rapid transformation. Land conversion, particularly for oil palm plantations, has led to widespread deforestation and drainage of peat swamps. These activities alter hydrological regimes, increase sedimentation, and cause degradation of water quality. Sedimentation, for example, can disrupt fish reproduction by reducing water clarity, smothering spawning substrates, and altering microhabitats required for egg development. Such changes are especially detrimental to species adapted to clear, stable environments, including many endemic cyprinids and loaches. River modification presents another major challenge. Channelisation, road crossings, and dam construction fragment habitats and disrupt natural flow regimes. Hydropower projects, while important for energy production, can significantly alter river connectivity and ecological processes.

Invasive species further compound these pressures. Introduced fishes such as *Channa micropeltes* can outcompete or prey upon native species (unpublished data from Batang Ai reservoir; Figure 5), altering community structure and ecosystem dynamics. Climate change adds an additional layer of uncertainty, with shifts in rainfall patterns and temperature likely to affect river hydrology and habitat stability.



Figure 5. Two cohorts of *Channa micropeltes* recently collected from the Batang Ai Reservoir, suggesting successful establishment following a suspected introduction around 2016. Scale: 1 cm

Among all freshwater habitats in Malaysian Borneo, peat swamps are the most threatened. These lowland ecosystems have experienced rapid decline due to drainage, logging, and agricultural expansion. Peat swamps are not only unique in their physical characteristics, but also in their biological communities. They support a suite of highly specialised, stenotopic species (Figure 6), organisms adapted to narrow environmental conditions. Many of these species are found nowhere else on earth. The degradation of peat swamps therefore has disproportionate consequences. The loss of even small habitat patches can lead to the disappearance of entire species, particularly those with extremely limited distributions. The decline of peat swamp habitats underscores the urgent need for targeted conservation efforts focused on these ecosystems. For example, our long-term monitoring of *Paedocypris micromegethes* at its type locality indicates a likely local disappearance, with only a single isolated habitat remaining where the species still persists.



Figure 6. A benthic stenotopic species *Kottelatlimia pristes* endemic to Borneo.

CONSERVATION EFFORTS: PROGRESS AND GAPS

Efforts to conserve freshwater fish in Malaysian Borneo are underway, but remain uneven in implementation. Protected areas, including national parks and water catchments, provide some level of habitat protection. Riparian buffer zones are increasingly recognised as essential for maintaining water quality and ecological integrity, although enforcement varies. Community-based management systems, such as *Tagang* in Sarawak (or *Tagal* in Sabah), have shown promising results in certain regions. These systems involve local communities regulating fishing activities to allow fish populations to recover, demonstrating the potential of participatory conservation approaches. Captive breeding programmes are also being developed for selected species, such as *Tor tambra*, while emerging technologies like environmental DNA (eDNA) and acoustic monitoring offer new tools for biodiversity assessment. Despite these efforts, significant knowledge gaps remain. Conservation initiatives are often fragmented, and many endemic species lack updated assessments of their conservation status. There is also a shortage of trained taxonomists, which limits the capacity to identify and describe new species.

Addressing these challenges requires a coordinated and forward-looking approach. Basin-wide biodiversity surveys are needed to provide comprehensive data on species distributions and population trends. Such surveys should prioritise underexplored habitats, including peat swamps and headwater streams. Updating IUCN Red List assessments is equally important, particularly for endemic species that may be at risk but remain poorly studied. Molecular tools, including DNA barcoding and metabarcoding, can help build reference libraries that support species identification and monitoring. Strengthening local capacity is another critical priority. Training the next generation of taxonomists and ecologists will ensure that expertise remains within the region, enabling sustained research and conservation efforts. Transboundary collaboration with Kalimantan (Indonesian Borneo) is also essential, as many river systems extend beyond national borders. Cooperative management can enhance understanding of ecological connectivity and improve conservation outcomes at a landscape scale.

Malaysian Borneo's freshwater fish diversity is globally significant. The region ranks among the richest in Southeast Asia in terms of species diversity per unit area, and its high level of endemism reflects a unique evolutionary history. Beyond their intrinsic value, freshwater fishes play vital ecological roles. They contribute to nutrient cycling, regulate food webs, and support livelihoods through fisheries. For many local communities, rivers are central to cultural identity and daily life. The loss of freshwater biodiversity therefore has far-reaching consequences, not only for ecosystems, but also for human well-being.

Malaysian Borneo can be viewed as a natural laboratory for understanding freshwater ecosystems. Its diverse habitats, complex biogeography, and ongoing environmental changes provide opportunities to study ecological and evolutionary processes in real time. At the same time, this uniqueness brings responsibility. Protecting freshwater fish diversity requires integrating scientific research with effective management and community engagement. It also demands a shift in perspective from viewing rivers as resources to recognising them as dynamic ecosystems that sustain life.

CONCLUSION

The freshwater fish of Malaysian Borneo represent an extraordinary yet vulnerable component of the region's natural heritage. High species richness, remarkable endemism, and ongoing discoveries highlight both the ecological significance and the incomplete state of current knowledge. However, rapid environmental change poses serious threats, particularly to specialised and narrowly distributed species. Conservation efforts, while promising, must be strengthened through coordinated action, improved data, and greater investment in research and capacity building. Ultimately, safeguarding this diversity will depend on our ability to balance development with ecological integrity. In doing so, Malaysian Borneo can continue to serve as a global reference point for freshwater biodiversity, and as a reminder of the intricate connections between nature and society.

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CHAPTER 12

A century of small mammal research in Borneo: Diversity trends, conservation status, and future directions

FAISAL ALI ANWARALI KHAN[1]*, MUHAMMAD AMIN IMAN AZMI[1], NUR IYLIA MAISARAH BAHAROM[1], MUHD AMSYARI MORNI[1,2], MUHAMMAD DANISH HAQEEM[1], VICTOR LEE SIEN[1] and ASFA HANIS MOHAMAD AZMI[1]

Abstract: Borneo is recognised as a global biodiversity hotspot, hosting a remarkable diversity of small mammals, including bats, rodents, shrews, and tree-dwelling insectivores. Despite their ecological importance in pollination, seed dispersal, and insect population control, these species remain understudied and often overlooked in conservation planning. This chapter examines the past and present diversity of Borneo's small mammals, synthesising knowledge from historical field surveys, taxonomic collections, and contemporary molecular and ecological studies. By integrating data from species inventories, phylogenetic analyses, and metagenomic approaches, the chapter explores patterns of species distribution, evolutionary adaptation, and biogeographic history across the island. This chapter also reviews the conservation trends, highlighting how anthropogenic effect have impacted population stability and species survival over time. The findings emphasise the dynamic interplay between evolutionary processes and human-driven environmental change, providing a clearer understanding of small mammal biodiversity in Borneo with an emphasise on Sarawak and Sabah. By combining traditional and modern research methods, this work underscores the critical role of small mammals in tropical forest ecosystems and the urgent need to integrate them into conservation strategies.

INTRODUCTION

Small mammals are typically defined as mammals weighing less than 5 kg and serves as a threshold that distinguishes them from medium and large-sized mammals (Merritt 2010). This group includes terrestrial members such as rodents (Order: Rodentia), treeshrews (Order: Scandentia) and shrews (Order: Eulipotyphla). In addition, volant mammals such as bats (Order: Chiroptera) are also categorised as small mammals. Collectively, these mammals play important roles in natural ecosystems by contributing to seed dispersal, predator–prey interactions and forest regeneration (Wells *et al*. 2009; Lacher *et al.* 2019). The study of these mammals is important because they serve as indicators of ecosystem health, as evidenced by the long history of research on these taxa spanning more than a century (Figure 1).

In the early 1900s, studies mainly relied on museum specimens and focused on describing and classifying species (Banks 1931). By the mid-20th century, researchers began conducting more intensive field surveys, which provided better understanding of where species occur and how they live in their natural environments (Banks 1952; Kobayashi and Hotta 1978). From the 1990s onwards, attention increasingly turned to how human activities such as logging and agricultural expansion affect small mammal communities

[1] Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94500 Kota Samarahan, Sarawak, Malaysia.
[2] Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, 94500 Kota Samarahan, Sarawak, Malaysia.
***Corresponding author: akfali@unimas.my**

(Brooks *et al.* 1999). In recent years, studies have also incorporated molecular approaches and conservation-focused perspectives, allowing researchers to better understand species relationships and population structure through genetics (Hinckley *et al.* 2022; Khan *et al.* 2025b). This progression reflects how advances in research methods and growing environmental concerns have gradually shaped the direction of small mammal studies.

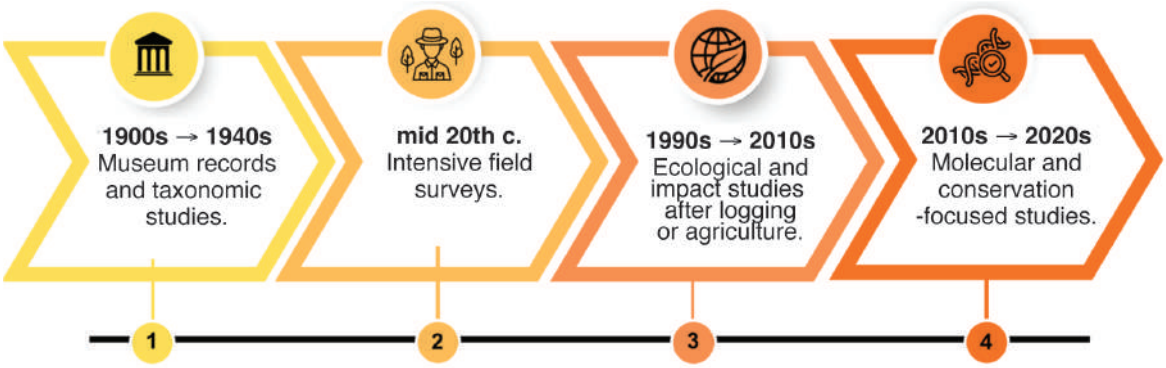

Figure 1. Conceptual timeline summarising the progression of small mammal research in Borneo, from early museum-based taxonomy to modern molecular and conservation studies.

Terrestrial small mammals in Borneo are represented by several families belonging to three main orders, each with distinct ecological roles (Phillipps and Phillipps 2018) (Figure 2). Shrews (Order: Eulipotyphla) are represented by the families Soricidae (true shrews) and Erinaceidae (gymnures), which are primarily insect-eating mammals that help regulate invertebrate populations. Treeshrews (Order: Scandentia) belong to the family Tupaiidae and are commonly found in undisturbed forested habitats. Rodents (Order: Rodentia) form the most diverse group and include the families Sciuridae (squirrels), Muridae (rats and mice) and Hystricidae (porcupines). Over time, the documented number of terrestrial small mammal species in Borneo has gradually increased, from 75 species in the early 1900s to 87 species by 2025 (Phillipps and Phillipps 2018; Mammal Diversity Database 2025) (Figure 3). While most of the families show relatively stable numbers, the number of Muridae species has increased as new species were described or recorded through continued field surveys and taxonomic work.

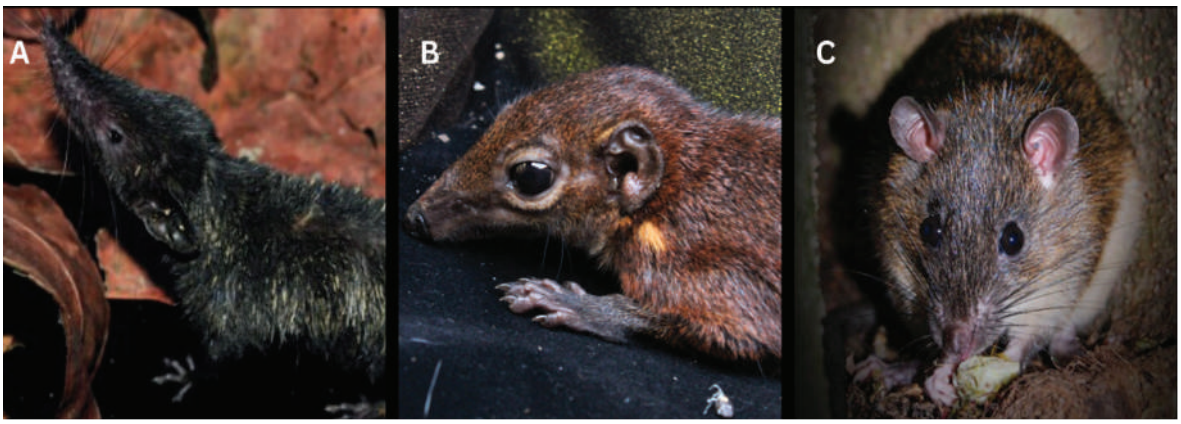

Figure 2. Representative terrestrial small mammal species from the three orders recorded in Borneo: **A.** Eulipotyphla, **B.** Scandentia, and **C.** Rodentia.

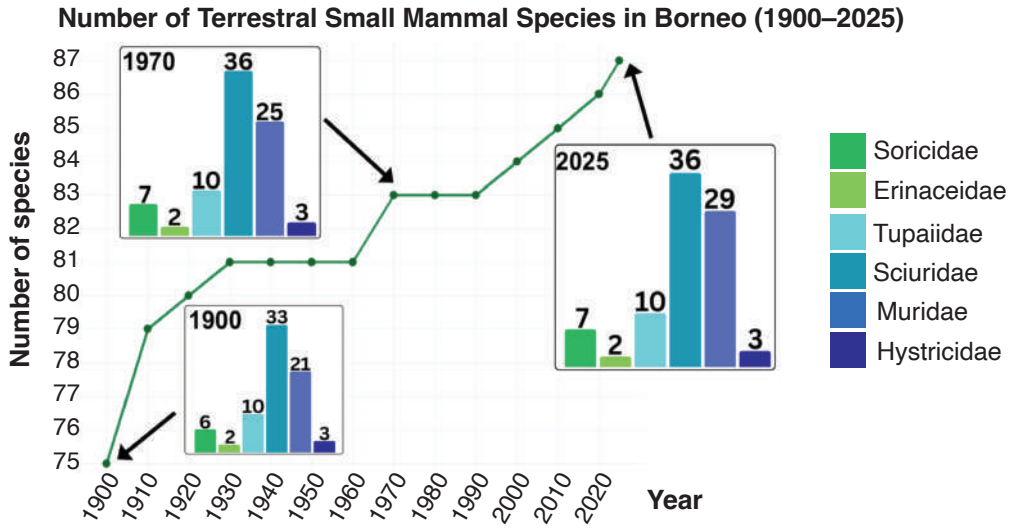

Figure 3. Changes in the recorded number of terrestrial small mammal species in Borneo between 1900 and 2025, illustrating the contribution of major taxonomic families.

Bats (Order: Chiroptera) represent the most diverse group of small mammals in Borneo and are classified into several families (Phillipps and Phillipps 2018) (Figure 4). Fruit bats in the family Pteropodidae, commonly known as flying foxes and fruit bats, play important roles in pollination and seed dispersal. In contrast, most other bat families are insect-eating species that help control insect populations. These include Rhinolophidae (horseshoe bats), Hipposideridae (leaf-nosed bats), Miniopteridae (bent-winged bats), Megadermatidae (false vampire bats), Nycteridae (slit-faced bats), Vespertilionidae (evening bats), Emballonuridae (sheath-tailed bats) and Molossidae (free-tailed bats). Similar to terrestrial small mammals, the recorded number of bat species in Borneo has increased over time, rising from 72 species in the early 1900s to 100 species by 2025 (Phillipps and Phillipps 2018; Mammal Diversity Database 2025) (Figure 5). This increase largely reflects continued exploration and the use of improved sampling methods, such as mist nets and harp traps, which have enabled researchers to detect bat species that were previously unrecorded.

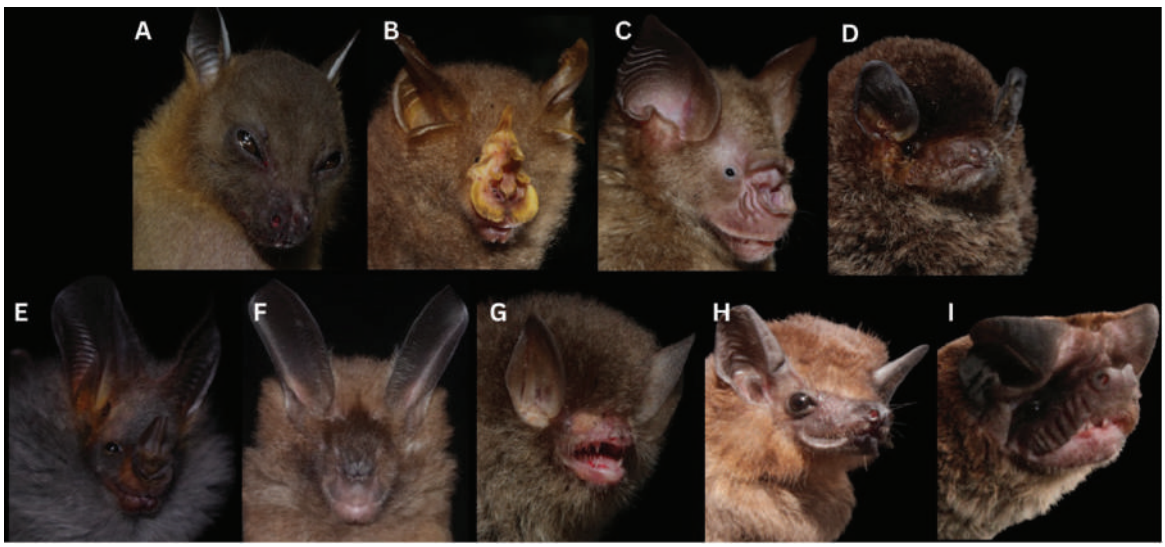

Figure 4. Representative bat species from the nine bat families recorded in Borneo (Order: Chiroptera): **A)** Pteropodidae, **B)** Rhinolophidae, **C)** Hipposideridae, **D)** Miniopteridae, **E)** Megadermatidae, **F)** Nycteridae, **G)** Vespertilionidae, **H)** Emballonuridae, and **I)** Mollosidae.

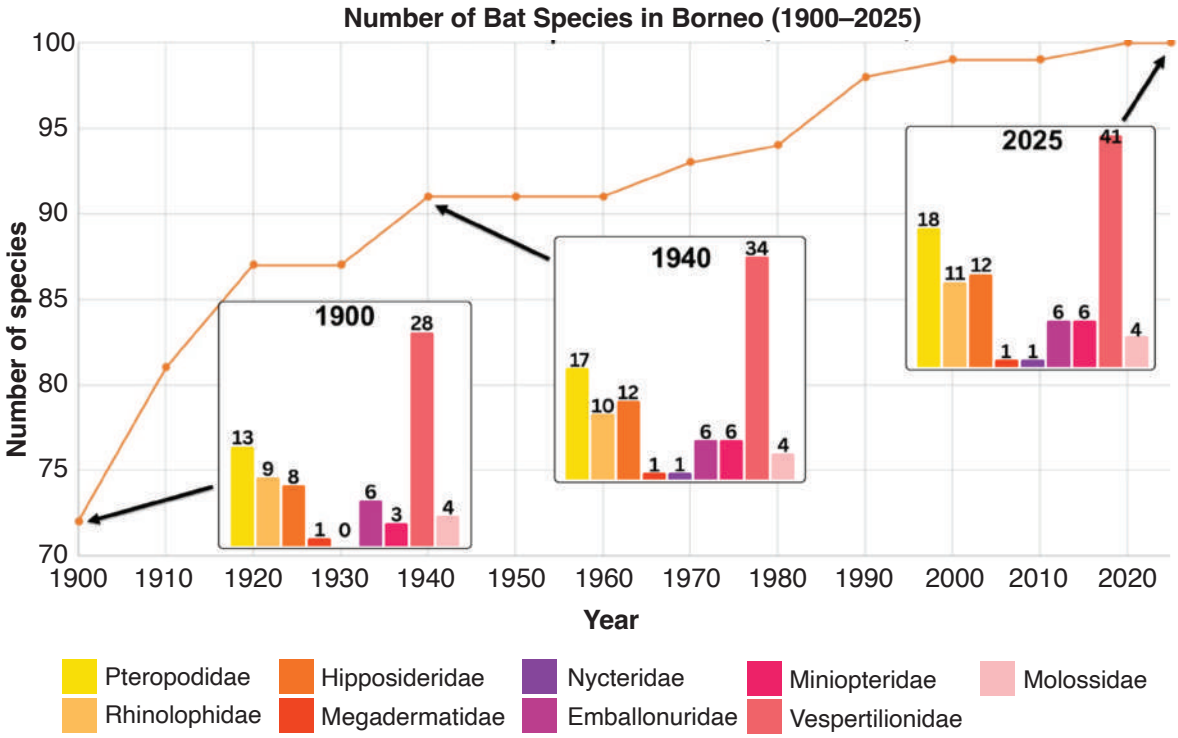

Figure 5. Historical increase in the number of bat species recorded in Borneo from 1900 to 2025, with family-level contributions highlighted for selected periods.

Conservation status of small mammal in Borneo

In terms of conservation status, the majority of terrestrial small mammal species in Borneo are currently classified as 'Least Concern' under the International Union for Conservation of Nature (IUCN) Red List (Figure 6). However, approximately 20% of species are listed as 'Data Deficient' in 2025, meaning that there is insufficient information to properly assess their risk of extinction. Notably, flying squirrels and tree mice within the rodent order make up about half of this category. This highlights an important research gap, particularly among flying squirrels, as several species within this group are already recognised as 'Vulnerable' or 'Endangered'. Improved ecological and population studies are therefore needed to better understand their conservation status and potential threats.

While terrestrial small mammals generally remain well represented in the lower-risk categories, the conservation outlook for bats in Borneo shows a slightly different pattern. Over the assessment period between 1996 and 2025, the proportion of bat species classified as 'Near Threatened', 'Vulnerable' or 'Endangered' has gradually increased, rising from about 15% in 1996 to around 25% in 2025 (Figure 7). Although most species are still considered 'Least Concern', this increase suggests that a growing number of Bornean bats face heightened risks of population decline and extinction. Factors such as habitat loss, disturbance of roosting sites and environmental change may contribute to these increasing conservation concerns.

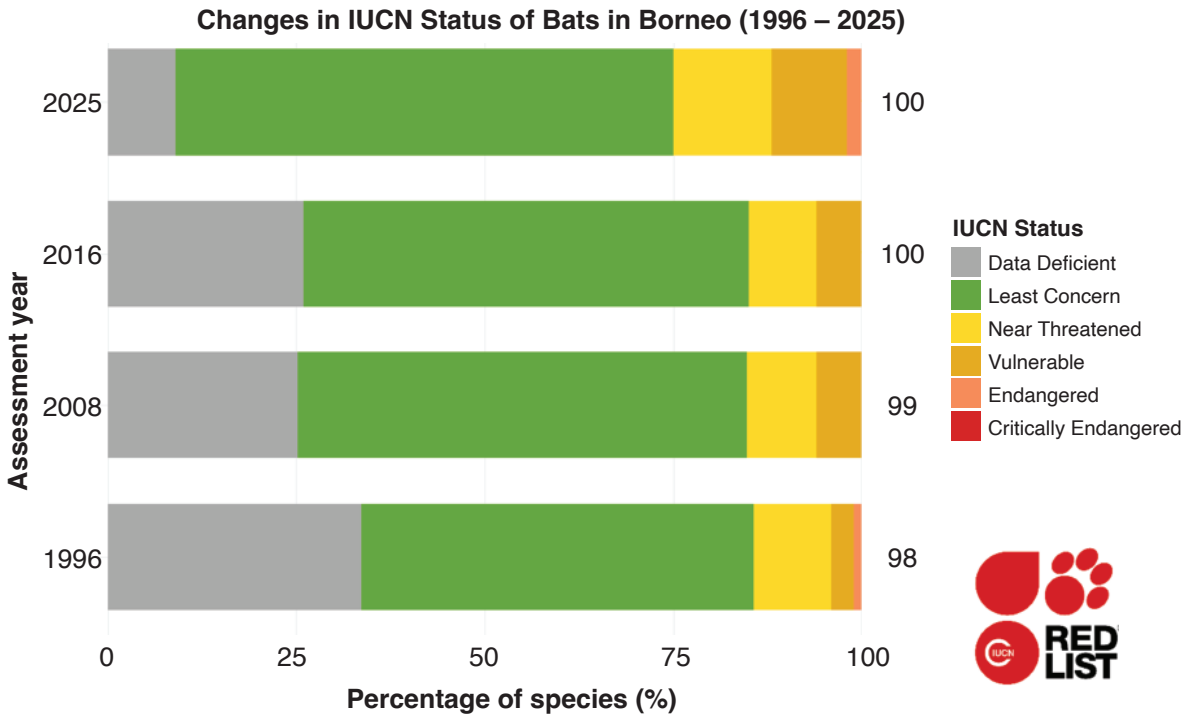

Figure 6. Conservation status of terrestrial small mammal species recorded in Borneo according to the IUCN Red List categories from 1996 to 2025, showing the proportion of species within each conservation status

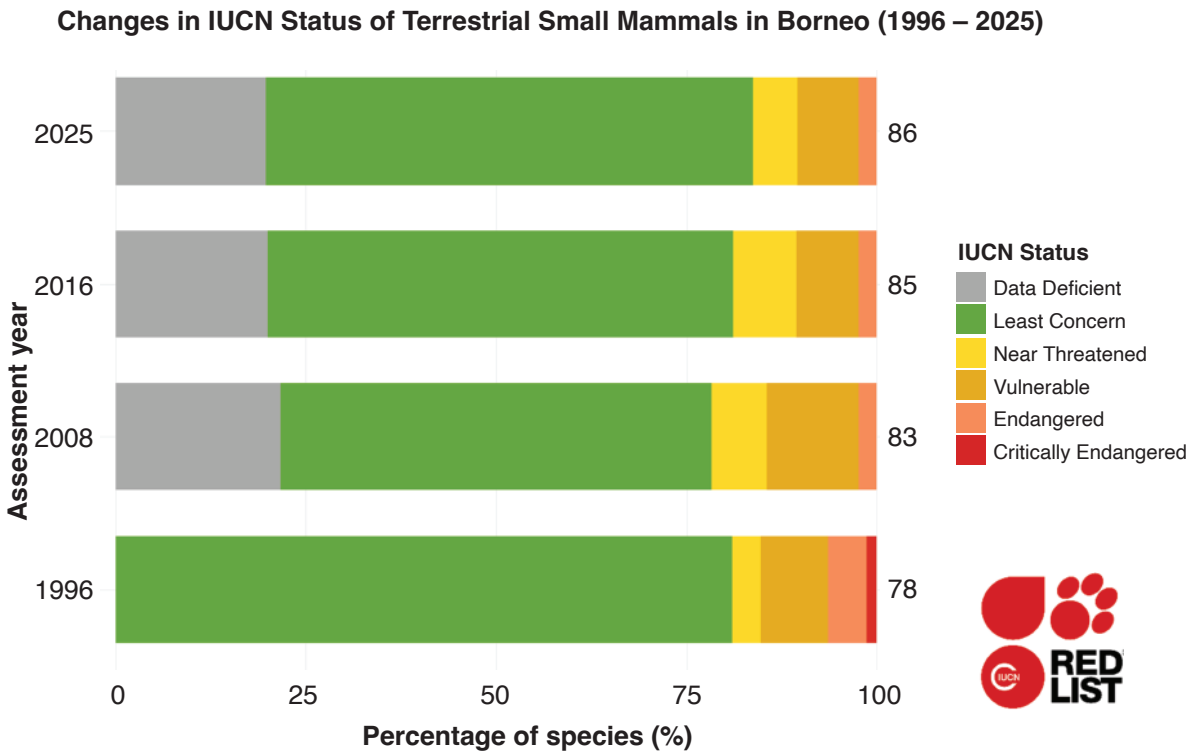

Figure 7. Conservation status of bat species recorded in Borneo based on the IUCN Red List categories from 1996 to 2025, illustrating proportion of species within each conservation status.

Trends in small mammal research in Borneo

The development of research on terrestrial small mammals in Borneo has followed a gradual trajectory, with early studies receiving limited scientific attention. These early contributions were instrumental in establishing the taxonomic framework for many Bornean taxa and provided the first systematic inventories of terrestrial small mammal fauna across different regions of the island (Figure 8). Nevertheless, many of these studies were constrained by limited sampling coverage and relied predominantly on morphological identification.

In recent decades, research on terrestrial small mammals has expanded significantly with the integration of modern ecological and molecular methodologies. Field-based studies have increasingly addressed patterns of species richness, community composition and habitat specialisation across different forest types, including lowland dipterocarp, montane and disturbed habitats (Kaicheen *et al.* 2025; Voon *et al.* 2025). Molecular phylogenetic analyses and DNA-based approaches have further revealed substantial cryptic diversity within several groups, leading to taxonomic revisions (Nations *et al*. 2022; Giarla *et al*. 2025). Additionally, rodents have gained attention in studies of disease ecology, highlighting their potential roles as reservoirs for zoonotic pathogens (Frederick *et al*. 2022; Widayati *et al*. 2022; Azmi *et al*. 2025). These developments highlight the growing recognition of terrestrial small mammals as key components of Borneo's biodiversity and as important indicators of environmental change.

The progression of bat research in Borneo reflects the broader development of mammalogy and tropical biodiversity studies in Southeast Asia. Early scientific investigations, primarily conducted during the late nineteenth and early twentieth centuries, were largely taxonomic and descriptive (Figure 9). These studies focused on specimen collection, morphological characterisation and the documentation of species distributions, often based on material deposited in major natural history museums (Banks 1931). Such foundational work was critical for establishing baseline knowledge of Bornean chiropteran diversity and for describing numerous species and subspecies within the region. However, research during this period was geographically limited and largely centered on accessible localities and major expeditions.

From the latter half of the 20th century onward, bat research in Borneo expanded substantially in both scope and methodological approaches. Ecological studies began to investigate community structure, habitat associations and trophic interactions, particularly within lowland dipterocarp forests and cave ecosystems (Kofron 1997; Khan *et al*. 2007; Shazali *et al*. 2017; Mc Arthur *et al*. 2024). Advances in bioacoustics, molecular phylogenetics and integrative taxonomy have also enabled researchers to identify cryptic species, reconstruct evolutionary relationships and refine species boundaries within several bat lineages (Khan *et al*. 2010; Ith *et al.* 2016). The incorporation of conservation biology has also become increasingly prominent, particularly in response to accelerating habitat loss and land-use change across Borneo. Collectively, these developments highlight a transition from primarily descriptive studies toward multidisciplinary research that integrates ecology, systematics, genetics and conservation science.

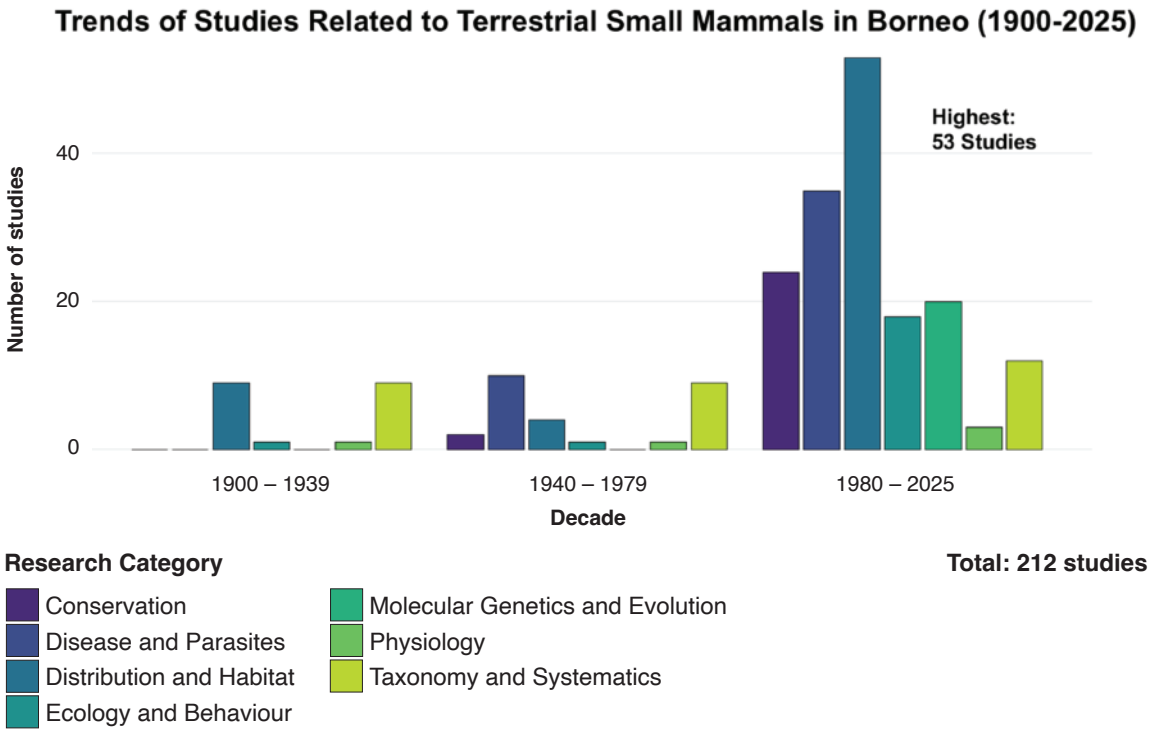

Figure 8. Trends in terrestrial small mammal research in Borneo based on research category from 1900 to 2025.

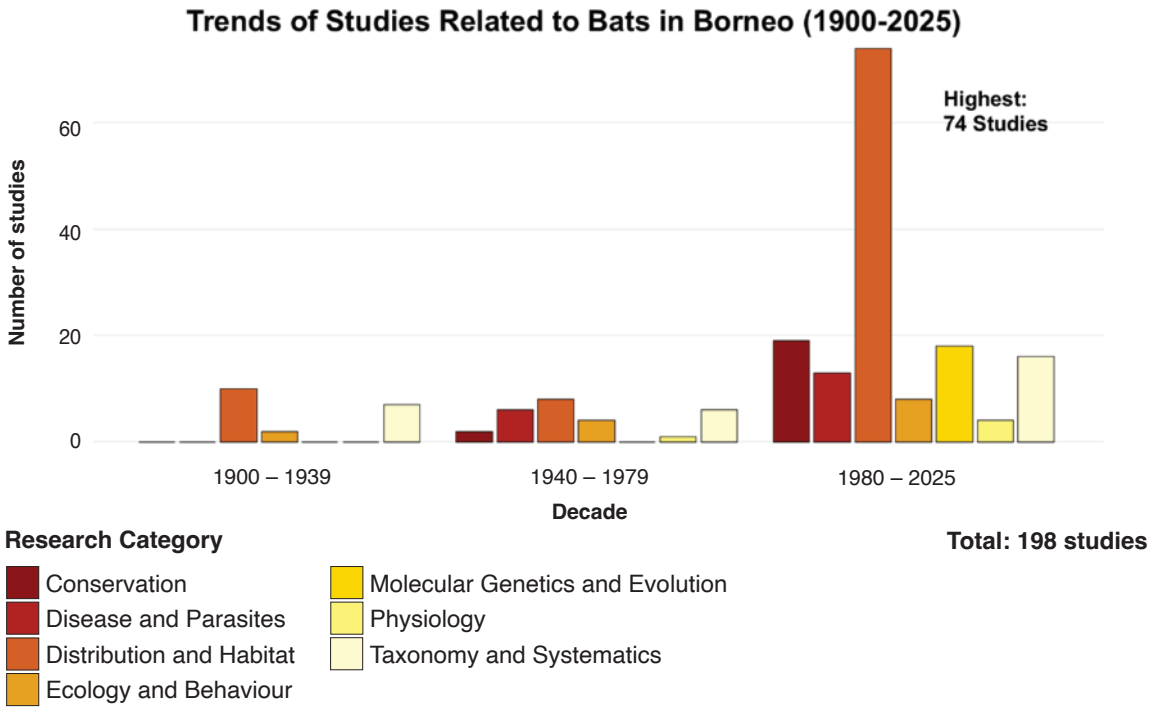

Figure 9. Trends in bats studies in Borneo according to research category from 1900 to 2025.

Distribution of small mammal research in Borneo

Studies on small mammals in Borneo are predominantly concentrated in northern Borneo, particularly in Sarawak, Sabah and Brunei, while relatively few investigations have been conducted in Kalimantan despite its extensive land area (Figure 10). In northern Borneo, research encompasses a wide range of themes, with distributional surveys, zoonotic disease investigations and conservation studies being particularly prevalent. Urbanised regions, especially around Kuching, have facilitated pathogen-related studies associated with synanthropic small mammals (Perison *et al.* 2022), whereas forested areas have supported distribution and conservation research on native species (Laneng *et al*. 2021; Khan *et al.* 2025a). In contrast, studies in Kalimantan remain sparse and are largely limited to conservation and genetic research. Although recent taxonomic discoveries from Kalimantan highlight its importance for uncovering undocumented diversity (Achmadi and Maryanto 2012; Dwijayanti *et al.* 2025), the region remains substantially underexplored.

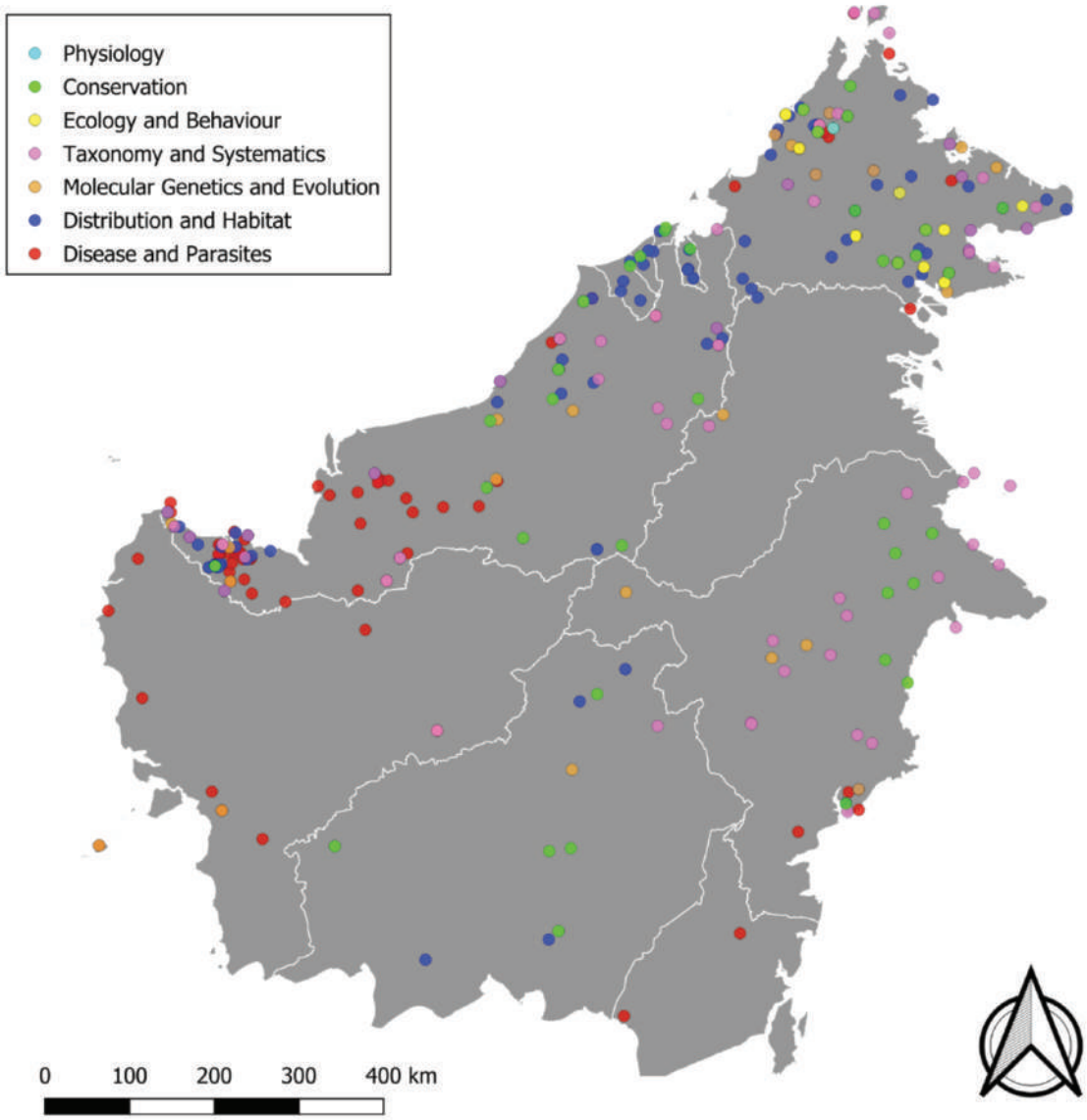

Figure 10. Distribution of research sites across Borneo compiled from published studies on small mammals, showing geographical coverage and research focus across the island.

Overall, small mammal research in Borneo has expanded considerably over the past century, evolving from early descriptive and distributional accounts to increasingly diverse and integrative research approaches. Early taxonomic and faunal surveys established the foundation for understanding species diversity and endemism on the island, while subsequent studies have broadened to include ecological, conservation and disease-related investigations. Collectively, these studies highlight the ecological significance of terrestrial small mammals in Bornean ecosystems and emphasise their importance for biodiversity assessments, conservation planning and public health research.

Despite these advances, substantial knowledge gaps remain. Research effort across the island is geographically uneven, with studies heavily concentrated in northern Borneo, particularly in Sarawak and Sabah, whereas Kalimantan remains comparatively under-represented despite comprising the largest portion of the island. In addition, physiological and functional studies on terrestrial small mammals remain relatively scarce compared with work on larger mammals. Expanding research in under-surveyed regions and incorporating emerging approaches such as next-generation sequencing will be essential going forward. Addressing these gaps will support more effective conservation and management strategies in the face of ongoing environmental change. Ultimately, continued research will be crucial for revealing the complete diversity and ecological significance of Borneo's terrestrial small mammals, the island's often overlooked yet vital "tiny titans."

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CHAPTER 13

An updated status of the primates of Malaysia

AINI HASANAH ABD MUTALIB[1,2]*, LIM XINYUE[3], LEE ZAN HUI[2], BENJAMIN GALEA[2,4], PRISCILLIA MIARD[2,3], SUSAN LAPPAN[2,5] and NADINE RUPPERT[2,3,6]*

Abstract: This chapter presents an overview of the primates of Malaysia, synthesising current knowledge on their population status, ecology, threats, and conservation. The literature on recent advances and emerging trends in primate research and conservation in Malaysia is systematically reviewed. This is followed by taxon-specific accounts that summarise the latest information on the distribution, population status, habitat use and ecology, threats, and conservation measures for all 26 Malaysian primate taxa. Primates play important ecological roles, including seed dispersal, pollination, and pest regulation but Malaysian primates are threatened with extinction and face increasing pressures from habitat loss and degradation, illegal wildlife trade, hunting, and other anthropogenic disturbances. At the same time, significant knowledge gaps continue to limit the development and implementation of effective conservation strategies, highlighting the need for targeted research to inform evidence-based management and policy decisions. To ensure the long -term persistence of Malaysia's primate diversity, research and conservation efforts must be closely aligned and strategically coordinated and addresses the existing knowledge gaps and conservation needs of each taxon.

INTRODUCTION

Primates are among the most diverse orders of mammals, with more than 500 species distributed across a range of habitats in tropical, subtropical, and temperate biomes (IUCN 2026). Most primate species occur only in forested habitats, and the highest primate diversity is found in tropical evergreen forests. While Malaysia occupies only a small proportion of the primate global distribution range, it is among the most important countries for primate biodiversity, supporting representatives of five primate families (Cercopithecidae, Hylobatidae, Hominidae, Lorisidae, and Tarsiidae) (Lappan and Ruppert 2019). This makes conservation of Malaysian primates important not only because of the crucial ecosystem services that primates provide as seed dispersers, pollinators, and pest control agents (e.g., Wiens *et al.* 2006; McConkey 2018; Holzner *et al.* 2019; Ong et al. 2022), but also as a significant component of Earth's biodiversity and Malaysia's natural heritage.

Our understanding of primate diversity in Malaysia has improved significantly since the 1991 publication of *The State of Nature Conservation in Malaysia* (Kiew 1991). While Bennett (1991) described 15 species of diurnal primates in five genera, and recognised two nocturnal species, we now recognise 26 Malaysian species in nine genera, including 21 diurnal and five nocturnal species. Research on nocturnal primate diversity and occurrence

[1] Institute for Tropical Biodiversity and Sustainable Development, Universiti Terengganu Malaysia, Kuala Terengganu, Malaysia.
[2] Malaysian Primatological Society, Kulim, Malaysia.
[3] Institute for Tropical Biodiversity and Conservation, Universiti Sabah Malaysia, Kota Kinabalu, Malaysia.
[4] School of Biological Sciences, Universiti Sains Malaysia, Gelugor, Pulau Pinang, Malaysia.
[5] Department of Anthropology, Appalachian State University, Boone NC, USA.
[6] Southeast Asia Biodiversity Research Institute and Center for Integrative Conservation, Xishuangbanna Tropical Botanical Garden – Chinese Academy of Sciences, Menglun, Yunnan, China.
***Corresponding author: a.hasanah@umt.edu.my / nadine@xtbg.ac.cn**

that additional taxa will be identified in Malaysia, either through the identification of cryptic species as distinct taxa or through improved knowledge of the distribution boundaries for known taxa. For example, the nocturnal Bengal slow loris (*Nycticebus bengalensis*) was only recently reported to occur in Langkawi, but its current distribution and abundance in Malaysia are not known (Roos *et al*. 2014; Md-Zain et al. 2019).

The primate fauna of Peninsular Malaysia (13 species) is almost entirely distinct from that of Malaysian Borneo (15 species), with only two macaque species, *Macaca fascicularis* and *M. nemestrina*, occurring in both regions. Representatives of three primate genera (*Cephalopachus*, *Nasalis*, and *Pongo*) are restricted to Sabah and Sarawak, while *Symphalangus* occurs only in Peninsular Malaysia (Figure 1). The remaining genera (*Hylobates*, *Macaca*, *Presbytis*, *Trachypithecus*, and *Nycticebus*) are represented in both regions (Ruppert and Lappan 2019).

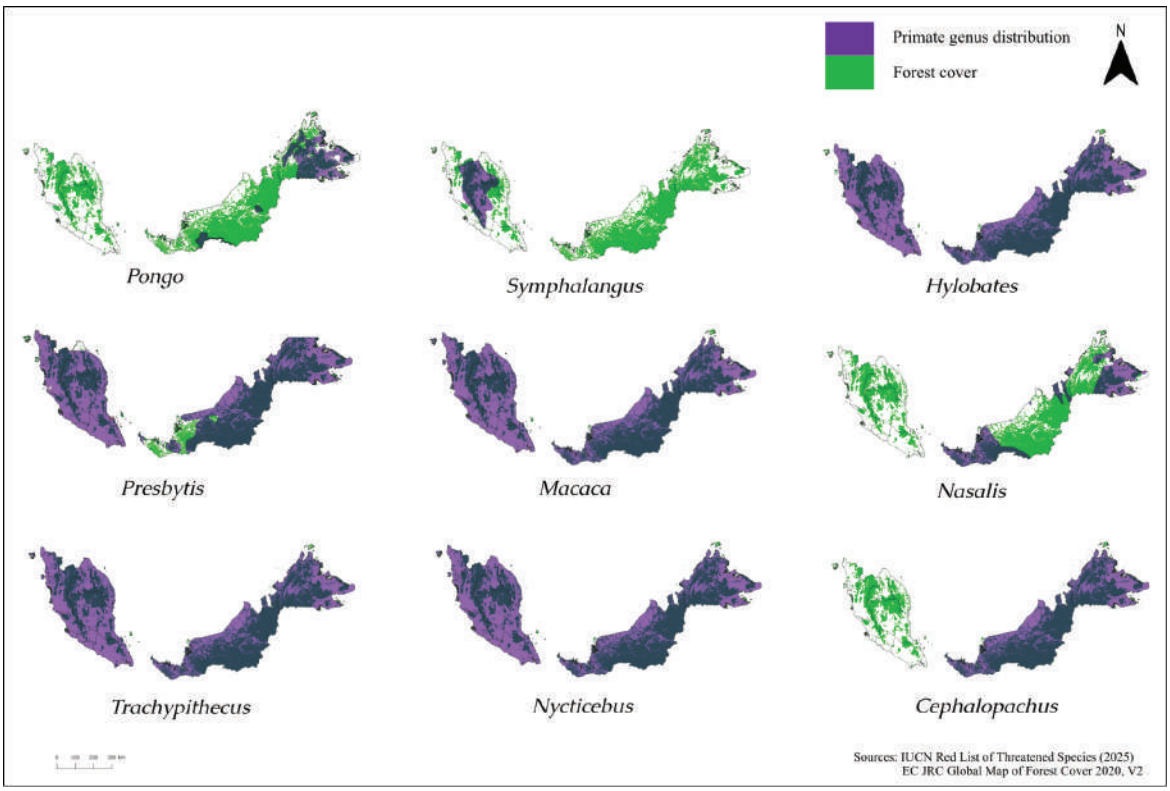

Figure 1. The distribution of primate genera across Malaysia.

Malaysian primates exhibit a remarkable diversity of ecological, physiological, and behavioural adaptations. For example, Malaysian primates range in size from the tiny Horsfield's tarsier (*Cephalopachus bancanus*; 60–150 g) (Phillipps and Phillipps 2018; Zahidin *et al.* 2019) to the majestic Bornean orangutan (*Pongo pygmaeus*; adult males 60–91 kg, females 24–56 kg) (Phillipps and Phillipps 2018; Delgado and Van Schaik 2000). Despite this diversity, all Malaysian primates almost exclusively depend on natural forest ecosystems, and most species rely heavily on closed-canopy forests. Consequently, habitat loss, degradation, and fragmentation remain the most significant threats to primate populations throughout Malaysia (Lappan and Ruppert 2019).

Although research on Malaysian primates has expanded considerably in recent decades, important knowledge gaps persist for most species, particularly regarding their distribution, population status, ecology, and responses to environmental change (Lappan and Ruppert 2019). These limitations constrain the development of effective conservation strategies at both local and national scales. To evaluate the current state of knowledge and identify research priorities, in the following we present a systematic review of the scientific literature on Malaysian primates, highlighting major research trends and key opportunities for conservation-oriented actions.

RESEARCH AND CONSERVATION TRENDS OF MALAYSIAN PRIMATES

Primate research

Detailed information on animal behaviour and ecology is crucial for effective conservation planning for long-lived, slowly reproducing animals with complex social and ecological needs and relationships. In the past few decades, understanding of some Malaysian primate species has improved substantially, but progress has been uneven. To better understand research trends, a systematic search on Scopus and a review of peer-reviewed publications was conducted for each Malaysian primate species using English search terms for species name and area: [(Species name or common name) AND ("Malaysia" or "Peninsular Malaysia" or "Sabah" or "Sarawak")] (Table 1). The search process followed a systematic workflow beginning with the identification of appropriate keywords based on the study's objectives. Searches were performed using Harzing's '*Publish or Perish*' software (https://harzing.com/resources/publish-or-perish), which is linked to the Scopus database to ensure access to peer-reviewed academic literature.

All retrieved records were manually screened to remove duplicates and non-relevant publications. Titles, abstracts, and keywords were reviewed to confirm their relevance to the study scope. Only journal articles published in English were included. Each publication was classified according to two main criteria: geographical location (representing the study area or region where the research was conducted) and thematic focus (based on the primary research topic addressed in the paper (e.g., ecology, behaviour, conservation, health, or human–wildlife interactions). This classification enabled the identification of spatial and thematic trends in the literature. The resulting dataset was subsequently used to visualise patterns (Word Clouds) in research distribution and thematic emphasis across regions (Figure 2).

A total of 622 scientific articles were found from 1963 until 2025 and classed into four broad themes (Table 2). Substantial research effort has been devoted to only a small number of diurnal primate species (Figure 3), including *Macaca fascicularis*, *M. nemestrina*, *Pongo pygmaeus*, and *Nasalis larvatus* (>50 publications each), and to a lesser extent to *Trachypithecus obscurus* and *Hylobates lar* (≥25 publications each). Much less research has been done on any aspect of nocturnal primates (e.g., *Nycticebus coucang*: 25 publications). Over the last 62 years, fewer than ten unique publications were produced for 15 species, including most *Presbytis* species, *M. arctoides*, *N. kayan*, *N. menagensis*, *H. agilis*, and *H. funereus*, and no publications were found for *H. abbotti* (Figure 3).

Table 1. Search terms used for each species for the systematic literature review and additional information on the 26 Malaysian primate species. Search terms included Species name, Common name and Area.

	Family	Species name	Common name	Area	Synonyms
1	Cercopithecidae	*Macaca arctoides*	Stump-tailed macaque	Peninsular Malaysia	*Macacus arctoides*, *M. speciosa*, *M. rhesoides*
2	Cercopithecidae	*Macaca fascicularis*	Long-tailed macaque	Malaysia (Peninsular Malaysia, Sabah, Sarawak)	*Cynomolgus fascicularis*, *Macacus cynomolgus*, *M. irus*, *Simia fascicularis*
3	Cercopithecidae	*Macaca nemestrina*	Southern pig-tailed macaque	Malaysia (Peninsular Malaysia, Sabah, Sarawak)	*Macacus nemestrinus*, *M. leonina*, *M. nemestrina pagensis*
4	Cercopithecidae	*Nasalis larvatus*	Proboscis monkey	Sabah, Sarawak	*N. concolor*, *N. larvatus orientalis*, *N. larvatus carlottae*
5	Cercopithecidae	*Presbytis chrysomelas*	Bornean banded langur	Sabah, Sarawak	*P. hosei chrysomelas*, *P. chrysomelas cruciger*
6	Cercopithecidae	*Presbytis femoralis*	Raffles' banded langur	Peninsular Malaysia	*P. femoralis femoralis*, *P. femoralis robinsoni*
7	Cercopithecidae	*Presbytis frontata*	White-fronted Langur	Sarawak	*P. frontata frontata*, *P. frontata nudifrons*
8	Cercopithecidae	*Presbytis hosei*	Hose's Langur	Sabah, Sarawak	*P. aygula*, *P. frontata hosei*
9	Cercopithecidae	*Presbytis robinsoni*	Robinson's Langur	Peninsular Malaysia	*P. melalophos robinsoni*, *P. femoralis robinsoni*
10	Cercopithecidae	*Presbytis rubicunda*	Maroon langur or Red langur	Peninsular Malaysia, Sabah, Sarawak	*P. rubicunda rubicunda*, *P. rubicunda rubida*, *P. rubicunda ignita*
11	Cercopithecidae	*Presbytis sabana*	Sabah grey langur	Sabah	*P. hosei sabana*
12	Cercopithecidae	*Presbytis siamensis*	White-thighed surili or Malayan pale-thighed langur	Peninsular Malaysia	*P. melalophos siamensis*, *P. femoralis siamensis*
13	Cercopithecidae	*Trachypithecus cristatus*	Silvery langur	Sabah, Sarawak	*Semnopithecus cristatus*, *T. villosus*, *T. argentatus*
14	Cercopithecidae	*Trachypithecus obscurus*	Dusky langur or Spectacled leaf monkey	Peninsular Malaysia	*Semnopithecus obscurus*, *T. phayrei obscurus*

15	Cercopithecidae	*Trachypithecus selangorensis*	Selangor silver langur	Peninsular Malaysia	*Semnopithecus cristatus*, *T. villosus*, *T. argentatus*, *T. cristatus selangorensis*
16	Hominidae	*Pongo pygmaeus*	Bornean orangutan	Sabah, Sarawak	*Simia satyrus*, *P. satyrus*, *P. wurmbii*
17	Hylobatidae	*Hylobates lar*	Lar gibbon, White-handed gibbon	Peninsular Malaysia	*H. entelloides*, *H. carpenteri*, *H. agilis lar*
18	Hylobatidae	*Hylobates agilis*	Agile gibbon, Black-handed gibbon	Peninsular Malaysia	*H. unko*
19	Hylobatidae	*Hylobates funereus*	Northern gray gibbon	Sabah	*H. muelleri funereus*
20	Hylobatidae	*Symphalangus syndactylus*	Siamang	Peninsular Malaysia	*Hylobtes syndactylus*, *S. continentis*
21	Hylobatidae	*Hylobates abbotti*	Abbott's gray gibbon	Sarawak	*H. cinereus abbotti*, *H. muelleri abbotti*
22	Lorisidae	*Nycticebus bengalensis*	Bengal slow loris	Peninsular Malaysia	*N. cinereus*, *N. incanus*, *N. tenasserimensis*
23	Lorisidae	*Nycticebus coucang*	Sunda slow loris	Peninsular Malaysia	*Tardigradus coucang*, *N. bengalensis coucang*, *N. coucang menagensis*, *N. javanicus*, *N. menagensis coucang*
24	Lorisidae	*Nycticebus menagensis*	Philippines slow loris	Sabah, Sarawak	*Lemur menagensis*, *N. coucang menagensis*, *N. menagensis philippinus*, *N. menagensis menagensis*, *N. borneanus*, *N. bancanus*, *N. menagensis borneanus*
25	Lorisidae	*Nycticebus kayan*	Kayan slow loris	Sabah, Sarawak	*Nycticebus menagensis* (Borneo), Bornean slow loris morphotype 4
26	Tarsiidae	*Cephalopachus bancanus*	Western tarsier, Horsfield's tarsier	Sabah, Sarawak	*Tarsius bancanus bancanus*, *T. bancanus borneanus*, *T. bancanus*, *T. borneanus*, *C. bancanus*

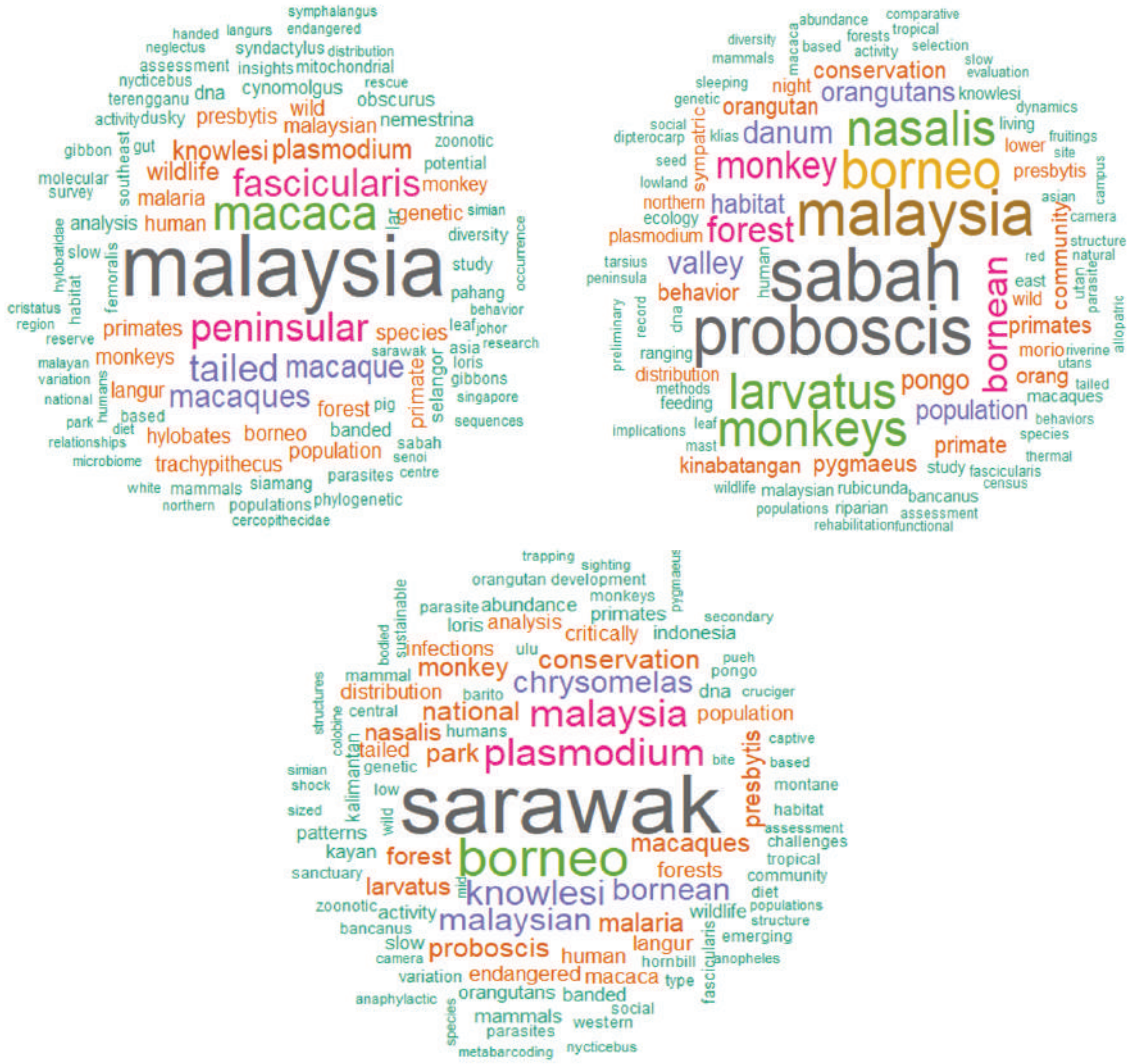

Figure 2. Word Clouds of terms used in publication titles of primate research in (Peninsular) Malaysia, Sabah and Sarawak. The bigger the word, the more often it was used in a title.

Table 2. Number of publications per theme and topic focussing on primates of each administrative region in Malaysia (Peninsular Malaysia, Sabah, and Sarawak).

Theme	Topic	Number of publications		
		Peninsular Malaysia	Sabah	Sarawak
General biology	Morphology, anatomy, physiology, behaviour	50	30	6
Phylogeny, distribution, and abundance	Population genetics, phylogenetics, molecular evolution, DNA barcoding, genetic diversity, gene flow, conservation genetics, distribution, abundance	112	33	27

Behavioural ecology and conservation	Feeding ecology, diet	34	24	7
	Habitat use, population, demography, habitat suitability, threats to habitats, conservation, movement, interactions with other species	35	26	9
	Human-primate interactions and conservation	44	19	112
Diseases and One Health	Diseases, pathogens, parasites	153	19	10
	Forensic science	6	0	0
Total		**434**	**151**	**171**

Note: The number of publications deviates from Figure 3 as several publications listed more than one study species, area, or topic.

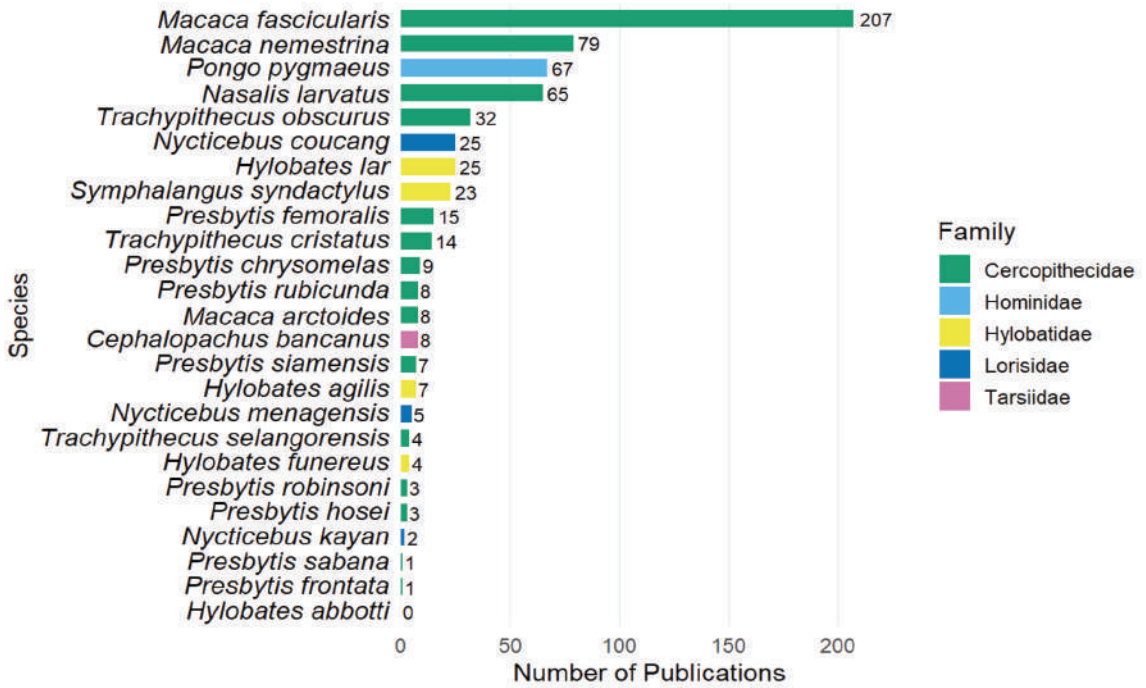

Figure 3. Number of unique publications per primate species in Malaysia from 1963 until 2025 (n = 622).

Significant taxonomic revisions in the genera *Hylobates* (Thinh 2010; Chan *et al.* 2013; Matsudaira and Ishida 2021), *Presbytis* (Osterholz *et al.* 2008; Meyer *et al.* 2011; Ang *et al.* 2024), and *Trachypithecus* (Osterholz *et al*. 2008; Roos *et al.* 2008) may have led to misclassification of some publications. This may have resulted in omissions, particularly for subspecies recently elevated to full species, such as *H. abbotti*, *H. funereus*, *P. chrysomelas*, *P. femoralis*, *P. robinsoni*, *P. sabana*, *P. siamensis*, and *T. selangorensis*, but this alone is unlikely to explain these skewed patterns adequately. The inclusion of search terms in Bahasa Malaysia or other local languages and grey literature outside peer-reviewed scientific databases could further increase the number of published references for certain taxa but is not expected to have a significant influence on the current results.

Most publications derived from Peninsular Malaysia (n = 434), with considerably fewer from Sarawak (n = 171) and Sabah (n = 151). Most research revolved around the themes of primate 'Diseases and One Health' (n = 188) and 'Phylogeny, distribution, and abundance' (n = 172; Table 2).

Conservation

Peninsular Malaysia had already lost half of its forest cover by 1990, and since the publication *The State of Nature Conservation in Malaysia* (Kiew 1991), forest loss has continued at an alarming pace. For example, from 2001 to 2025, remotely sensed data suggest that Malaysia has lost an estimated 3 million ha of primary forest, and 9.5 million ha of tree cover, with particularly high losses of tree cover in the Peninsular Malaysian states of Johor (51%) and Melaka (60%) (World Resources Institute 2025). Other states lost between 28% and 37% of their tree cover during this interval (World Resources Institute 2025), but since baseline tree cover in Sabah and Sarawak was higher, and these states together comprise more than half of Malaysia's land area, the total area of forest lost in these states was very high (5.3 million ha of tree cover and 2.2 million ha of primary forest). Accordingly, the conservation status of Malaysia's forest-dependent primates has become increasingly dire.

Bennett (1991) assessed the status of Malaysian diurnal primates on a national level using the IUCN Red List criteria then in place (v. 1.0; Table 3). Several of the taxa included in Bennett's (1991) assessment have since been revised, such that the 15 diurnal taxa that Bennett assessed correspond with 21 species now recognised to occur in Malaysia (Table 3). This chapter uses the taxonomy currently accepted by the IUCN and its Red List Categories from the most recent global assessment available for each Malaysian primate taxon, since recent national-level assessments have not been conducted.

The Red List assessments confirm that, while our understanding of primate biodiversity in Malaysia has improved, the conservation situation for Malaysian primates has significantly deteriorated in the past few decades (Figure 4). In 1991, two of 15 species evaluated were assessed as Endangered in Malaysia, and seven species as Vulnerable (Bennett 1991). *Macaca arctoides* was assessed as "possibly extinct in Malaysia," based on its very small area of occurrence in northern Peninsular Malaysia. The three remaining diurnal species, *Macaca fascicularis*, *M. nemestrina*, and *Hylobates lar*, were assessed as Not Threatened in Malaysia (Bennett 1991). However, in 2025, most Malaysian species (23 of 26) are listed as Threatened (i.e., Vulnerable, Endangered, or Critically Endangered), and the remaining three species are Near Threatened (Table 3; Figure 4). In 1991, no Malaysian primate was Critically Endangered, but by 2025, three species are in this highest threat category. The nocturnal primate species known to occur in Malaysia were not included in Bennett's (1991) assessment, and three of these species (*Nycticebus coucang*, *N. kayan*, and *N. menagensis*) were not assessed by the IUCN before 2020, when they were assessed as Vulnerable. *Cephalopachus bancanus* was first assessed in 1996 as "Lower Risk" (a category that corresponds with the category "Least Concern" in post-2000 assessments and is abbreviated as "LC" in Table 3) but is currently listed as Vulnerable. *Nycticebus bengalensis* was listed as Data Deficient in 2000, Vulnerable in 2008, and Endangered in 2015, so additional survey effort to determine the occurrence of *N. bengalensis* in Malaysia is needed for conservation planning.

Table 3. Malaysian primate species, organised by area of occurrence and family, with their Malaysian conservation status in 1991 (Malaysia), 1996 (global), the most recent IUCN global assessments available in 2025, main threats globally in 2025, and protection status in each Malaysian legal framework (Peninsular Malaysia, Sabah, and Sarawak). The 1991 evaluations are national assessments generated by Bennett (1991) using IUCN Categories and Criteria v. 1.0. The 1996 (v. 2.3; IUCN 1994) and 2025 (v. 3.1; IUCN 2001) statuses are IUCN Red List Categories (IUCN 2025). Abbreviations: CR = Critically Endangered; DD = Data Deficient; EN = Endangered; LC = Least Concern[1]; N = Not Threatened (categorised by Bennett 1991); NT = Near Threatened[1]; P = Protected; PM = Peninsular Malaysia; SB = Sabah; SW = Sarawak; TP = Totally Protected; VU = Vulnerable.

Family	Species (common name)	1991 *Malaysian status according to Bennett 1991 (following IUCN Categories and Criteria v. 1.0.)*	1996 *Global IUCN Red List Categories (v. 2.3[1])*	2025 *Global IUCN Red List Categories (v. 3.1)*	Main threats in 2025 *(following Global IUCN Red List)*	Legal protection in Malaysia[2]
Peninsular Malaysia, Sabah and Sarawak						
Cercopithecidae	*Macaca fascicularis* (Long-tailed macaque)	N	NT	EN (A2cd+3cd+4cd)	Habitat loss, hunting, human-wildlife conflict, pet trade, trade for biomedical research, roadkill	P (all)
	M. nemestrina (Southern pig-tailed macaque)	N	VU	EN (A2cde+3cde)	Habitat loss, hunting, human-wildlife conflict, pet trade, agricultural pesticides	P (all)
Peninsular Malaysia only						
Cercopithecidae	*M. arctoides* (Stump-tailed macaque)	Possibly extinct in PM	VU	VU (A2cd+3cd)	Habitat loss, hunting	TP (PM)
	Presbytis femoralis[3] (Raffles banded langur)	N (assessed as *P. melalophos*[3])	NT (assessed as *P. femoralis*, a taxon that also included *P. percura* and *P. robinsoni*)	CR (C2a(i)	Habitat loss, habitat fragmentation, low genetic variability	TP (SW), P (PM, SB)

	P. robinsoni[3] (Robinson's banded langur)	N (assessed as *P. melalophos*[3])	NT (assessed as *P. femoralis*, a taxon that also included *P. percura* and *P. robinsoni*)	NT (A2cd)	Habitat loss, pet trade	TP (SW), P (PM, SB)
	P. siamensis[3] (White-thighed surili/ Malayan pale-thighed langur)	N (assessed as *P. melalophos*[3])	LC	NT (A2cd)	Habitat loss	TP (SW), P (PM, SB)
	Trachypithecus obscurus[4] (Dusky langur)	N (*P. obscura*[4])	LC	EN (A2cd)	Habitat loss, hunting, roadkill	P (PM, SW)
	T. selangorensis[5] (Selangor silvery langur)	EN (assessed as *P. cristata*[5])	NT (assessed as *T. cristatus*[4])	NT (A2c)	Habitat loss, hunting, fires	P (PM, SW)
Hylobatidae	*Hylobates agilis* (Agile gibbon/ Black-handed gibbon)	VU	NT	EN (A2cd+4cd)	Habitat loss, hunting, pet trade	TP (PM, SW), P (SB)
	H. lar (White-handed gibbon/ Lar gibbon)	N	NT	EN (A2cd+3cd)	Habitat loss, habitat fragmentation, hunting, pet trade	TP (PM, SW), P (SB)
	Symphalangus syndactylus[6] (Siamang)	VU (*Hylobates syndactylus*[6])	NT (*Hylobates syndactylus*[6])	EN (A4cd)	Habitat loss, hunting, pet trade, disease	TP (PM, SW), P (SB)
Lorisidae	*Nycticebus bengalensis* (Bengal slow loris)	-	- (first assessed as DD in 2000)	EN (A2acd+3cd+4acd)	Habitat loss, fires, human-wildlife conflict, pet trade	TP (PM, SW), P (SB)
	N. coucang (Greater slow loris)	-	-	EN (A2acde+4acde)	Habitat loss, human-wildlife conflict, pet trade, invasive species	TP (PM, SW), P (SB)

Sabah and Sarawak only						
Cercopithecidae	*Nasalis larvatus* (Proboscis monkey)	EN	VU	EN (A2acd+4acd)	Habitat loss, hunting	TP (all)
	Presbytis chrysomelas[3] (Bornean banded langur) (SW only)	N (assessed as *P. melalophos*[3])	-	CR (A2ac+3c)	Habitat loss	TP (SW), P (PM, SB)
	P. frontata (White-fronted langur) (SW only)	VU	DD	VU (A2cd+3cd)	Habitat loss, hunting	TP (SW), P (PM, SB)
	P. hosei[7] (Hose's langur)	VU	-	VU (A2cd+3cd)	Habitat loss, hunting	TP (SW), P (PM, SB)
	P. rubicunda (Maroon langur/ Red langur)	VU	LC	VU (A4acd)	Habitat loss, hunting	TP (SW), P (PM, SB)
	P. sabana[7] (Sabah grizzled langur) (SB only)	VU (assessed as *P. hosei*[7])	-	EN (A2acd+4acd)	Habitat loss, hunting	TP (SW), P (PM, SB)
	Trachypithecus cristatus[5] (Silvery langur)	EN (*P. cristata*[5])	NT	VU (A2cd+3cd)	Habitat loss, hunting	P (PM, SW)
Hylobatidae	*Hylobates abbotti*[8] (Abbott's gray gibbon) (SW only)	VU (assessed as *H. muelleri*[8])	NT (assessed as *H. muelleri*[8])	EN (A4cd)	Habitat loss, hunting, fires, pet trade	TP (PM, SW), P (SB)
	H. funereus[8] (Northern gray gibbon)	VU (assessed as *H. muelleri*[8])	NT (assessed as *H. muelleri*[8])	EN (A4cd)	Habitat loss, hunting, fires, pet trade	TP (PM, SW), P (SB)
Hominidae	*Pongo pygmaeus* (Bornean orangutan)	VU	EN	CR (A4abcd)	Habitat loss, hunting, fires, habitat fragmentation, lack of awareness, climate change	TP (all)
Lorisidae	*Nycticebus kayan* (Kayan River slow loris)	-	-	VU (A2cde+3cde)	Habitat loss, pet trade, fires	TP (PM, SW), P (SB)
	N. menagensis (Philippine slow loris)	-	-	VU (A2cd+3cd)	Habitat loss, pet trade, fires	TP (PM, SW), P (SB)

Tarsiidae	*Cephalopachus bancanus*[9] (Horsfield's tarsier)	-	LR (*Tarsius bancanus*[9])	VU (A2cde+3cde)	Habitat loss, human-wildlife conflict, pet trade, agricultural pesticides	P (PM, SB), TP (SW)

[1] Version 2.3 of the IUCN Red List Criteria and Categories (IUCN 1994) used a single "Lower Risk" Category, which included three ordered subcategories: "Lower Risk (conservation dependent) (LR/cd), "Lower Risk (near threatened) (LR/nt), and Lower Risk (least concern) (LR/lc). To facilitate longitudinal comparisons of threatened status, here we treat a designation of LR/nt under version 2.3 (IUCN 1994) as equivalent to the category "Near Threatened (NT)" in version 3.1 (IUCN 2001), and treat a designation of "LR/lc" under version 2.3 (IUCN 1994) as equivalent to the category "Least Concern (LC)" in version 3.1 (IUCN 2001).

[2] Wildlife in Malaysia is protected under different regulations in different regions. In Peninsular Malaysia, protection is under the Wildlife Conservation Act 2010 (Act 716; Laws of Malaysia 2010) and its 2022 amendment (Wildlife Conservation (Amendment) Act 2022 (Act A 1646; Laws of Malaysia 2022) in Sabah, protection is under the Wildlife Conservation Enactment 1997 (State of Sabah 1997). In Sarawak, protection is under the Wild Life Protection Ordinance 1998 (Laws of Sarawak 1998).

[3] Revision of *Presbytis taxonomy* resulted in the elevation of *Presbytis chrysomelas*, *P. femoralis*, *P. robinsoni*, and *P. siamensis*, formerly within *P. melalophos*, to full species level (Osterholz *et al.* 2008; Meyer *et al.* 2011; Ang *et al.* 2020a, 2024). This revision means that *P. melalophos* does not occur in Malaysia.

[4] *Trachypithecus obscurus* was listed as *Presbytis obscurus* in Bennett (1991).

[5] *Trachypithecus cristatus* was listed as *Presbytis cristata* in Bennett (1991). *Trachypithecus selangorensis*, formerly a subspecies of *T. cristatus*, was subsequently elevated to full species level (Osterholz *et al.* 2008).

[6] *Symphalangus syndactylus* was listed as *Hylobates syndactylus* in Bennett (1991) and IUCN (1996).

[7] *Presbytis sabana* was included within *P. hosei* in Bennett (1991).

[8] Revision of *Hylobates* taxonomy resulted in the elevation of *Hylobates abbotti* and *H. funereus*, formerly within *H. muelleri*, to full species level (Thinh 2010; Chan *et al.* 2013; Matsudaira and Ishida 2021). This revision means that *H. muelleri* is not known to occur in Malaysia.

[9] *Cephalopachus bancanus* was assessed as *Tarsius bancanus* in IUCN (1996). Taxonomic revision of lorises in Sarawak placed *Nycticebus kayan* and *N. menagensis*, formerly under *N. coucang*, under the same Totally Protected status in the Wild Life Protection Ordinance 1998.

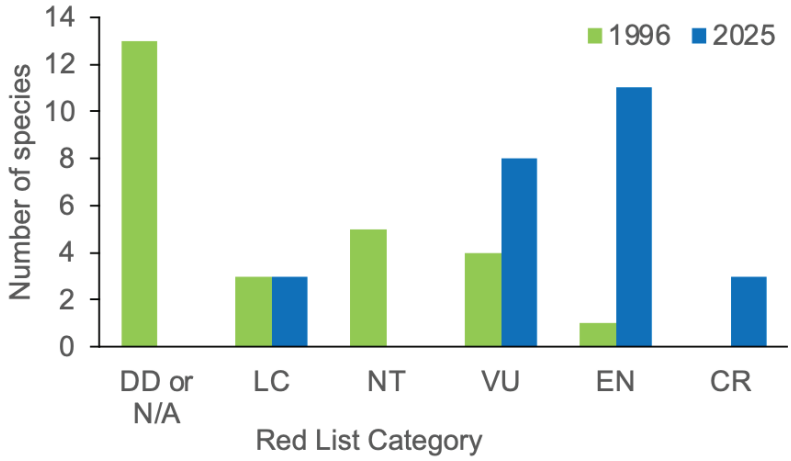

Figure 4. IUCN Red List Categories for 25 primate species with confirmed occurrence in Malaysia in 1996 and 2025. DD = Data Deficient, N/A = No assessment was available in 1996, LC = Least Concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, CR = Critically Endangered.

STATUS OF MALAYSIAN PRIMATES IN 2025

All Malaysian primates were listed as Threatened (i.e., Vulnerable, Endangered, or Critically Endangered) or Near Threatened in the most recent IUCN Red List assessments. While global assessments do not always capture the situation in individual nations, and changes in taxonomy, especially among *Presbytis* (Osterholz *et al*. 2008; Meyer *et al.* 2011; Ang *et al.* 2020a, 2024) and *Hylobates* (Thinh 2010; Chan *et al.* 2013; Matsudaira and Ishida 2021) species, make direct comparisons across years difficult for several taxa, the significant increase in the proportion of Malaysian taxa listed as Endangered and Critically Endangered clearly reflects increasing threats to primates in Malaysia as well as globally.

Below, we briefly review the status of each primate genus in Malaysia. The Bornean orangutan (*Pongo pygmaeus*) is also reviewed more thoroughly in another chapter in the *State of Nature Conservation in Malaysia 2025*.

1. *Cephalopachus*

Distribution

In Malaysia, the tarsier population is represented by a single subspecies, *Cephalopachus bancanus borneanus*, which is shared with the neighbouring regions of Kalimantan and Brunei. Its distribution within Malaysia is restricted to Sabah and Sarawak (Shekelle and Yustian 2020).

Population

Population studies on tarsiers in Malaysia are limited and often dated. In Sabah, foundational studies by Crompton and Andau (1987) in Kabili-Sepilok Forest Reserve recorded a density of 12 individuals/km^2. Elsewhere in the state, the primary protected forest of Danum Valley supported 15 ind./km^2 (Bernard *et al*. 2014), while the mixed riverine forest of the Lower Kinabatangan Wildlife Sanctuary sustained a much lower density of 3 ind./km^2 (Munds *et al.* 2013a). In Sarawak, the earliest population assessment reported an exceptionally high -density estimate of 80 ind./km^2 in Semenggoh (Niemitz 1979), and more recent research in the secondary and rehabilitated forest patches of Universiti Putra Malaysia (UPM), Bintulu, has documented a density of 36 ind./km^2 (Sahimi *et al.* 2018).

Habitat and ecology
The species inhabits lowland and hilly areas in both primary and secondary forests, as well as some cultivated landscapes and coastal zones (Crompton and Andau 1987; Shekelle and Yustian 2020). Its populations are predominantly found in the dense understory of lowland rainforests (Phillipps and Phillipps 2018; Shekelle and Yustian 2020). This preference is driven by its strictly nocturnal and carnivorous foraging ecology, as it hunts insects and small vertebrates primarily in the lower forest stratum (<2 m) (Crompton and Andau 1987; Shekelle and Yustian 2020).

Threats to survival
Cephalopachus bancanus faces significant extinction risk primarily from widespread habitat loss and degradation due to forest conversion for agriculture, logging, and fires across its range in Borneo and Sumatra. This is compounded by localised pressure from illegal capture for the pet trade and potential impacts from invasive species, pathogens, and pollution, collectively driving population declines (Shekelle and Yustian 2020).

Conservation measures
Tarsiers receive formal legal protection across multiple jurisdictions to mitigate extinction risks. Internationally, *C. bancanus* is listed under CITES Appendix II, which regulates and monitors all international commercial trade. Domestically within Malaysia, it is shielded by a framework of federal and state-level legislation. In key areas like Danum Valley and Rainforest Discovery Centre, Sepilok, regulated wildlife tourism generates essential conservation revenue and local economic benefits, while promoting public education under controlled conditions (Shekelle and Yustian 2020).

2. *Hylobates*
Distribution
Four *Hylobates* species occur in Malaysia: two in Peninsular Malaysia and two in Borneo. *Hylobates abbotti* occurs in western Kalimantan and Sarawak (Roos *et al.* 2014; Cheyne *et al.* 2020a). *Hylobates agilis* is distributed in Peninsular Malaysia, southern Thailand, and Sumatra (Geissmann *et al.* 2020), with its distribution in Malaysia limited to parts of Perak, Kedah, and Kelantan. *Hylobates funereus* occurs in Sabah and eastern Sarawak (Roos *et al.* 2014), although the precise distribution boundary between *H. abbotti* and *H. funereus* remains poorly understood (Nijman *et al*. 2020a). *Hylobates lar* ranges from southern China, Myanmar, Thailand, and Laos to Peninsular Malaysia and Sumatra and is widespread throughout forested areas in Peninsular Malaysia, except in Melaka, Penang, and a narrow zone between the Perak and Muda rivers (Brockelman and Geissmann 2020).

Population
Little is known about the abundance and population trends of most Malaysian *Hylobates* species (Sop *et al.* 2024). While the occurrence of *H. abbotti* in Sarawak has been confirmed, no recent information is available on its abundance or distribution, representing a major knowledge gap (Cheyne *et al.* 2020a; Sop *et al*. 2024). In Ulu Muda Forest Reserve, *H. agilis* densities were estimated at 4.03 ± 0.14 groups/km^2, with a total population of approximately 2,927 ± 102 groups (Pang *et al.* 2022), but comparable estimates from other important populations are lacking. For *H. funereus*, a recent assessment estimated approximately 100,000 individuals in Sabah, compared to more than 360,000 individuals in 1980, although this estimate was derived from spatial models of forest loss rather than direct surveys (Sop *et al.* 2024; Shabrani *et al.* 2026). Recent estimates for *H. lar* range from 3.55 ± 0.9 groups/km^2 in Sungai Yu and Tanum Forest Reserves (Kamaruzaman *et al*. 2023) to 0.24 – 1.7 groups/km^2 in Taman Negara Pahang and adjacent forests (Mohd Rameli 2021), but no national population estimate is available (Brockelman and Geissmann 2020).

Habitat and ecology

Malaysian gibbons primarily inhabit lowland, swamp, and hill dipterocarp forests. They are highly arboreal, spending nearly their entire lives in the forest canopy, where they feed predominantly on fruits supplemented with leaves, flowers, and invertebrates. *Hylobates* spp. like other gibbons, are among the most specialised brachiators, travelling rapidly through the canopy using arm-swinging locomotion. They typically live in small, territorial family groups consisting of an adult pair and their offspring. Pair bonds are maintained through coordinated territorial defence and species-specific loud morning duets, which play important roles in mate bonding, territory advertisement, and population spacing. Due to their dependence on continuous forest canopies and fruit resources, gibbons are particularly sensitive to habitat disturbance and changes in forest composition (Caldecott 1980; Light *et al.* 2021; O'Brien *et al*. 2024).

Threats to survival

Habitat loss, degradation, and fragmentation are the principal threats to all Malaysian gibbons, including *Hylobates* spp. (Brockelman and Geissmann 2020; Cheyne and Nijman 2020, Geissmann *et al*. 2020; Nijman *et al*. 2020). Large areas of suitable habitat have been converted for agriculture, infrastructure, and other land uses, resulting in population declines and range contractions. Gibbons are particularly vulnerable to fragmentation because they rarely descend to the ground and are reluctant to cross canopy gaps. Consequently, roads, railways, and other linear infrastructure can isolate populations even when forest cover remains largely intact (Cheyne *et al*. 2013; Asencio *et al.* 2021; Saralamba *et al*. 2022). As strict arboreal frugivores, they are also highly sensitive to changes in forest structure and tree species composition (Caldecott 1980; Light *et al*. 2021, Hankinson *et al*. 2021; O'Brien *et al*. 2024).

Hunting, trade, and trafficking represent additional and increasingly severe threats to *Hylobates* spp. and other gibbons (Brockelman and Geissmann 2020; Cheyne & Nijman 2020; Geissmann *et al.* 2020; Nijman *et al*. 2020). Malaysia has recently emerged as an important hub for international gibbon trafficking, and *Hylobates* spp. represent a substantial proportion of trafficked gibbons, exceeded only by *Symphalangus syndactylus* (TRAFFIC 2025; Pinto-Rodrigues 2026; Rao 2026). Many trafficked gibbons are wild-caught infants obtained by killing their mothers, making trade particularly damaging to already declining populations (Cheyne 2025).

Conservation measures

All Malaysian *Hylobates* spp. are listed on CITES Appendix I and currently classified as Endangered on the IUCN Red List (Brockelman and Geissmann 2020; Cheyne *et al.* 2020a; Geissmann *et al.* 2020; Nijman *et al*. 2020a). All species also receive legal protection throughout their Malaysian range. All *Hylobates* species are Totally Protected in Peninsular Malaysia (Laws of Malaysia 2010). *Hylobates abbotti* and *H. funereus* are also Totally Protected in Sarawak (as *H. muelleri*; Laws of Sarawak 1998) and Protected (as *H. muelleri*, State of Sabah 1997) in Sabah. Conservation efforts for all species should prioritise the protection of remaining lowland forests, maintenance of canopy connectivity between habitat fragments, and the incorporation of wildlife crossings into infrastructure development. For *H. agilis* and *H. lar*, improved population monitoring and continued protection of key strongholds such as Ulu Muda, Belum-Temenggor, Endau-Rompin, Kenyir, and Taman Negara landscapes are vital.

Malaysia is unique among gibbon range countries in having several urban landscapes (e.g., Kluang, Kuala Lumpur, Kuantan, Taiping) with small forest fragments that continue to support gibbons. Engagement of local communities, close monitoring of small and isolated populations, and enhancement of forest quality and connectivity are crucially important for the persistence of these populations and represent an opportunity for positive

community engagement. For the poorly known *H. abbotti* and *H. funereus*, comprehensive surveys are required to clarify distributions, population sizes, and conservation status. Across all species, public awareness campaigns against pet-keeping and stronger enforcement against illegal trade, improved transboundary cooperation with Indonesia and Thailand, and long-term ecological monitoring are essential to secure viable populations in Malaysia.

3. *Macaca*

Distribution

Three macaque species occur in Malaysia: *Macaca arctoides*, *M. fascicularis*, and *M. nemestrina*. Within Malaysia, *M. arctoides* is restricted to a small area in Wang Kelian, Perlis, along the border with Thailand, whereas *M. fascicularis* and *M. nemestrina* are widely distributed throughout Peninsular Malaysia and Borneo, although their occurrence may be patchy in some regions. Beyond Malaysia, *M. arctoides* is distributed across South and Southeast Asia, including parts of Cambodia, China, India, Laos, Myanmar, Thailand, and Viet Nam (Chetry *et al*. 2020). *Macaca fascicularis* has one of the broadest distributions of any Southeast Asian primate extant in Brunei, Cambodia, India (Nicobar Island); Indonesia; Lao People's Democratic Republic; Malaysia; Myanmar; Philippines, Singapore, Thailand; Timor-Leste and Viet Nam but recently extinct from Bangladesh (Hansen *et al.* 2025). *Macaca nemestrina* occurs throughout Sumatra, Peninsular Malaysia, and Borneo (Ruppert *et al.* 2022).

Population

Population information for Malaysian macaques remains limited. The only recent estimate for *Macaca arctoides* reported 11 – 176 individuals in Perlis State Park between 2018 and 2019 (Syamil *et al.* 2019), highlighting the species' rarity in Malaysia. For *M. fascicularis*, available evidence suggests a sharply declining trend despite its continued widespread occurrence. Karuppanam *et al.* (2014) estimated 127,050 individuals in Peninsular Malaysia in 2011, whereas Koch Liston *et al*. (2024) estimated 119,499 individuals for the whole of Malaysia in 2024, suggesting a severe reduction. This pattern is consistent with broader regional declines and the estimated 50% reduction across the species' range over the last three generations (Hansen *et al*. 2025). Locally high densities associated with human food provisioning, urban environments, and tourist sites represent exceptions rather than overall population trends (Koch Liston *et al*. 2024). No nationwide population estimates are available for *M. nemestrina*, but declining habitat occupancy and increasing local extinction risk have been documented in disturbed forests, indicating that populations are likely decreasing and becoming increasingly fragmented (Holzner *et al*. 2021).

Habitat and ecology

Malaysian macaques occupy a broad range of habitats, including lowland, hill, and montane forests, mangroves, peat swamps, coastal habitats, and human-modified environments. However, the three species differ markedly in their ecology and adaptability. *Macaca arctoides* is the most forest-dependent species and spends much of its time on the ground, foraging for fruits, seeds, flowers, roots, shoots, and other forest resources. It typically inhabits dense evergreen and semi-evergreen forests, requires extensive home ranges, and depends on suitable forest structure for sleeping sites and daily movements, making it particularly vulnerable to habitat fragmentation (Chetry *et al.* 2020). In Perlis, it is found using oil palm plantations and limestone hills near primary forest (Syamil *et al.* 2019). *Macaca fascicularis* is adaptable, opportunistic, and highly synanthropic. It occupies a wide variety of natural habitats, including mangroves, riverine forests, swamp forests, and lowland forests, but is equally successful in human-dominated environments such as agricultural landscapes, roadsides, temples, parks, villages, and cities (Fooden 1995; Hansen *et al.* 2025). Human-modified habitats form an important component of the species' ecological niche. In contrast, Macaca nemestrina is primarily associated with lowland and hill dipterocarp forests but increasingly exploits agricultural landscapes, particularly oil palm plantations.

Individuals may forage hundreds of metres into plantations while relying on adjacent forest for resting and sleeping (Ruppert *et al*. 2018). This species can provide ecosystem services by reducing rodent pests in plantations (Holzner *et al*. 2019), but altered activity budgets, elevated infant mortality, and dependence on intact forest indicate that agricultural habitats alone cannot sustain viable populations over the long term (Holzner *et al*. 2024).

Threats to survival

Habitat loss, degradation, and fragmentation are the principal threats facing all Malaysian macaques. Due to its highly restricted distribution in Malaysia, *M. arctoides* is especially vulnerable to local extinction from habitat disturbance, infrastructure development, road mortality, and hunting, even at relatively low levels (Chetry *et al*. 2020). Its predominantly terrestrial behaviour further increases its susceptibility to human-related threats. Although often perceived as common, *M. fascicularis* faces substantial conservation pressures. Widespread deforestation, mangrove loss, and urban expansion continue to reduce suitable habitat and increase contact with humans. Human–wildlife conflict is a major issue, frequently resulting in translocations or culling; nearly 494,000 individuals were reportedly culled in Malaysia between 2011 and 2018 (Koch Liston *et al*. 2024).

Additional threats include illegal pet ownership and capture for the trade. Across its range, the species is heavily exploited for biomedical research, with legal and illegal trade contributing to continued removals from wild populations (Hansen *et al*. 2025). For *M. nemestrina*, the expansion of oil palm plantations represents the most significant threat. Large-scale conversion of lowland forests has reduced habitat availability, increased fragmentation, and exposed macaques to agrochemicals and other anthropogenic disturbances. Although the species can utilise plantation landscapes, declining occupancy in disturbed forests and high infant mortality rates suggest that these environments function as suboptimal habitats (Holzner *et al.* 2021, 2024). Human–wildlife conflict, illegal trade, and exploitation for trade further exacerbate population declines.

Conservation measures

All three macaque species are legally protected in Malaysia and benefit from the protection afforded by national parks, wildlife reserves, and other protected areas. The only known Malaysian population of *M. arctoides* occurs within Perlis State Park and adjacent forest reserves, which are connected to the larger Thale Ban National Park in Thailand, making transboundary habitat protection particularly important for the species' persistence in Malaysia (Chetry *et al*. 2020). Continued monitoring and targeted conservation measures are needed to assess population trends and mitigate the impacts of habitat loss and hunting. For *M. fascicularis*, conservation efforts should focus on improving coexistence between humans and macaques. Although local initiatives led by Langur Project Penang and Animal Neighbours Project (see www.primatesmalaysia.org) have demonstrated successful approaches to conflict mitigation through education and community engagement, such programmes remain geographically limited. A nationwide monitoring programme, stronger enforcement against illegal trade and pet ownership, and science-based management strategies are needed to replace reactive culling approaches and ensure long-term population viability.

Conservation of *M. nemestrina* depends largely on maintaining substantial areas of connected forest within agricultural landscapes. Protecting forest fragments, retaining ecological corridors, reducing the use of harmful pesticides, and promoting wildlife-friendly plantation management would benefit the species while maintaining its ecological role as a natural pest controller (Holzner *et al.* 2019). More broadly, comprehensive surveys, long-term monitoring, and research on distribution, abundance, ecology, and threats remain priorities for all three Malaysian macaque species and are essential for evidence-based conservation planning and management.

4. *Nasalis*

Distribution

Nasalis larvatus is the only species in this genus and endemic to Borneo. It occurs in Brunei, Kalimantan, Sabah and Sarawak. Historically, it occupied the entire coastal region of Borneo and was also present on the nearby islands of Berhala, Sebatik, and Pulau Laut (Groves 2001; Boonratana *et al*. 2021).

Population

In Sarawak, fewer than 1,000 individuals remain, scattered across habitat fragments. In Sabah, sizeable populations persist only in the Kinabatangan floodplain and around Dewhurst Bay in the Eastern Deltas, while Brunei maintains a single estuarine population. The species is more numerous in Kalimantan, where population sizes vary widely from >1,000 to <100 individuals depending on local pressures (Meijaard and Nijman 2000), although some formerly large populations, such as those in Pulau Kaget and the Mahakam Delta, have been lost due to habitat conversion, including extensive coastal swamp clearance for shrimp farming (Boonratana *et al*. 2021).

Habitat and ecology

This species is closely tied to riparian and coastal lowland habitats, including mangroves, peat swamps, and freshwater swamp forests, and seldom ranges far from waterways, likely due to mineral-rich diets unavailable in inland soils (Bennett and Sebastian 1988; Boonratana 2000; Meijaard and Nijman 2000). It occurs at low elevations (≤350 m asl) and is primarily folivorous and frugivorous, with seasonal shifts in diet, regularly swimming across major rivers and maintaining home ranges of over 200 ha (Yeager 1989; Boonratana 2000). Although it avoids heavily deforested or agricultural areas, it can persist in secondary forests where hunting pressure is low (Salter and MacKenzie 1985).

Threats to survival

This species is declining primarily due to the large-scale loss of its riverine and coastal habitats, which are heavily targeted for logging, agriculture, settlement, and infrastructure development. These activities remove mangroves, clear riverbanks, and intensify the impact of forest fires, such as the extensive 1997–1998 burns in Borneo (Boonratana *et al.* 2021). Because it is slow-moving and easily approached, it is highly vulnerable to hunting for meat and bezoar stones, leading to rapid local extirpations. Although hunting pressure has historically been strongest in the Bornean interior, it is increasingly affecting coastal populations as well (Meijaard and Nijman 2000).

Conservation measures

This species is legally protected across its entire range and listed under CITES Appendix I, yet conservation effectiveness is often limited by inadequate funding, weak enforcement, and insufficient management capacity (Meijaard and Nijman 2000). It is currently known from 16 protected areas across Indonesia and Malaysia, including sites such as Bako National Park, Kabili-Sepilok Forest Reserve, and the Lower Kinabatangan Wildlife Sanctuary, though it has already been lost from areas like Pulau Kaget Nature Reserve. The species is rarely kept in captivity outside Asia due to its highly specialised folivorous diet, which makes long-term maintenance difficult (Boonratana *et al.* 2021).

5. *Nycticebus*

Distribution

Malaysia is home to four species of slow lorises: *Nycticebus bengalensis* and *N. coucang* in Peninsular Malaysia, and *N. kayan* and *N. menagensis* in Malaysian Borneo. *Nycticebus bengalensis* possesses the genus's largest geographic range, occurring from northeastern India and southern China throughout mainland Southeast Asia (Brandon-Jones *et al*. 2004). Within Peninsular Malaysia, its presence has been confirmed by molecular evidence from

from Langkawi Island, and populations may also occur in the forest remnants of northern Perlis (Md-Zain *et al.* 2019). *Nycticebus coucang* is distributed throughout Peninsular Malaysia and extends into neighbouring Sumatra, Singapore, and Thailand (Nekaris *et al.* 2020b). Its subspecies, *N. c. insularis*, persists on Malaysia's Tioman Island (Rovie-Ryan *et al.* 2018; Md Fauzi *et al.* 2021). *Nycticebus kayan* occurs throughout central and northern Borneo, including both Sabah and Sarawak. Its range extends to the northernmost coast of Sabah, with its southern limits defined by the Rajang River in Sarawak and the Mahakam River in East Kalimantan in Indonesia (Munds *et al.* 2013b, Nekaris and Miard 2020). *Nycticebus menagensis* has a broader distribution, occurring in the coastal regions of northern and eastern Borneo within Sabah and Sarawak, where its range partially overlaps with that of *N. kayan* (Nekaris *et al*. 2020a).

Population

Nycticebus bengalensis in Malaysia has only been confirmed through molecular analyses, and population information is not available (Nekaris *et al*. 2020c). *Nycticebus coucang* exhibits variable densities across Peninsular Malaysia. Short-term surveys recorded low densities, such as 0.01 – 0.02 individuals/km^2 at Pasoh Forestry Research Centre (Negeri Sembilan) and 0.4 ind./km^2 in Petaling Jaya (Selangor) (Nekaris *et al.* 2020b). Similarly, a longer-term, two-year study on island populations recorded low encounter rates of 0.12 and 0.29 ind./km^2 on Penang and Langkawi islands, respectively (Miard *et al.* 2024). However, other longer-term mainland studies have found higher densities: Nekaris *et al.* (2020b) found 0.3 – 0.8 ind./km^2 in logged forests and 0.5 – 1.2 ind./km^2 in unlogged primary forests in Sungai Tekam Forestry Concession (Pahang), 1.6 – 4.0 ind./km^2 in primary forests and 0.4 – 1.0 ind./km^2 in logged swamp and secondary savanna in Segari, Manjung District (Perak). An earlier report estimated a density of 20 – 80 ind./km^2 of slow lorises in Peninsular Malaysia (Wiens 2002). *Nycticebus menagensis* is widespread in Borneo, with 0.12 ind./km^2 observed at Danau Girang (Munds *et al.* 2013). *Nycticebus kayan* lacks published wild population data (Nekaris and Miard 2020).

Habitat and ecology

Slow lorises exhibit significant ecological flexibility, inhabiting environments from pristine montane forests to disturbed lowlands and agricultural landscapes (Munds *et al.* 2013; Nekaris *et al.* 2020a, 2020b). *Nycticebus coucang* occupies various forest types, including dipterocarp, swamp, and logged primary forests (Nekaris *et al.* 2020b). Its omnivorous diet encompasses plant exudates, nectar, fruits, and insects (Wiens 2002; Md Fauzi *et al*. 2021). *Nycticebus menagensis* primarily consumes sap, insects, and small vertebrates, supplementing with fruit. All species display characteristically slow, deliberate locomotion and are incapable of jumping (Phillipps and Phillipps 2018; Md Fauzi *et al*. 2021). A defining characteristic of slow lorises is that they are one of few venomous mammals, and one of only two genera of venomous primates (Nekaris *et al.* 2013) with the pygmy lorises, *Xanthonycticebus*.

Threats to survival

Slow lorises face critical threats from widespread habitat loss and illegal trade. They are poached for traditional medicine, fuelled by superstitious beliefs in their healing properties, and captured for the pet market (Miard *et al.* 2017). The subsequent unauthorised release of former pets introduces additional risks to wild populations. These combined pressures have caused substantial population declines throughout their range (Md-Zain *et al.* 2019, Nekaris and Miard 2020).

Conservation measures

All slow loris species are listed on the IUCN Red List, with *N. coucang* and *N. bengalensis* classified as Endangered and the *N. kayan* and *N. menagensis* as Vulnerable. They receive the highest level of international protection under CITES Appendix I, which prohibits commercial trade. Domestically in Malaysia, they are protected by federal and state-level legislation, which prohibits capture or possession without a permit.

6. *Pongo*

Pongo pygmaeus research and conservation aspects are reviewed in detail in another chapter of this volume.

Distribution

Pongo pygmaeus is confined to the island of Borneo, occurring in Sabah and Sarawak as well as across North, East, Central, and West Kalimantan in Indonesia (Ancrenaz *et al.* 2024). Its distribution is highly fragmented, with the species rare or absent in parts of southeastern Borneo and the region between the Rejang and Padas rivers, including Brunei. Although it is primarily a lowland forest species below 500 m asl, it can range to elevations of about 1,500 m, and its dispersal is strongly constrained by large rivers, which act as barriers to gene flow and population connectivity (Goossens *et al.* 2005).

Population

Climatic change and human pressures have drastically reduced the range and abundance of *P. pygmaeus*. In Malaysia, Sabah supports the only comprehensively surveyed population, with aerial nest surveys estimating approximately 11,000 individuals (Ancrenaz *et al*. 2005). Across Borneo, population modelling suggests that orangutan numbers declined from approximately 288,500 individuals in 1973 to 104,700 in 2010, with further declines projected under continuing habitat loss and unsustainable mortality (Wich *et al.* 2012). Although much of the modelling data originated from Kalimantan, the widespread impacts of deforestation, habitat fragmentation, and killing across Borneo indicate that Malaysian populations are subject to the same regional pressures (Ancrenaz *et al.* 2024).

Habitat and ecology

Pongo pygmaeus is largely arboreal but also travels considerable distances on the ground, historically thriving in diverse lowland dipterocarp forest mosaics that buffered seasonal food shortages, with a diet dominated by fruit but supplemented by leaves, bark, flowers, and insects. They are semi-solitary, with males dispersing to establish large territories and females occupying smaller ranges shaped by forest type and food availability. Their extremely slow reproductive rate of only one infant every 6 to 8 years and late female maturity make populations highly vulnerable to any additional mortality or habitat loss (Ancrenaz *et al.* 2024).

Threats to survival

In Sabah and Sarawak, *P. pygmaeus* faces the same major threats driving declines across Borneo, with rapid deforestation, large-scale forest conversion, and recurrent fires reducing and fragmenting the remaining habitat available to their already patchily distributed populations. Although illegal killing is best documented in Kalimantan, the species' extremely slow reproduction means that any comparable mortality in Malaysian Borneo would quickly undermine population viability, especially in smaller, isolated subpopulations. Climate-change projections further indicate substantial future habitat loss, underscoring the urgency of protecting and managing the remaining strongholds in eastern and northeastern Borneo, including those within Sabah and Sarawak (Ancrenaz *et al.* 2024).

Conservation measures

Pongo pygmaeus is fully protected in both Sabah and Sarawak, yet a substantial share of their habitat (around 20% of the range in Sabah) lies outside protected areas, highlighting the need for conservation strategies that extend beyond formal reserves. Long-term survival in Malaysia will depend on securing large, strictly protected forests where logging and hunting are effectively controlled and where populations are large enough to withstand fires, disease, and climate-driven environmental change. To achieve this, Sabah and Sarawak must implement science-based, landscape-level land-use planning that maintains ecological connectivity and integrates sustainable forest management around core orangutan strongholds (Ancrenaz *et al*. 2024).

7. *Presbytis*

Only limited information is available for most Malaysian *Presbytis* species. The most comprehensive and up-to-date treatment of the genus is provided by the IUCN Asian Langurs (*Presbytis*) Conservation Action Plan 2024–2034, developed through transboundary collaboration among Malaysia, Indonesia, Thailand, and Brunei (Ang *et al.* 2024). The following summary is largely based on this action plan.

Distribution

Eight species of *Presbytis* occur in Malaysia, three in Peninsular Malaysia (*P. femoralis*, *P. robinsoni*, and *P. siamensis*) and five in Borneo (*P. chrysomelas*, *P. frontata*, *P. hosei*, *P. rubicunda*, and *P. sabana*). Most species exhibit largely allopatric distributions, often separated by major rivers or mountain ranges. *Presbytis femoralis* is restricted to southern Peninsular Malaysia, mainly Johor and southeastern Pahang, and Singapore. *Presbytis robinsoni* occurs in northwestern Peninsular Malaysia, southern Thailand, and southern Myanmar (Ang *et al*. 2021a), while *P. siamensis* has the widest distribution in Peninsular Malaysia, occupying forests between the Perak and Pahang Rivers and extending into southern Thailand and Sumatra (Ang *et al*. 2020b). In Borneo, *P. chrysomelas* has one of the most restricted ranges, occurring along the west coast of Sarawak and West Kalimantan, with two recognised subspecies (Nijman *et al*. 2020b). *Presbytis frontata* is patchily distributed in Sarawak and Kalimantan (Cheyne *et al*. 2020b), *P. hosei* occurs in Sabah, Sarawak, Brunei and Kalimantan, and *P. sabana* is largely confined to Sabah. *Presbytis rubicunda* has the broadest distribution among Bornean *Presbytis*, occurring throughout much of Borneo and on Karimata Island (Cheyne *et al.* 2020c).

Population

No systematic population censuses have been conducted for any Malaysian *Presbytis* species, except *P. femoralis*, and most historical density estimates are outdated due to extensive habitat loss (Ehler-Smith 2014; Hon 2021). All species are believed to be declining (Ang *et al*. 2024). *Presbytis femoralis* is the most threatened species in Peninsular Malaysia, with fewer than 250 mature individuals remaining across its range and isolated populations occurring mainly in fragmented forests in Johor and southeastern Pahang (Ang *et al*. 2022). *Presbytis robinsoni* and *P. siamensis* are considered Near Threatened, but recent information on their abundance is scarce (Ang and Traeholt 2020; Ang *et al*. 2021). In Borneo, *P. frontata*, *P. hosei*, *P. rubicunda*, and *P. sabana* all show declining populations, although reliable estimates are lacking. The current area of occupancy of *P. chrysomelas* is estimated to represent less than 5% of its historical range, and recent records in Sarawak have been extremely scarce (Ang *et al*. 2024). Most Malaysian *Presbytis* populations occur outside protected areas, with important protected strongholds including Royal Belum State Park, Greater Ulu Muda Forest Complex, Danum Valley Conservation Area, Tabin Wildlife Reserve, Gunung Mulu National Park, Usun Apau National Park, and the Kinabatangan landscape (Cheyne *et al.* 2015, 2020; Setiawan and Traeholt 2020; Nijman *et al*. 2021; Ang *et al* 2024).

Habitat and ecology

All *Presbytis* langurs are medium-sized, mostly arboreal colobines specialised for folivory. They possess a unique multi-chambered foregut with symbiotic microflora for fermenting leaves and seeds and molars with pronounced shearing crests for processing tough vegetation. Despite being commonly known as leaf monkeys, they also consume fruits, flowers, and fungi. Adults exhibit diverse colour patterns, whereas infants are generally born with pale grey or white pelage. Most species live in one-male, multi-female groups, although group size and composition vary among species. They inhabit a variety of lowland, hill, montane, riparian, peat swamp and secondary forests and may persist in fragmented landscapes, peri-urban parks, and agricultural mosaics, although long-term viability in such habitats is uncertain (Ang *et al*. 2024).

Threats to survival
Habitat loss, degradation, and fragmentation resulting from agricultural expansion, urbanisation, infrastructure development, and mining are the principal threats to Malaysian *Presbytis* langurs. Fragmentation isolates populations, reduces gene flow, and increases risks from road mortality and electrocution. Additional threats include hunting and poaching, particularly in Borneo where bezoar stones are commercially valuable, human–wildlife conflict, predation by dogs and raptors, and peat swamp fires associated with El Niño events. Small and isolated populations are particularly vulnerable to genetic erosion and local extinction. Notably, the Critically Endangered *P. chrysomelas* and *P. femoralis* are listed among the world's 25 most endangered primates (Ang *et al*. 2022, 2024; Zaini *et al*. 2024).

Conservation measures
Current conservation efforts focus on habitat protection, research, population monitoring, public awareness, and implementation of regional conservation strategies. Protection of key habitats in Royal Belum, Ulu Muda, Danum Valley, Tabin, Kinabatangan, and peat swamp forests remains essential. For *P. femoralis*, maintaining connectivity among fragmented populations and implementing genetic monitoring are priorities. Conservation of *P. chrysomelas* requires urgent research of its distribution and abundance, population monitoring, and protection and fire management in peat swamp forests. For *P. hosei*, *P. frontata*, *P. rubicunda*, and *P. sabana*, increased surveys and improved protection of forests outside protected areas are needed. Across all species, priorities include restoring habitat connectivity, reducing roadkills and electrocution through canopy bridges and wildlife-friendly infrastructure, strengthening anti-poaching enforcement, and expanding long-term ecological and genetic monitoring. Because most species occur across international borders, transboundary implementation of the Asian Langurs (*Presbytis*) Conservation Action Plan 2024–2034 will be essential to safeguard this shared Sundaic natural heritage (Ang *et al.* 2024).

8. *Symphalangus*
Distribution
Symphalangus is a monotypic genus, with a single species, *S. syndactylus*, that occurs in Peninsular Malaysia and Sumatra, with a very small population in southern Thailand near the border with Malaysia (Nongkaew *et al*. 2018). In Malaysia, *S. syndactylus* is distributed in forested areas in central Peninsular Malaysia in parts of Kelantan, Negeri Sembilan, Pahang, Perak, Selangor, and Terengganu. A recent genetic study based on mitochondrial DNA suggested Malaysian siamangs may represent a distinct subspecies from Sumatran siamangs (Sariyati *et al*. 2024).

Population
Symphalangus syndactylus densities in Malaysia vary across habitats, with very low densities (Mean = 0.18 groups/km^2), reported in lowland (<500 m a.s.l.) forests near their distribution boundaries in Taman Negara Pahang (Mohd Rameli 2021), but much higher densities (2.75 groups/km2) in two forest reserves in forests of similar elevation immediately east of Taman Negara (Kamaruzaman *et al.* 2023). Earlier studies in Malaysia reported densities ranging from <1 group/km^2 to 1.5 groups/km^2 in hill forests in the Titiwangsa Range (450 – 750 m a.s.l.; Chivers 1974). Current data are not adequate to evaluate population trends within specific locations, but substantial areas of forest cover have been lost across the siamang distribution range in Malaysia in the last three decades, which indicates that the population in Malaysia is declining.

Habitat and ecology
Symphalangus syndactylus and other gibbons are strictly arboreal and occur only in tropical semi-deciduous and evergreen forest, using all levels of the forest canopy (Nijman *et al*. 2020c). S. syndactylus can persist in degraded and secondary habitats but densities in degraded forests are lower (O'Brien *et al.* 2004; Nijman *et al.* 2020), and *S. syndactylus*

avoids badly degraded areas (Lappan *et al.* 2021). While siamangs occur in montane forests, surveys in lowland primary forests (<500 m asl) in Sumatra (Yanuar 2009) and Malaysia (Kamaruzaman *et al*. 2023) suggest that they may reach their highest densities in this habitat type. Siamangs in intact forests very rarely descend to the ground (S. Lappan, pers. obs.). However, in a few locations in Malaysia, *S. syndactylus* living adjacent to human settlements descend to the ground to cross gaps or in response to human provisioning. This behaviour has resulted in at least one siamang death due to roadkill (Mohan 2023).

Symphalangus syndactylus diets are composed primarily of plant parts, including leaves, ripe fruits, and flowers, occasionally supplemented with insects (Chivers 1974; Palombit 1997; Lappan 2009), Small groups, usually including an adult pair with dependent offspring, but occasionally including >2 adults (Lappan 2007, 2008), defend territories ranging in size from 15 ha to >50 ha (Nijman *et al.* 2020c) with very stable boundaries (Lappan *et al.* 2021), which may limit their ability to respond to habitat loss and disturbance. Wild siamangs have very slow life histories, with long interbirth intervals (2.5 – 4 years) and slow maturation. Lifespans of >30 years have been recorded in wild (Lappan *et al.* 2023) and captive (Weigl 2005) populations.

Threats to survival

Forest loss, degradation, and fragmentation have led to the loss of >40% of siamang habitat in Sumatra between 1985 and 2007 (Laumonier *et al.* 2010), and most remaining forests are fragmented. While quantitative estimates of siamang range loss in Malaysia are only approximate, forest loss, fragmentation, and degradation, especially in lower-elevation areas, are high, and pose major threats to this taxon (Nijman *et al.* 2020c). In some landscapes, siamangs have been observed crossing roads on the ground, being provisioned by forest visitors, or otherwise coming into close contact with humans (Lappan *et al*. 2020; Mohan 2023). Outbreaks of an unknown but lethal epizootic disease have been reported in two separate populations of this taxon (Lappan *et al.* 2017), making close human-siamang contact a particular concern because of the two-way potential for disease transmission.

In recent years, commercial pet trade has emerged as a distinct and major threat to *S. syndactylus*, and Malaysia has emerged as a central trafficking hub for this species (Serhadli 2025; TRAFFIC 2025; Pinto-Rodrigues 2026). Because of their slow development and long inter-birth intervals, *S. syndactylus* intrinsic population growth rates are very low (O'Brien *et al.* 2003), making systematic hunting of *S. syndactylus*, or any gibbon species, unsustainable. While most surrendered or confiscated gibbon between 2018 and 2025 were adults (TRAFFIC 2025), many individuals rescued or confiscated from trafficking enforcement are infants and small juveniles, which are thought to have been captured by killing the mother (Serhadli 2025). While little quantitative information is available about this trade from the supply side, evidence from confiscations indicates that the conditions of captivity are associated with high mortality, and every animal reaching the market likely reflects a substantially larger loss from the wild population from which they were sourced (Serhadli 2025). The source of animals trafficked through Malaysia in recent years is not known, but this trade clearly represents a major threat to wild populations, and if stronger protections are not put into place and demand remains high, Malaysian populations will remain vulnerable.

Conservation measures

Symphalangus syndactylus is Totally Protected in Peninsular Malaysia and Sarawak and Protected in Sabah. Because most of the species' mainland range occurs within Malaysia, the country has a crucial responsibility for conserving this globally Endangered species (Nijman *et al*. 2020c). Protection, restoration, and reconnection of suitable habitats are essential, particularly within the Central Forest Spine, including the Titiwangsa and Tahan Forest Ranges. Other priority areas include Krau, the southern Belum-Temengor landscape,

and Kledong Saiong. As siamangs are highly arboreal and reluctant to descend to the ground, habitat fragmentation exposes them to road mortality, dogs, electrocution, and unsafe interactions with humans. Consequently, habitat restoration and the installation of canopy bridges are particularly important in fragmented landscapes.

Communication, education, and public awareness (CEPA) programmes are also needed to discourage provisioning, capture, and demand for siamangs and all other primates as pets. Strict enforcement of laws against the killing, capture, keeping, and trafficking of *S. syndactylus* is essential. Transboundary collaboration with Indonesia, Thailand, and countries involved in the illegal trade, such as India (TRAFFIC 2025; Rodrigues 2026), should be strengthened to disrupt trade routes, improve enforcement, and facilitate repatriation of confiscated animals. Demand reduction campaigns for pet primates should also be expanded. Further research on the phylogeography of *S. syndactylus* across Malaysia, Indonesia, and Thailand is needed to identify source populations and guide forensic investigations and reintroductions. In parallel, Malaysia should strengthen its capacity for the rescue, rehabilitation, and reintroduction of confiscated gibbons, although prevention of trafficking should remain the primary conservation priority.

9. *Trachypithecus*

Distribution

Trachypithecus obscurus is distributed across southern Myanmar, southern Thailand, and Peninsular Malaysia, including several offshore islands. Peninsular Malaysia represents a major part of its global range and harbours multiple subspecies (Boonratana *et al.* 2020). The species occurs primarily in lowland forests but can also be found in hill and montane forests where suitable habitat persists. *Trachypithecus selangorensis*, formerly included within *T. cristatus*, was recently recognised as a distinct species (Roos *et al*. 2008, 2014). *Trachypithecus selangorensis* occurs only in Peninsular Malaysia, whereas *T. cristatus* occurs in Borneo and Sumatra (Meijaard and Nijman 2020). Within Malaysia, *T. cristatus* is found throughout coastal and lowland regions of Sabah and Sarawak, including several offshore islands. The species is particularly associated with riverine, mangrove, peat swamp, and other lowland forest habitats. *Trachypithecus selangorensis* is endemic to the west coast of Peninsular Malaysia, ranging from Kedah southwards through Perak, Selangor, Negeri Sembilan, Melaka, and Johor. It is primarily associated with coastal and lowland habitats, particularly mangrove and riparian forests (Ang *et al.* 2021b).

Population

All three species show declining population trends, largely driven by habitat loss and fragmentation. *Trachypithecus obscurus* is classified as Endangered on the IUCN Red List, with populations declining throughout its range (Boonratana *et al.* 2020). Although once considered relatively common in Peninsular Malaysia, habitat loss and fragmentation have resulted in local population declines and increasing isolation of groups. *Trachypithecus cristatus* is listed as Vulnerable (Meijaard and Nijman 2020). While comprehensive population estimates are lacking, evidence suggests substantial declines over recent decades due to habitat loss and hunting. Its populations remain locally common in some protected areas but are increasingly fragmented by logging and agricultural expansion. *Trachypithecus selangorensis* is currently classified as Near Threatened (Ang *et al.* 2021b); however, its narrow endemic range along the west coast of Peninsular Malaysia makes it a taxon of particular concern given pressures on its habitat. Although no range-wide population estimate exists, historical surveys indicate substantial declines, and many populations are now restricted to isolated habitat patches. The species remains locally abundant at a few protected and popular tourist sites, such as Kuala Selangor.

Habitat and ecology

All Malaysian *Trachypithecus* species are highly arboreal and predominantly folivorous colobines inhabiting primary and secondary forests, mangroves, coastal forests, and other wooded habitats. Their specialised foregut-fermenting digestive system allows efficient digestion of leaves, although fruits, flowers, seeds, and other plant parts also contribute to the diet. As folivores and seed dispersers, they play important roles in forest ecosystem functioning. Trachypithecus cristatus is strongly associated with mangrove forests, riverine forests, peat swamps, and lowland dipterocarp forests, although it can also occur in secondary and disturbed habitats (Meijaard and Nijman 2020). Studies of *T. obscurus* in Penang have demonstrated its ability to persist in fragmented and human-modified landscapes, utilising secondary forests, coastal vegetation, orchards, and urban-edge habitats (Yap *et al.* 2019). Nevertheless, the species remains dependent on forest cover and habitat connectivity. Trachypithecus selangorensis is most often found in mangrove, riparian, and coastal forests but may also occur in secondary forests and plantation landscapes where sufficient tree cover remains (Ang *et al.* 2021b).

Threats to survival

Habitat loss and fragmentation are the primary threats facing all Malaysian *Trachypithecus* species. Conversion of forests to oil palm plantations, agriculture, urban development, roads, and other infrastructure has reduced and fragmented suitable habitat throughout their ranges. For *T. cristatus*, extensive conversion of lowland forests, peat swamps, and mangroves in Borneo has resulted in increasingly isolated populations. Logging, infrastructure development, hunting, and opportunistic capture for the pet trade further threaten the species (Meijaard and Nijman 2020). In Peninsular Malaysia, *T. obscurus* faces additional threats from increasing urbanisation, which has led to road mortality, electrocution, and human–wildlife conflict (Yap *et al.* 2022). Hunting, poaching, and persecution as agricultural pests continue to affect some populations. Similarly, *T. selangorensis* is threatened by ongoing development of coastal habitats, including urban expansion, tourism infrastructure, and agricultural conversion. Additional threats include forest fires, hunting, road mortality, electrocution, and increasing human–wildlife conflict (Ang *et al.* 2021b).

Conservation measures

All three species are protected under Malaysian wildlife legislation and are listed in Appendix II of CITES. Conservation efforts focus on habitat protection, maintenance of forest connectivity, mitigation of human–wildlife conflict, and improved population monitoring. For *T. cristatus*, conservation priorities include the protection of remaining lowland, riverine, peat swamp, and mangrove forests in Sabah and Sarawak (Meijaard and Nijman 2020). Recent assessments have highlighted the need for greater research and monitoring to inform conservation planning. Conservation of *T. obscurus* includes habitat protection within national parks and forest reserves, as well as targeted initiatives such as the Langur Project Penang, which has implemented canopy bridges, public education programmes, and long-term monitoring to reduce anthropogenic threats (Yap *et al*. 2022; Langur Project Penang 2025). For *T. selangorensis*, priority actions include protecting and restoring mangrove and riparian habitats, maintaining connectivity among fragmented populations, and strengthening community-based conservation and public awareness programmes along the west coast of Peninsular Malaysia (Ang *et al.* 2021b).

DISCUSSION

Despite considerable advances in primate research over the past six decades, significant taxonomic, geographic, and thematic biases remain in Malaysian primatology. Research effort has focused disproportionately on a small number of species, particularly *Macaca fascicularis*, *M. nemestrina*, *Pongo pygmaeus*, and *Nasalis larvatus*, while many threatened

taxa, especially *Presbytis langurs*, Bornean gibbons, and nocturnal primates remain poorly studied. Most available studies have concentrated on phylogeny, distribution, abundance, and diseases, whereas long-term ecological, behavioural, demographic, and conservation -focused research remains scarce for many taxa. These knowledge gaps limit the development of evidence-based conservation strategies and hinder the evaluation of management interventions.

At the same time, the conservation status of Malaysian primates has deteriorated substantially. Habitat loss, degradation, and fragmentation remain the dominant threats across all primate taxa, driven by agricultural expansion, infrastructure development, logging, and urbanisation. Additional pressures include hunting, illegal wildlife trade, human–wildlife conflict, road mortality, electrocution, forest fires, and emerging threats associated with climate change and disease. The increasing proportion of Malaysian primates classified as Endangered or Critically Endangered highlights the urgent need to integrate research, conservation management, and policy implementation at both national and regional scales.

MOVING FORWARD: BRIEF POLICY RECOMMENDATIONS

- Strengthen protection of remaining primate habitats including secondary forests.
- Maintain and restore arboreal connectivity through landscape-scale conservation corridors.
- Integrate primate conservation into land-use, infrastructure, and agricultural planning.
- Expand and effectively manage protected areas, particularly in biodiversity hotspots.
- Establish a national primate monitoring programme with standardised survey protocols.
- Prioritise research on poorly known and highly threatened taxa.
- Increase investment in long-term ecological and behavioural primate studies.
- Strengthen enforcement against hunting, illegal wildlife trade, and pet ownership and implement communication, education, and public awareness (CEPA) activities to reduce demand for primates as pets.
- Promote science-based human–primate coexistence programmes and integrative management plans in high-risk areas.
- Reduce roadkill and electrocution through wildlife-friendly infrastructure.
- Encourage wildlife-friendly plantation and forestry management practices.
- Expand One Health monitoring at human–wildlife interfaces.
- Improve data sharing among government agencies, NGOs, and researchers.
- Support community-based conservation and local stakeholder engagement.
- Develop and implement species-specific conservation action plans for threatened taxa.
- Strengthen transboundary conservation initiatives with neighbouring countries.
- Incorporate climate change adaptation into primate conservation planning.
- Increase public awareness of the ecological and conservation importance of primates.

CONCLUSION

Malaysia harbours one of the richest primate assemblages in Southeast Asia, encompassing 26 taxa that represent an exceptional diversity of ecological, behavioural, and evolutionary adaptations. However, most species are now threatened with extinction, reflecting decades of habitat loss and increasing anthropogenic pressures. While scientific knowledge of Malaysian primates has expanded considerably since the early 1990s, major information gaps remain for many taxa, particularly those with the greatest conservation needs. Future conservation success will depend on strengthening the link between research and management, improving habitat protection and connectivity, and implementing coordinated,

evidence-based conservation actions. Ensuring the long-term persistence of Malaysia's primates will require sustained collaboration among researchers, government agencies, conservation organisations, local communities, and the private sector to safeguard this irreplaceable component of the nation's natural heritage.

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CHAPTER 14

Assessing the conservation status of the Bornean orangutan

JOSHUA PANDONG[1]*, DONNA SIMON[2],
ABANG ARABI BIN ABANG AIMRAN[3], SUNDAI SILANG[3],
LUKMANN HAQEEM ALEN[4], CYNTHIA CHIN[4], SYLVIA NG[1],
NUR NABILA SARKAWI[5], MARC ANCRENAZ[6] and MARK RAYAN DARMARAJ[1]

Abstract: Bornean orangutan (*Pongo pygmaeus*) represents one of Asia's most iconic and critically endangered great apes, with Sabah and Sarawak hosting vital populations that require integrated approaches to harmonise conservation with sustainable development. This paper attempts to provide a comprehensive review of the status of orangutans across both states based on published papers, field studies, and conservation initiatives to present an updated assessment of their distribution and population. Current published information suggests a minimum of 13,000 orangutans in Sabah and Sarawak, with 80 – 90% occurring within protected areas. This paper also outlines the conservation challenges and their underlying factors, including habitat conversion, illegal wildlife activities, and forest fires, among others. Case studies from key conservation sites including protected areas and community -managed areas illustrate both successful interventions and ongoing challenges. These examples demonstrate diverse approaches ranging from habitat protection and restoration to conflict mitigation and ecotourism development. Critical opportunities for enhanced conservation include enforcement capacity, landscape connectivity initiatives, local community partnerships, and integrated land-use planning and cross-sectoral and inter-state collaboration between Sabah and Sarawak. Building upon significant conservation efforts already undertaken by both state governments, sustained and coordinated action across governmental, private sector, non-governmental organizations, and local communities remain essential to ensure the long-term survival of the Bornean orangutan for future generations.

INTRODUCTION

Orangutans are one of Asia's most iconic great apes and are endemic to the islands of Borneo and Sumatra. Three distinct species are currently recognised: the Bornean orangutan (*Pongo pygmaeus*), Sumatran orangutan (*Pongo abelii*), and the more recently described Tapanuli orangutan (*Pongo tapanuliensis*) (Ancrenaz *et al*. 2024; Nowak *et al*. 2024; Singleton *et al*. 2024). Within Borneo, conservation geneticists further recognise three subspecies based on their geographical distribution: *P. p. morio* in northeastern Borneo including Sabah, *P. p. pygmaeus* in northwestern Borneo including Sarawak, and *P. p. wurmbii* in southwestern and central regions of the island (Utami-Atmoko *et al.* 2017; Simon *et al.* 2019; Santika *et al.* 2022). All three orangutan species are listed as Critically Endangered on the IUCN Red List of Threatened Species (Ancrenaz *et al.* 2024). As custodians of important orangutan populations in Sabah and Sarawak, Malaysia plays a vital role in securing the long-term survival of these great apes across their ranges.

[1] Wildlife Conservation Society (WCS) Malaysia, No. 7 Jalan Ridgeway, 93200 Kuching, Sarawak, Malaysia.
[2] World Wide Fund for Nature (WWF)-Malaysia (Sabah Office), Suite 1-6-W11 6th Floor, CPS Tower, Centre Point Complex No. 1, Lorong Centre Point, Pusat Bandar, 88000 Kota Kinabalu, Sabah, Malaysia.
[3] Sarawak Forestry Corporation (SFC), Wisma Lestari, Lot 218, KCLD, Jalan Tapang, Kota Sentosa, 93250 Kuching, Sarawak, Malaysia.
[4] World Wide Fund for Nature (WWF)-Malaysia (Sarawak Office), Bangunan Binamas, 7th Floor, Lot 138, Section 54, Jalan Padungan, Sarawak, 93100 Kuching, Sarawak, Malaysia.
[5] Sabah Wildlife Department, Sepilok Orangutan Rehabilitation Centre, Jalan, 14, Jalan Sepilok, 90009 Sandakan, Sabah, Malaysia.
[6] HUTAN, The Peak Vista, Block B, Lorong Puncak 1, Tanjung Lipat, 88400 Kota Kinabalu, Sabah, Malaysia.
***Corresponding author: jpandong@wcs.org**

DISTRIBUTION AND POPULATION

Across the two states, Sabah hosts a larger orangutan population distributed across both protected and non-protected areas, while Sarawak's smaller population is more concentrated in specific protected areas, particularly the Batang Ai-Lanjak-Entimau (BALE) Landscape.

Sabah

In the 1980s, a statewide orangutan population survey in Sabah revealed an estimated 9,800 to 21,000 individuals, with a major decline reported during the 1980s-1990s due to large -scale deforestation for cocoa and oil palm plantations (Payne 1988). Twenty years later, aerial surveys conducted in 2002 – 2003 estimated Sabah's total orangutan population at approximately 11,000 individuals, which showed a minimum of 35% population decline from earlier estimates. Subsequently, with the exhaustion of Sabah's timber combined with the slowing down of forest conversion for agriculture and improved forest practices in the next 15 years, the species has remained at about 10,300 orangutans. Surveys conducted between 2014 – 2017, which covered 63% of previously surveyed areas, confirmed this population estimate (Simon *et al.* 2019).

Given these recent numbers and the additional 1,159 orangutans from Ancrenaz *et al.* (2005), the population is considered stable at about 11,000 individuals. However, orangutan losses may be higher in state land or alienated land, as these statewide surveys have not assessed orangutan numbers in forests outside of forest reserves or state parks. With the expansion of protected areas driven by the Sabah Government's goal of securing 30% of its landmass as Totally Protected Area (TPAs) by 2025, about 80% of the orangutan populations in Sabah are now within protected areas.

Sarawak

Batang Ai National Park and Lanjak-Entimau Wildlife Sanctuary are home to 90% of the orangutans in Sarawak. Nest count surveys conducted between 2003 and 2007 at the core orangutan habitats of this Batang Ai-Lanjak-Entimau (BALE) Landscape provided an estimate of 1,984 orangutans with a 95% confidence interval of 1,175 to 2,582 individuals (Pandong *et al.* 2018). Subsequently, nest count surveys conducted at seven study sites outside of protected areas in Sarawak resulted in a combined estimate of 355 orangutans with a 95% highest density interval of 135 to 602 individuals (Pandong *et al.* 2018). One of the orangutan habitats located in an area outside of established protected areas is the Ulu Sungai Menyang Conservation Area. The orangutan population in this approximately 140 km^2 area was estimated at 167 individuals in 2025 (Ling 2025). Beyond the BALE Landscape, orangutans are also present in the Sedilu-Sebuyau-Lesong Landscape, situated about 130 km west of Lanjak–Entimau Wildlife Sanctuary. However, the population size and viability of this group is still uncertain (Ling 2023).

HABITAT ECOLOGY

Habitat types

Habitat requirements in Sabah and Sarawak both emphasise lowland dipterocarp and peat swamp forests with high canopy connectivity. Studies in Sabah by Davies *et al*. (2017) using light detection and ranging (LiDAR) and drone surveys reveal that orangutans preferentially move through areas with tall, closed canopies. However, this preference does not preclude their use of open or fragmented habitats, as growing evidence indicates that orangutans are more terrestrial than previously assumed and can persist in heavily degraded landscapes, including areas with discontinuous canopy cover and even oil palm plantations (Ancrenaz *et al.* 2014; Gregory *et al.* 2014).

In the multiple-use landscapes of Sabah, orangutan distribution correlates strongly with the presence of key food sources such as strangler figs, indicating that forest quality and resource availability shape ranging patterns (Milne *et al.* 2021). This finding is supported in sustainably managed logged forests in Deramakot and Tangkulap, where aerial nest surveys show that large populations persist in these forest reserves, while fragmented populations in eastern Sabah surrounded by oil palm have declined (Simon *et al.* 2019). These findings underscore the importance of continuous forest blocks for long-term viability. However, it is increasingly recognised that orangutans are highly adaptable and are actively learning to cope with intense forest degradation and fragmentation. Individual orangutans have been documented roaming and living in oil palm-dominated landscapes, representing a critical dimension of their contemporary ecology that conservation strategies must account for (Ancrenaz *et al.* 2014; Gregory *et al.* 2014). In Sarawak, wild populations are now largely confined to the BALE Landscape and smaller peat swamp fragments of the Sedilu-Sebuyau-Lesong Landscape (Tisen and Silang 2016).

Ranging patterns

Orangutan ranging behaviour reflects semi-solitary ecology, but they have shown to change this pattern when their habitat is disturbed. In intact forests, females maintain stable home ranges overlapping with males, while in fragmented habitats, individuals increasingly use small forest patches and even oil palm mosaics for movement, though such behaviour elevates mortality risk (Singleton *et al.* 2009; Seaman *et al.* 2025). Long-term monitoring in Deramakot shows density fluctuations linked to logging cycles, yet well managed forests can sustain orangutans if hunting is controlled (Simon *et al.* 2019). Overall, orangutans in Sabah and Sarawak have been observed to persist in selectively logged forests and mixed-use landscapes (Ancrenaz *et al.* 2010), provided structural canopy integrity and connectivity are maintained, and anthropogenic threats minimised (Davies *et al.* 2017; Pandong *et al.* 2019; Simon *et al.*2019).

THREATS TO SURVIVAL

Bornean orangutans in Sabah and Sarawak face mounting challenges to their survival due to ongoing habitat conversion, increasing illegal wildlife activities and forest fires, underscoring the urgency to address both current and emerging risks.

Habitat conversion

Sabah has had the highest deforestation rates in Borneo between 1973 – 2010, particularly for agriculture expansion and tree plantation development (Gaveau *et al.* 2014). In the 1980s, more than 50% of Sabah was logged, with reports of a few orangutans killed during tree felling and large numbers displaced to other undisturbed areas (Davies 1986). However, it was expected that larger numbers of orangutans declined during the vast agricultural expansion between the 1980s and 2000s (Ancrenaz *et al.* 2005). In the past 20 years (2002 – 2024), 12% of natural forests were lost and it was mainly caused by oil palm expansion. This land-use change has contributed to the fragmentation of orangutan habitats and is associated with estimated population reductions of up to 30% in some areas since 2001 (Voigt *et al.* 2018). At present, oil palm plantations cover about 20% of Sabah's landmass and forests account for 63.3% of Sabah's landmass, of which 26.4% is designated as TPA (Sabah JASPO 2025).

At present, approximately 6,000 km^2 of commercial forest reserves have been allocated for the establishment of industrial tree plantation (ITP) (Sabah Forestry Department 2022). About 2,000 km^2 were deemed unsuitable for planting, leaving 4,000 km^2 for development by 2036. As of 2022, about 1,600 km^2 have been planted. This initiative is helping to reduce logging pressure in the natural forests, but a substantial portion of the

planned ITP zones also overlap with known orangutan habitats. While orangutans have demonstrated resilience in tree plantation landscapes, it is not known whether the populations will be viable in the long run (Meijaard *et al.* 2010; Wiggs and Cunningham 2022). Another emerging threat to orangutan habitat in Sabah is large-scale mining exploration with concessions overlapping within TPAs. However, the impact of mining on orangutans there are currently not precisely known.

In Sarawak, land-use changes have primarily resulted from regulated logging activities, the establishment of industrial plantations such as oil palm and pulpwood, and associated infrastructure development (Pandong *et al.* 2019; C. Chin, pers. comm). These initiatives have led to the concentration of wild orangutans within the BALE Landscape and smaller peat swamp areas (Tisen and Silang 2016). While ongoing landscape fragmentation presents challenges to ecological connectivity, the Sarawak Government remains committed to implementing zero-loss policies and sustainable management practices to safeguard remaining habitats (Pandong *et al.* 2019; A. Aimran, pers. comm).

Illegal wildlife activities

Poaching and illegal trade continue to pose significant conservation challenges for orangutans in Malaysian Borneo, though comprehensive data remain limited. Research by Sherman *et al.* (2022) in Indonesian Borneo indicates that orangutan mortality from hunting may surpass the 1 – 2% annual threshold that jeopardizes population sustainability, while law enforcement rates are currently low, with only 0.9% of reported cases resulting in convictions.

In the 1980s, hunting of orangutans was reported in the west and south-west regions of Sabah, with some local communities engaging in this activity for subsistence, and for 'sport' killing using shotguns in incidences involving timber camp employees (Davies 1986). At present, strengthened legal protections, heightened public awareness, and limited expansion of oil palm plantations in recent years have contributed to a significant decline in orangutan killings. Nevertheless, continued vigilance is required, as unreported incidents may still occur and isolated cases of illegal pet keeping have been observed over the past decade (Simon 2022). In Sarawak, the gradual decline of traditional taboos against hunting orangutans has led to instances of opportunistic hunting, particularly in areas where law enforcement and community engagement require further strengthening (Pandong *et al.* 2019).

Forest fires

Fire risk is lower in Sabah and Sarawak compared to Kalimantan, but degraded forests in Sabah and peat swamp areas in Sarawak remain vulnerable during drought years. Reviews by Chew *et al.* 2022 on fire management in Malaysia highlight that episodic fires—often linked to land clearing—degrade habitat quality and exacerbate fragmentation, indirectly affecting wildlife survival by reducing food resources and forcing displacement. While large-scale fire events have not been as devastating in Malaysian Borneo as in Central Kalimantan, the growing incidence of fires and regional haze linked to human activities such as land clearing poses increasing long-term health risks to orangutans and other wildlife (Erb *et al.* 2018).

Other emerging threats

Human-wildlife conflict increasingly occurs as orangutans venture into agricultural areas, necessitating community-based mitigation strategies (Abas *et al.* 2025). Infrastructure development, including roads and mining activities, facilitates access to previously remote habitats (Santika *et al.* 2022). Forest fragmentation continues to isolate populations, reducing genetic diversity and compromising long-term viability (Bruford *et al.* 2010; Santika *et al.* 2017).

In addition, several emerging risks in anthropogenic landscapes also warrant urgent attention. Orangutans navigating human-dominated environments face heightened exposure to diseases, road kills, and conflict with domestic dogs and other animals, while the destruction of natural bridges above rivers through logging activities and the creation of artificial barriers such as drainage canals further impede movement and accelerate functional isolation (Lanjouw *et al.* 2024). Translocation, although widely practiced as a conservation intervention, has also been increasingly recognised as potentially deleterious to the long-term sustainability of wild populations, as released individuals may struggle to integrate into existing social structures and compete for limited resources (Sherman *et al.* 2025).

Addressing these interconnected and emerging threats through integrated conservation planning, enhanced enforcement, improved landscape connectivity, and broad stakeholder collaboration is essential to ensure the long-term survival of orangutans in both states.

CONSERVATION MEASURES TAKEN

Conservation efforts in Sabah and Sarawak have progressed to address the interwoven threats highlighted above through three key interventions: habitat protection, conflict mitigation and community partnerships, and habitat restoration for connectivity.

Habitat protection

Both states have expanded TPAs to safeguard orangutan habitats. In Sabah, Bukit Piton Forest Reserve exemplifies successful habitat protection and restoration. Once degraded, it was reclassified as a Class I Protection Forest in 2012 and rehabilitated through partnerships between the Sabah Government, the private sector, and non-governmental organisations (Mansourian *et al.* 2020). Today, it supports nearly 400 orangutans, with ongoing monitoring via aerial nest surveys to ensure long-term viability (Fong 2024). The Sarawak Government has set aside over 2,340 km^2, including Lanjak-Entimau Wildlife Sanctuary and Batang Ai National Park, which together support 90% of the state's estimated 2,000 wild orangutans (Pandong *et al.* 2019). Patrol efforts under the United Nations Development Programme and Global Environment Facility (UNDP-GEF)'s Global Wildlife Programme Malaysia have strengthened boundary security and law enforcement particularly at the Sedilu -Sebuyau-Lesong Landscape (Aubrey 2025), complemented by community-inclusive strategies such as the recruitment of local community members and army veterans as Wildlife Guardian Rangers (DayakDaily 2024).

Conflict mitigation and local community partnerships

Practical solutions in both states emphasise co-existence and livelihood diversification. In Sabah's Kinabatangan floodplain, HUTAN has pioneered community-based wildlife wardens and conflict mitigation squads, alongside ecotourism ventures that provide economic benefits to participating communities (Sinajin 2019). As orangutans are increasingly encountered in oil palm plantations and local orchards, occasional conflicts with landowners do arise. However, research by Ancrenaz *et al.* (2025) shows that the actual damage to oil palms was often minimal. Despite this, negative perceptions toward orangutans persist among some landowners, which can fuel intolerance and lead to retaliatory actions, including increased killing. Addressing these perceptions through community engagement, mitigating human-orangutan interactions, and demonstrating the economic value of co-existence is critical for fostering sustainable solutions that benefit both people and orangutans.

In Sarawak, the Ulu Sungai Menyang Conservation Area showcases inclusive conservation, where indigenous communities participate in monitoring and habitat management. These partnerships have stabilised local populations and fostered stewardship, demonstrating that integrating traditional knowledge with scientific monitoring can yield measurable outcomes (Ling 2025).

Habitat restoration and landscape connectivity
Restoration initiatives target fragmented landscapes to reconnect orangutan habitats. In Sabah, the Bukit Piton project restored 24 km^2 of degraded forest, creating corridors that enable orangutan movement and reduce isolation (Mansourian *et al.* 2020). Similar efforts in Mount Wullersdorf-Ulu Kalumpang Forest Reserves have earned global recognition for applying best practices in ecological connectivity (Lee 2025).

In Sarawak, as development in the form of road infrastructure grows deeper through previously inaccessible forests, establishing ecological connectivity for orangutan habitat becomes critical. One such potential area is a 3.89 km^2 corridor linking Gunung-Lesong and Ulu Sebuyau National Parks. Community conservation, co-management and community-led initiatives would be ideal but needs to be coordinated and executed well so that all stakeholders are on a level playing field (C. Chin, pers. comm).

FURTHER ACTION NEEDED

Enhancing law enforcement initiatives and spatial planning
Strengthening enforcement requires targeted investment in inter-agency coordination, ranger capacity, and surveillance technology using the Spatial Monitoring And Reporting Tool (SMART) approach (Pandong *et al.* 2019). Research highlights that low conviction rates for wildlife crimes undermine deterrence, so resources should focus on improving investigative capacity and judicial follow-through (DayakDaily 2025). Both states have recommended the integration of habitat connectivity into spatial planning by using ecological modelling to identify priority corridors linking TPAs. Embedding these measures into state development plans ensures long-term protection beyond project-based interventions.

Cross-sectoral coordinated actions
Orangutan conservation is a collective effort and the stakeholders involved span beyond forestry and wildlife agencies (Morgans *et al.* 2019). Sabah's experience with the Bagahak Ecological Corridor restoration that was achieved through partnerships between the Tabin Wildlife Reserve, NGOs, and private sector, demonstrates how corporate engagement can accelerate habitat recovery (Miwil 2023). Scaling such models requires formal frameworks for public-private partnerships and incentives for plantation companies to maintain riparian buffers and wildlife corridors. In Sarawak, community-led initiatives in the Ulu Sungai Menyang Conservation Area show how ecotourism and participatory monitoring can align livelihoods with conservation goals (Ling 2025).

Coordinated monitoring platforms and shared databases between agencies in Peninsular Malaysia, Sabah and Sarawak such as under the UNDP-GEF Global Wildlife Programme, would enhance the protection of iconic Malaysian wildlife species including Bornean orangutans by strengthening the capacity to prevent, combat and investigate inter-state wildlife crimes (Aubrey 2025; Zainal 2025). The way forward hinges on embedding orangutan conservation into enforceable policies, financing mechanisms, and cross-sector partnerships, while fostering community stewardship and inter-state collaboration to secure habitat connectivity and long-term population viability.

Promoting co-existence between people and orangutans
Securing the long-term future of orangutans in Sabah and Sarawak requires a fundamental shift in how agricultural and forest landscapes are planned and managed. Agricultural practices must be adapted to accommodate orangutan survival within productive landscapes, including through agroforestry to restore habitat connectivity and food resource availability (Meijaard *et al.* 2023). Priority should be given to retaining and restoring fragmented forest

patches, particularly those occupied by resident females whose home ranges anchor local population continuity (Ancrenaz *et al.* 2021). In addition, robust best management practice frameworks should be developed to guide industries operating in wildlife-inhabited areas, alongside proactive conflict mitigation strategies (Massingham *et al.* 2023a).

Moreover, long-term population monitoring and rigorous evaluation of conservation interventions must be embedded into state-level wildlife management plans to ensure evidence-based and adaptive decision-making (Ancrenaz *et al.* 2021). Crucially, conservation outcomes will only be sustained if local livelihoods are meaningfully improved. Expanding wildlife-based tourism and providing equitable economic incentives in orangutan-inhabited areas can transform local communities into active conservation stewards. Finally, underpinning all these efforts, promoting positive human wellbeing is recognised as a pragmatic and inclusive way forward to co-exist with one of the world's most iconic great apes (Massingham *et al.* 2023b).

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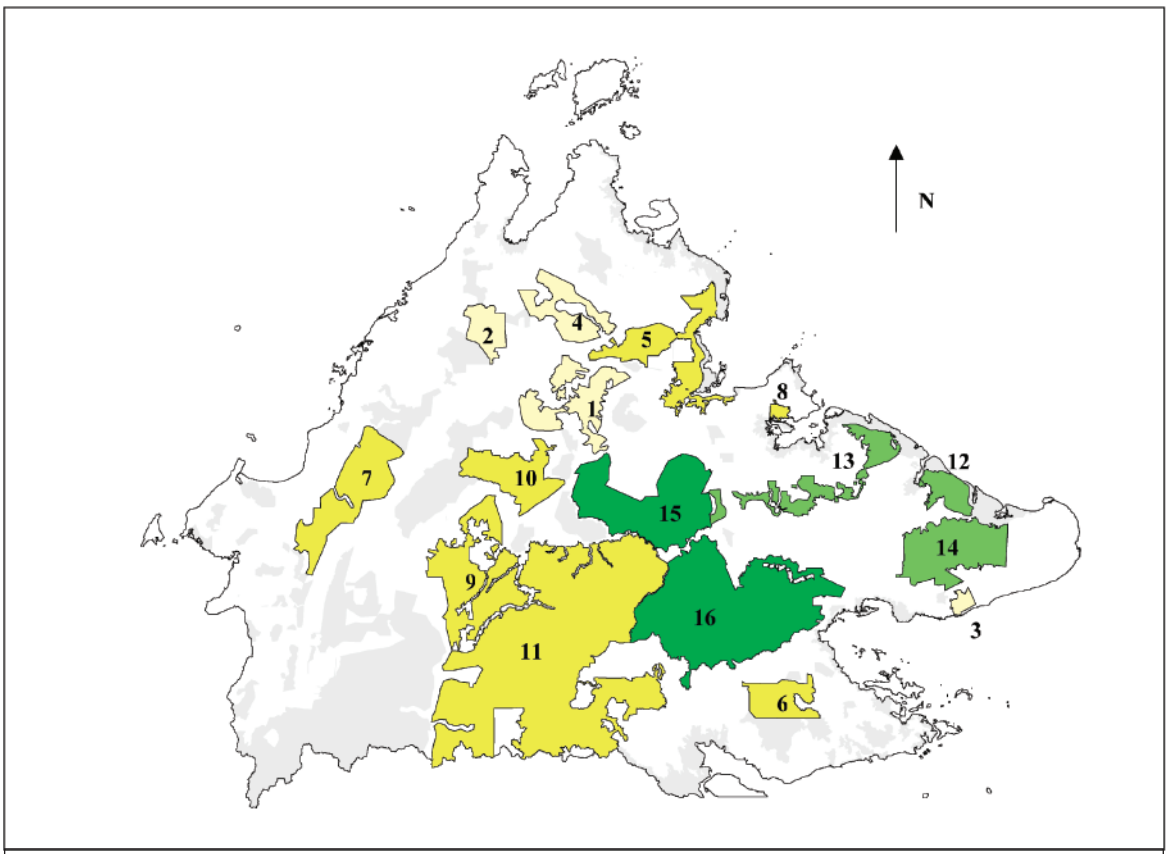
SUPPLEMENTARY MATERIALS

Appendix 1. Map of orangutan distribution and population groups in Sabah based on the 2002 - 2003 aerial survey by Ancrenaz *et al*. (2005).

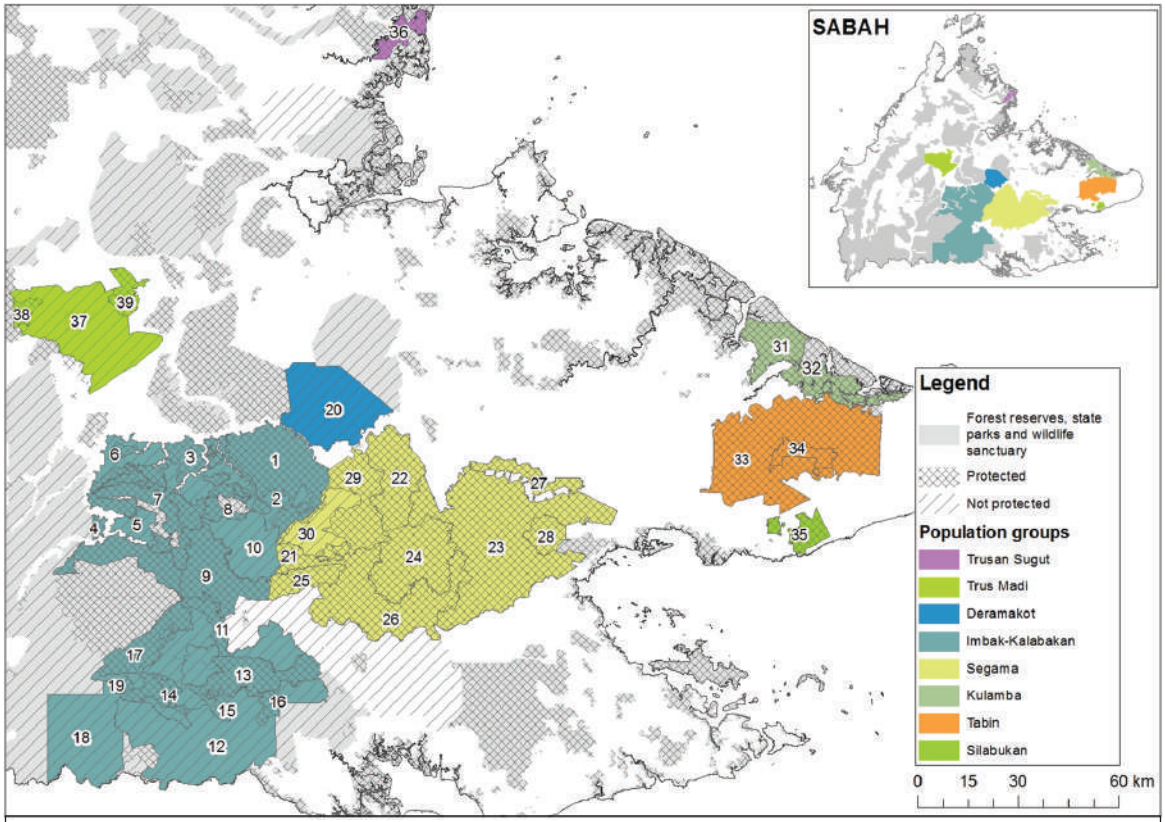


Population

1	Ulu Tungud	9	Pinangah
2	Mount Kinabalu	10	Trus Madi
3	Silabukan	11	Kuamut
4	Lingkabau	12	Kulamba
5	Bongaya	13	Kinabatangan
6	Ulu Kalumpang	14	Tabin
7	Crocker Range	15	Upper Kinabatangan
8	Sepilok	16	Segama

Forest areas without orangutans
<100 individuals
100 – 500 individuals
500 – 1500 individuals
>1500 individuals

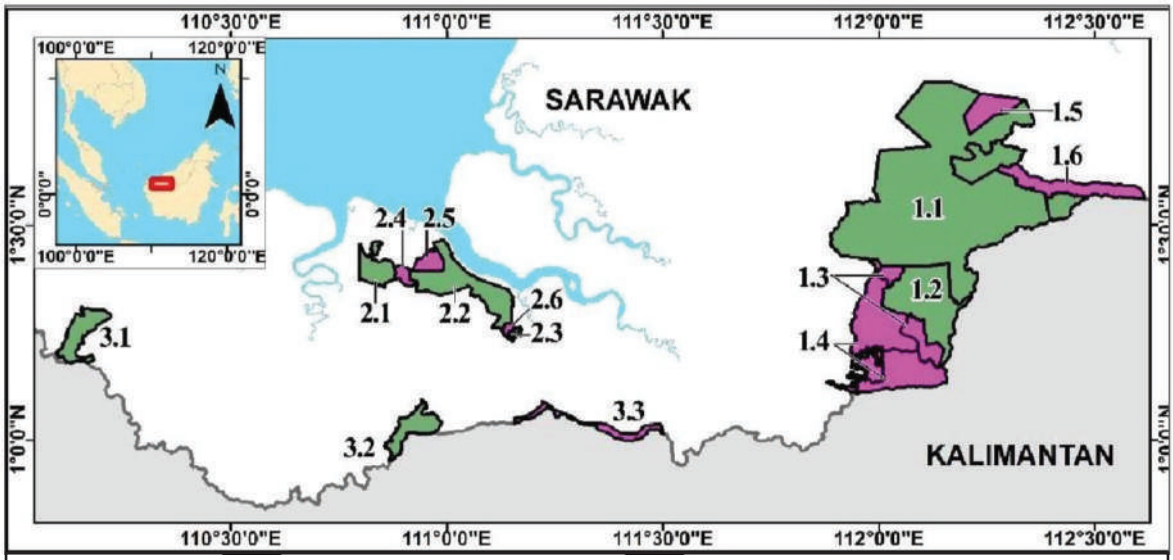
Appendix 2. Map of orangutan distribution and population groups in Sabah based on the 2014 - 2017 aerial survey by Simon *et al.* (2019).



Forest Reserve

1	Northern Kuamut (West)
2	Kuamut (West)
3	Sg Imbak Bufferzone
4	Sg Lulunguyon
5	Sg Pinangah
6	Sg Ayop
7	Imbak Canyon
8	Sg Imbak
9	Gunung Magdalena (West)
10	Gunung Rara
11	Gunung Rara Corridor
12	Kalabakan
13	Sg Tiagau and Ext
14	Tambulanan
15	Sg Anjeran Jemut
16	Sg Sumagas
17	Maliau Buffer
18	Sapulut
19	Nurod-Urod
20	Deramakot
21	Northern Gunung Bera
22	Malua
23	Ulu Segama
24	Danum Valley
25	Gunung Magdalena (East)
26	Gunung Louisa
27	Bukit Piton
28	Sg Taliwas
29	Northern Kuamut (East)
30	Kuamut (East)
31	Kulamba
32	Kuala Meruap
33	Tabin
34	Gunung Hatton
35	Silabukan
36	Trusan Sugut
37	Trus Madi
38	Nuluhon Trus Madi
39	Bukit Taviu

Appendix 3. Map of sites with conservation interest for orangutans in Sarawak as adapted from the study by Pandong *et al*. (2019).



Gazetted areas Areas proposed for protection

1. Core habitats	1.1	Lanjak-Entimau Wildlife Sanctuary (LEWS)
	1.2	Batang Ai National Park (BANP)
	1.3	Proposed BANP extensions
	1.4	Ulu sungai Menyang Conservation Area
	1.5	Proposed LEWS extension
	1.6	Ta Ann Group's Ulu Pasin Concession Area
2. Remnant sites	2.1	Sedilu National Park
	2.2	Ulu Sebuyau National Park
	2.3	Gunung Lesong National Park
	2.4	Proposed Ulu Sebuyau-Sedilu Corridor
	2.5	Proposed Ulu Sebuyau extension
	2.6	Proposed Ulu Sebuyau-Gunung Lesong connector
3. Historical ranges	3.1	Bungo Range National Park
	3.2	Sabal National Park
	3.3	Proposed Klingkang Range National Park

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CHAPTER 15

Large mammals – Malayan seladang and Bornean banteng

JOHN PAYNE[1]*, ABDUL HAMID AHMAD[2]
and ZAINAL ZAHARI ZAINUDDIN[1]

Abstract: Malaysia has two native wild cattle species that have a mixed grazing and browsing diet. Their post-Pleistocene distribution and survival are linked to grassland, a habitat now concentrated along roadsides and rare elsewhere as permanent agriculture has replaced swidden farming. Coupled with a long history of hunting, near-absence of grassland in remaining forests has led to a decline in both species to a few small, separate herds on a trajectory towards extinction. Interventions led by BORA (www.bringingbackourrareanimals.org) over the period 2019 – 2025 are described in this paper, with emphasis on creation of managed grasslands in Royal Belum State Park and Tabin Wildlife Reserve.

INTRODUCTION

Malaysia has three native species in the family Bovidae: Serow (*Capricornis sumatraensis*, not mentioned further in this paper), seladang or Malayan gaur (*Bos gaurus hubbackii*) and tembadau or Bornean banteng (*Bos javanicus lowii*). Seladang represents the southernmost race of the largest wild bovid on mainland Asia, while Bornean banteng represents one of three races of a formerly widespread species now with a disjunct distribution on mainland Asia, Java and Borneo. Both latter species have a mixed grazing and browsing diet. Neither species is well-known to the public, partly because they are extremely rare, but also because they are regarded as "just cattle".

After the Last Glacial Maximum (around 18,000 years ago), sea levels rose to cover the former savannah and woodlands that are now under the South China Sea. Charles Wharton (1968) demonstrated that, after around 11,000 years BP, human use of fire to burn forest and in more recent millennia to grow food crops — thereby evolving a swidden farming system with long fallows containing grasses — was key to sustaining habitats that allowed survival of wild bovids in Southeast Asia during the Holocene epoch.

Both species in Malaysia were widespread and locally common in the late 19th century. Sixty-four years ago, concern was expressed in the Malayan Nature Journal 21st Anniversary Special Issue over the status of both seladang (Kitchener 1961) and Bornean banteng (Burgess 1961). In 2025, the problem to be addressed is not that the estimated overall numbers of both species are in the very low hundreds of individuals. It is that no herd consists of more than about thirty individuals. The herds are isolated from each other and that absence of grassland is preventing recovery.

In the Malayan Nature Journal 81st Anniversary Special Issue 2021, Payne *et al.* (2021) described the status of both species in Malaysia, concluding that their extinction can be prevented only by creating managed grasslands within forests and through *ex-situ* (captive) breeding. The thinking behind feeding sites is simple: bovids require a large percentage of grasses in their diet; there is very little grass in places where the few remnant herds exist; without interventions, the already-low productivity of grasslands available to these bovids

[1] Borneo Rhino Alliance (BORA), c/o Faculty of Science and Technology, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia.
[2] Faculty of Sustainable Agriculture, Universiti Malaysia Sabah, 90509 Sandakan, Sabah, Malaysia.
***Corresponding author: sabahpayne@gmail.com**

will decline as woody vegetation tends to overtake grasslands in equatorial, high-rainfall areas. The thinking behind captive breeding is also simple: an enormous amount of information and experience exists on managing captive cattle, and captive breeding provides insurance against possible failure to maintain wild herds.

CONSERVATION STATUS

Malayan seladang in Royal Belum State Park, 2021-2025

Belum is now one of the few relatively accessible sites containing a remnant cluster of seladang. Initially, a programme conducted there over 2021 – 2023, co-led by Perak State Parks Corporation and BORA, and co-financed by the National Conservation Trust Fund, aimed to investigate relatedness of individuals using faecal DNA. However, more urgent concerns quickly became apparent.

Reports on seladang presence in camera trap images commonly fail to distinguish between bull seladang (which may wander many tens of kilometers from breeding herds) and herds, and between herds that consist only of adults and herds with calves. The latter are vital to prevent extinction. Camera trap images of seladang in Belum dating from 2007 to 2021 provided by PSPC and WWF-Malaysia were analysed by one of the authors (ZZZ) with the intention to assess changes in observed numbers, body condition, reproduction and demography.

Evidence was found of only two reproducing herds in Belum. One was along the upper reaches of the Perak river at about 20 individuals, while the other, even smaller, was around Tiang-Kuak. The number of female seladang in adjacent forest reserves (Amanjaya and Temenggor) is even fewer. Interviews with old residents of upper Perak indicated that most former seladang habitat is either now inhabited by humans or has been under water for the past 50 years when the Temenggor Dam was completed. The Belum camera trap images and records of footprints indicated that cow seladang reproduce only in areas, where there is grassland and natural concentrated mineral sources, which represent less than 0.5% of Belum's total area. Despite being within a totally protected area, seladang numbers had not increased in Belum over 15 years (2007 – 2022). Furthermore, population numbers are likely experiencing a gradual decline. The actual birth rate is significantly lower than the species' reproductive potential, while body condition in seladang varies through the year. There are probably more males than females, and weaning of calves appears to be slower than is normal for cattle. Lack of grass was identified as probably the main reason for these observations.

In parallel with the Belum field work, a detailed analysis of the captive seladang herd initiated since the mid-1980s at Jenderak Selatan, Pahang, revealed that the observed high mortality prior to adulthood and poor breeding performance in this herd is closely related to an unsound captive environment and poor management practices, with no evidence of genetic problems (Norsyamimi *et al.* 2023).

Despite initial concerns over planting grasses in a protected area, a decision was made by the authority to initiate expansion of grassland at one experimental riverside site within Belum commencing in September 2022. An old female seladang was shot dead next to the grassland on 3 August 2023. A post-mortem examination revealed that she had been wounded by shooting on at least two previous occasions. Clearly, both lack of grasslands and illegal hunting in Belum are both threats to the species there.

A two-day workshop was convened in September 2023 to present the results of the programme and obtain stakeholder feedback. Amongst the 44 participants, representatives from PERHILITAN, Forestry Department, Malaysian Army (which has a long-standing

camp near to the grassland) and several NGOs were present on both days. In early 2024, a report on the work was provided to the main project donor, along with 'A preliminary seladang conservation plan for Royal Belum State Park and adjacent areas' and a list of plants that had been identified during the work as seladang food plants in Belum, including 16 grasses and sedges, and 18 other plant species. In early 2024, three NGOs (BORA, The Habitat Foundation and WWF-Malaysia) wrote to the Minister of Natural Resources and Environmental Sustainability, proposing several seladang conservation initiatives. On 30 August 2024, the National Biodiversity Council agreed to recognise the seladang as an endangered species of national importance, to stabilise the seladang population, and that a seladang conservation management plan will be developed.

Bornean banteng in Tabin Wildlife Reserve, 2019–2025

The Bornean Banteng Action Plan for Sabah 2019 – 2028 (Sabah Wildlife Department 2018), currently under review, indicates fifteen separate locations supporting this species, with fewer than 400 individuals in total. Apart from one small cluster in the Sarawak and Brunei border area (Phillipps and Phillipps 2018), the Bornean banteng exists in a few scattered sites in some Kalimantan provinces (Dewi and Santoso 2020). There are no Bornean banteng in captivity.

Work was conducted by BORA from 2019 – 2025 within the western boundary of Tabin Wildlife Reserve, Sabah, to monitor by monthly examination of camera trap videos the response of a wild Bornean banteng herd to development and maintenance of a 5-hectare pasture with added mineral sources. The site was chosen because BORA has been based nearby since 2009. Prior to the 1960s, the entire region was covered in closed-canopy dipterocarp forest, with prime banteng habitat confined to the banks of the largest rivers in the region more than 5 km from the remnant herd. By 2018, the area where the residual banteng spent most of their time included a privately-owned grassland initiated around year 2000, an oil palm estate and an abandoned road (known as Tomanggong road) built and used from around 1972 to 1984 for log extraction from the surrounding forest. By 2018, most of the Tomanggong road had been reduced to a 1 – 2 meters wide pathway maintained by ungulates through thick secondary plant growth composed largely of native and invasive exotics forbs and shrubs. In 2019, BORA chose a 2.5 km stretch of the road for interventions aimed at improving banteng nutrition. Monitoring by BORA and WWF-Malaysia throughout Tabin Wildlife Reserve since 2021 indicates that the herd reported here is now the only remaining herd of banteng in the Reserve.

Starting in 2020, grasses on the road were manually cut to favour new growth while plant species rarely or never eaten by banteng were removed manually, monthly. Ten kilograms of multi-mineral blocks (containing Na, Ca, P, S, Fe, Mn, Mg, Zn, I, Co, K, Se and Cu) were put in place at five sites along the road, with replacement as necessary. Initial preparation of the 5 hectares (2.5 km × 20 m) took almost one year of effort. Monitoring was done using eight to twelve camera traps from October 2019 to present. Images and video clips have been analysed manually every month by ZZZ, and tabulated for body condition scores, health, behaviour, age, individual identification, reproduction, and distribution. Initially, the ages of banteng seen on camera traps were estimated based on daily records of weight and height of two Bali cattle (closely related to Bornean banteng), one male and one female that were hand-raised from a week after their birth by BORA staff from January 2020 to mid-2021 in the Faculty of Sustainable Agriculture, Universiti Malaysia Sabah. Subsequently, the known ages of Bornean banteng calves born during this study were used as a guide. Measuring stakes were installed in front of several camera traps to measure the shoulder height of individual banteng as an indicator of age and growth. It was assumed that, as with cattle and Malayan gaur (Norsyamimi *et al.* 2023), individual Bornean banteng cows can calve once a year in healthy condition.

All the observed favoured food plants were grasses, notably (in decreasing order of preference) carpet grass (*Axonopus compressus*), buffalo grass (*Paspalum conjugatum*), giant paspalum (*Paspalum urvillei*), itchgrass (*Rottboellia glandulosa*) and *Leptochloa panicea*. *Paspalum urvillei* and *R. glandulosa* had to be trimmed periodically before the culm became too tall for banteng to feed on them, but the other three species were grazed sufficiently by banteng and deer to retain a lower height. Weed removal proved to be the major consumer of time. Airborne and bird dispersed seeds of forbs, shrubs and woody plants frequently shower the Tomanggong road, and germinate rapidly, one of the worst being *Clidemia hirta*. The multi-mineral blocks proved to be a very significant attraction to the banteng. Actual usage by banteng is impossible to gauge, as the same blocks were licked by many other wild mammal species. Rainfall hastened loss.

It was found that a small number of videos provided far more information than any number of still images. Video imagery captured a greater proportion of a herd, the subtle differences between individuals that are usually unclear in still images could usually be seen, deciding on individual body condition was more accurate, and interactions could be seen between individuals, providing further clues on age, relatedness and dominance. We found that perineal markings were visible in about 30% of all individuals from as early as six months of age, with size, shape and configurations of the markings unique to each individual and not changing with time. Demography, births and overall herd size of the Tomanggong road banteng, as observed from camera trap videos and images, are summarised in Table 1.

Table 1. Demographic data of the Bornean banteng recorded along Tomanggong Road in Tabin Wildlife Reserve from 2019 to 2024, based on observations from camera trap images and videos.

Year	**2019**		**2020**		**2021**		**2022**		**2023**		**2024**	
Age Categories	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
Dominant bull	2	5	4	4	2	3	3	4	2	3	3	4
Adult bull	1	2	2	3	1	3	1	3	2	3	4	6
Heifer bull	2	3	3	4	1	5	2	3	4	5	5	5
Cow	5	6	5	6	6	7	6	6	8	8	10	10
Heifer	1	3	3	3	3	5	1	4	3	4	4	5
Calves	3	3	3	3	3	3	6	6	8	8	6	6
Total	14	22	20	23	16	26	19	26	27	31	32	36
Average	**18**		**21.5**		**21**		**22.5**		**29**		**34**	

CONCLUSIONS

The observed increase in calving percentage (number of calves born / number of 'exposed' females × 100) in the Tomanggong road banteng herd from 48% for years 2019 – 2021 to 86% for 2022 – 2024 suggests that the grassland and mineral block intervention has been beneficial. Recovery of seladang and Bornean banteng must involve creation and maintenance of more managed grasslands as well as anti-poaching effort. Captive breeding effort has stagnated and requires governmental leadership.

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CHAPTER 16

The conservation status of Malayan tapir (*Tapirus indicus*) in Peninsular Malaysia

DAVID MAGINTAN*, DONNY YAWAH, MOHD ADLI AHMAD, PAZIL ABDUL PATAH and ABDUL KADIR ABU HASHIM

Abstract: The Malayan tapir (*Tapirus indicus*), the only tapir species in Asia, is an iconic large mammal of Southeast Asian forests and an important indicator of ecosystem health. In Peninsular Malaysia, the species has experienced a substantial population decline over the past three decades and is currently classified as Endangered. This article reviews the conservation status of the Malayan tapir in Peninsular Malaysia by synthesising available information on population trends, habitat use, threats, governance frameworks, and conservation interventions. Current estimates suggest that only 700 – 800 individuals remain, primarily due to habitat loss and fragmentation driven by agricultural expansion, infrastructure development, and urbanisation. Additional threats include road mortality, human-tapir conflict, and incidental capture in illegal hunting activities. The review highlights the role of national legislation, international agreements, and policy instruments such as the Malayan Tapir Conservation Action Plan (2021–2030) in addressing these challenges. Ongoing conservation efforts encompass habitat connectivity initiatives, law enforcement, *ex-situ* management, research, and community engagement. Strengthening inter-agency coordination, improving roadkill mitigation, and expanding long-term research and public awareness are essential to ensure the long-term survival of the Malayan tapir in Peninsular Malaysia.

INTRODUCTION

The Malayan tapir (*Tapirus indicus*) is the only tapir species found in Asia and one of the four extant species within the family Tapiridae, of which it is the largest in size. In Peninsular Malaysia, it is recognised as one of the five largest terrestrial mammals (PERHILITAN 2017). The species is easily identifiable by its distinctive black-and-white coloration and inhabits tropical rainforests across Southeast Asia, including Peninsular Malaysia, southern Thailand, and Sumatra.

In Peninsular Malaysia, the Malayan tapir occupies a range of forest ecosystems, including lowland dipterocarp, peat swamp, and montane forests. Its presence across these habitats highlights its ecological adaptability and its role as an important indicator of forest health (Lim *et al.* 2022). Despite this adaptability, extensive habitat destruction and fragmentation resulting from agricultural expansion, deforestation, and urbanisation have significantly reduced suitable habitats for the species (Rayan *et al*. 2012; Clements *et al.* 2012; Mohd Samsudin *et al.* 2022; Magintan *et al*. 2024).

[a] Following Groves and Grubb (2011), the Malayan tapir has been reclassified as *Acrocordia indica*, reflecting its placement within a distinct Asian tapir lineage separate from the American tapirs. However, *Tapirus indicus* is retained as the scientific name used throughout this article. This is consistent with its designation under the Wildlife Conservation Act 2010 (Act 716), as well as the nomenclature used in official PERHILITAN records, conservation documents and national reporting. *Tapirus indicus* also continues to be used by the IUCN SSC Tapir Specialist Group in its conservation work and materials. Retaining *Tapirus indicus* therefore ensures continuity with existing legal, administrative and conservation records and the scientific literature cited in this article.

Department of Wildlife and National Parks, Peninsular Malaysia (PERHILITAN), KM10, Jalan Cheras, 56100 Kuala Lumpur
***Corresponding author: davidm@wildlife.gov.my**

The Malayan tapir is a highly selective browser, primarily feeding on immature leaves and young shoots (Williams and Petrides 1980; Khan 1997). Dietary studies conducted in Peninsular Malaysia have recorded more than 115 plant species consumed in natural habitats (Khan 1997). Additional research on tapirs maintained within a semi-wild 30-hectare enclosure documented browsing on 217 plant species, particularly from the families Phyllanthaceae, Myristicaceae, and Sapindaceae (Simpson *et al.* 2013). Collectively, these studies indicate that the Malayan tapir depends on a highly diverse diet comprising at least 380 plant species.

Among the species' range countries, the Malayan tapir population in Peninsular Malaysia and southern Thailand is considered the most stable and extensively studied (Traeholt *et al.* 2016). Early population estimates in Peninsular Malaysia varied widely, ranging from approximately 1,300 – 1,700 individuals (Traeholt *et al.* 2016) to as many as 3,500 individuals (Khan 1997; Zainal *et al*. 2001). However, subsequent evaluations suggest that these figures were likely overestimated. More recent assessments by PERHILITAN, based on camera trap surveys, wildlife inventories, road mortality records, public sightings, and data from the First National Tiger Survey (2016 – 2020), indicate a substantially smaller remaining population of approximately 700 – 800 individuals (PERHILITAN 2020; Lim *et al.* 2022; Magintan *et al*. 2024).

Over the past three decades, the Malayan tapir has undergone a significant population decline and is now classified as globally threatened (PERHILITAN 2021). In Peninsular Malaysia, ongoing land-use changes driven by agricultural development and infrastructure expansion have intensified habitat degradation and fragmentation. Additional threats include increased human-wildlife conflict, vehicle collisions, and unintended capture associated with illegal poaching activities. In light of these challenges, this article provides a comprehensive review of the historical and current conservation issues affecting the Malayan tapir in Peninsular Malaysia.

LEGAL AND POLICY FRAMEWORK

Strong legal and institutional mechanisms underpin protection of the Malayan tapir in Peninsular Malaysia. The Wildlife Conservation Act 2010 (Act 716) and Wildlife Conservation (Amendment) Act 2022 [Act A1646], enforced by PERHILITAN, serve as the main legislation regulating wildlife protection and management. It designates the Malayan tapir as a Totally Protected Species, prohibiting its hunting, trade, or possession, while strengthening penalties for wildlife-related offences. Complementing this national legislation is the International Trade in Endangered Species Act 2008 [Act 686], which was enacted to regulate and control the international commercial trade of wildlife in accordance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). As the Malayan Tapir is listed under CITES Appendix I, all forms of international trade involving the species are prohibited except under exceptional, non-commercial circumstances such as scientific research. The Act ensures that Malaysia meets its international obligations to curb wildlife trafficking and prevent exploitation of endangered species.

At the policy level, the National Policy on Biological Diversity (NPBD) 2022–2030 outlines Malaysia's strategic direction for biodiversity conservation, integrating it into national development planning (NRECC 2023). Complementing this, Malayan Tapir Conservation Action Plan (MATCAP) 2021–2030 provides species-specific strategies focused on habitat connectivity, roadkill mitigation, and population monitoring (PERHILITAN 2021). Malaysia's participation in the Convention on International Trade in Endangered Species (CITES) further regulates international trade of endangered species and promotes compliance with global standards. Together, these instruments form a comprehensive governance framework

aimed at protecting the Malayan tapir and maintaining ecological balance. However, implementation challenges persist. Limited enforcement resources, overlapping jurisdictions, and continued land-use conflicts reduce policy effectiveness. Although legislation provides protection, the success of conservation efforts depends on coordinated land-use planning and collaboration among government agencies, NGOs, and local communities (Magintan *et al.* 2024). Enhancing habitat connectivity through ecological corridors, strengthening data-sharing systems, and improving public engagement are critical next steps to ensure the species' survival in Peninsular Malaysia.

THREATS

Malaysia's pursuit of high-income nation status has driven rapid economic development and a shift from agriculture and mining to manufacturing and services. This transition has placed significant pressure on natural resources, especially biodiversity, resulting in habitat loss, degradation, and fragmentation (KATS 2019). The Malayan tapir is among the species most affected, with numerous studies highlighting threats from habitat loss and forest fragmentation (Kinnaird *et al.* 2003; Rayan *et al*. 2012; Clements *et al.* 2012; Magintan *et al.* 2012, 2024; PERHILITAN 2021; Lim *et al.* 2022).

Population growth remains one of the main drivers of biodiversity loss in Malaysia, increasing demand for land, housing, infrastructure, and urban development (NRECC 2023). In Peninsular Malaysia, forest cover accounts for 43.4% of the land area (FDPM 2021). Deforestation is mainly driven by agriculture, industry, mining, road construction, dam development, and settlement expansion. These activities fragment tapir habitat, a challenge shared across its range (Lim *et al.* 2022). Increased forest clearing and expanding road networks have been linked to higher roadkill rates (Magintan *et al.* 2021, 2024), similar to threats observed in Thailand (Tipkantha *et al.* 2022). As of 2021, 5.73 million ha of forest remain, divided among permanent reserves, government land, and wildlife reserves, with 778,433 ha managed by PERHILITAN (2020). The Malayan Tapir Conservation Action Plan (2021–2030) focuses on identifying viable habitats. Studies show a weak but present relationship between forest loss (2006 – 2019) and roadkill trends (Magintan *et al.* 2021).

Illegal hunting also contributes to wildlife decline. PERHILITAN recorded 61 illegal hunting cases from 2013 to 2019 (PERHILITAN 2020). Snare traps, illegal in Malaysia, pose a severe risk. From 2013 to 2018, encounters rose from 44 to 2,890 snares, killing at least 52 animals, including eight tapirs (Nur-Hazwani and Salman 2018). Although tapirs are not targeted species due to cultural beliefs (Kawanishi *et al*. 2002), they are frequent non-target victims. Indigenous hunting persists on a limited scale, with tapirs taken occasionally (Loke *et al.* 2020). To reduce snaring, PERHILITAN conducts continuous anti-snare patrols (KATS 2019).

Roadkill remains one of the most significant threats to tapirs. Since 2014, roadkill incidents have doubled or tripled, correlating with rising road density from rapid urbanisation (KATS 2019). Highway expansion often cuts through tapir habitats (PERHILITAN 2021), and cumulative forest loss further increases vulnerability (Magintan *et al.* 2021). Between 2006 and 2019, 115 cases of tapir roadkills were reported, with a peak in 2017. In certain locations, as many as 67 mammal roadkills were recorded along an 8 km stretch of highway within a six-month period (Hui *et al.* 2021). Although the Central Forest Spine (CFS) Master Plan includes ecological corridors and viaducts to reduce roadkill (PlanMalaysia 2022), incidents remain consistently high, exceeding ten cases annually since 2014 (Magintan *et al.* 2021).

Human-tapir conflict is another rising issue. The first displaced tapir case was reported in 1991 (Zainal *et al*. 2001). Increasing land-use change and habitat degradation bring tapirs into closer contact with people (Wong *et al*. 2024), contributing to conflicts involving property damage, crop loss, and public safety concerns (PERHILITAN 2021). Amirul *et al.* (2024) reported that there were 78 human-tapir conflict cases in Negeri Sembilan from 2013 to 2018. Between 2011 and 2021, 410 conflict complaints were recorded (PERHILITAN 2021). Another report by Siti Nurnajihah Zuber *et al.* (2024) mentioned that the total number of cases involving human-tapir conflict complaints in Peninsular Malaysia was 244 spanning the years 2013 to 2019. Most reports involve tapirs straying into settlements, orchards, and plantations (Magintan *et al.* 2012), reflecting growing pressures from population expansion and development (NRECC 2023).

CONSERVATION EFFORTS

Enforcement

Malaysia has long enforced the protection of large mammals under the Wildlife Protection Act 1972 [Act 76]. This was replaced by the Wildlife Conservation Act 2010 [Act 716] and its 2022 amendment [Act A1646], under which the Malayan tapir is classified as a "Totally Protected" species. Offenses involving hunting, possession, or trade of tapirs without a special permit carry strict penalties. The Malayan tapir is also listed as Endangered by the IUCN (Traeholt *et al*. 2016) and by the PERHILITAN (2017a) under the Red List for mammals of Peninsular Malaysia, based on historical and current data on its distribution and population size.

To address illegal wildlife activities, PERHILITAN has implemented *Operasi Bersepadu Khazanah*, an integrated operation targeting encroachment, illegal logging, harvesting of forest products, and wildlife hunting. In its six years of implementation, the initiative has recorded significant success. Between 2019 and 2022, it recorded 291 cases with confiscations valued at RM224.08 million (PERHILITAN 2022). In the year 2023 alone, 105 cases were recorded, with confiscations valued at RM32.2 million (PERHILITAN 2023a).

Additionally, PERHILITAN established the Community Rangers programme, involving Malaysian Armed Forces veterans, police veterans, Indigenous communities, and local residents to curb encroachment and illegal hunting across national parks, reserves, forest reserves, and Ramsar sites — all key tapir habitats. By 2022, 901 individuals had been appointed (PERHILITAN 2022).

Conflict prevention efforts

To improve wildlife conservation and reconnect fragmented forest landscapes, the Malaysian government introduced the Central Forest Spine (CFS) Masterplan, which includes constructing viaducts to reduce wildlife vehicle collisions. The first viaduct projects were built along the Kuala Berang Chiku highway (Magintan *et al*. 2012). Studies show Malayan tapirs and multiple mammal species have used these structures (Clements *et al*. 2012; Magintan *et al.* 2022). However, continued management such as habitat restoration, artificial salt licks, and long-term monitoring is required to increase effectiveness (Tan *et al*. 2015; Magintan *et al*. 2021).

The Public Works Department has built ten viaducts nationwide to support wildlife movement (KATS 2019). In 2020, PERHILITAN introduced the Smart Green Linear Infrastructure (SGI) guideline, standardising crossing designs for large mammals (Wan-Nordin *et al.* 2020). The Forestry Department further supports forest connectivity through its policy framework, emphasising wildlife ecological corridors and designating Wildlife Protection Forests to preserve habitats (FDPM 2021).

PERHILITAN is also finalising a new Malayan Tiger Conservation Plan, replacing the National Tiger Conservation Action Plan (NTCAP) 2008–2020. This plan, while focused on tigers, will benefit other species including the tapir. The National Elephant Conservation Action Plan 2023–2030 (NECAP 2.0) similarly supports habitat and corridor conservation that indirectly protects tapirs (PERHILITAN 2023b). Additionally, PERHILITAN installs wildlife crossing signage at hotspot areas to reduce roadkill incidents involving species such as the Malayan tapir (Magintan *et al.* 2012, 2021).

REINFORCING *EX-SITU* CONSERVATION STRATEGIES

Ex-situ conservation serves as an essential complement to *in-situ* protection efforts for the Malayan tapir. Under the Malayan Tapir Conservation Action Plan (MaTCAP 2021–2030), *ex-situ* efforts are recognised as one of the four strategic pillars alongside habitat management, research, and communication, education, and public awareness (CEPA) (PERHILITAN 2022). These initiatives play interconnected roles maintaining an insurance population, enhancing husbandry and reproductive knowledge, supporting education and outreach, and providing potential donor animals for future supplementation or reintroduction when ecological conditions allow.

Captive management and breeding efforts

Captive breeding is a key strategy to support the Malayan tapir population. Malaysia's *ex-situ* tapir management involves a coordinated network of institutions led by the Department of Wildlife and National Parks (PERHILITAN). The Sungai Dusun Wildlife Conservation Centre (SDWCC), established in 2004, remains the cornerstone of the national breeding and rehabilitation programme (Mohd-Adib *et al*. 2024), successfully maintaining tapirs under semi-wild conditions (Donny *et al.* 2022). Complementing this are Zoo Negara Malaysia, Zoo Taiping, Zoo Melaka, A'Famosa Safari and other zoological institutions across Peninsular Malaysia that contribute to breeding and long-term care. To enhance breeding capacity, a new Malayan tapir centre is planned in Kenaboi, Negeri Sembilan.

Reproductive research and technological advances

Significant research advances have deepened understanding of tapir reproduction. Semen collection via electroejaculation, semen evaluation, and hormonal profiling have been successfully demonstrated in Malaysian facilities (Donny and Hiew 2024). These studies provide a foundation for the development of assisted reproductive technologies (ART) such as artificial insemination and cryopreservation. Ongoing research at National Wildlife Rescue Centre (NWRC) and SDWCC on estrous cycle monitoring has refined breeding timing and improved reproductive success. However, practical application of ART faces operational limitations, including under-developed cryobank infrastructure, limited technical expertise, and funding constraints. Addressing these barriers will be essential for ART to progress from experimental studies to applied conservation tools.

Rehabilitation and rescue

Rescue and rehabilitation are vital *ex-situ* activities, particularly as road development and forest fragmentation continue to threaten wild tapirs. PERHILITAN is responsible for responding to incidents involving Malayan tapirs, such as road accidents or animals trapped in hazardous situations. Injured tapirs are assessed by veterinarians to determine whether treatment or immediate release is appropriate (Mohd-Samsudin *et al.* 2022). Rescue and rehabilitation operations are coordinated through the NWRC in Sungkai, Perak. Severely injured, sick, or orphaned tapirs undergo rehabilitation involving medical care, conditioning, and behavioral training before release (Magintan *et al.* 2023). Once deemed fit, rehabilitated individuals are released back into suitable habitats and monitored to ensure successful adaptation.

AWARENESS AND COMMUNITY ENGAGEMENT

Public awareness is an essential component of tapir conservation. PERHILITAN conducts education and outreach programmes for schools, universities, indigenous groups, local communities, NGOs, and other stakeholders. These programmes cover wildlife legislation, management practices, protected areas, and human-wildlife conflict, including appropriate actions when encountering Malayan tapirs.

Local and indigenous communities are actively involved in conflict mitigation initiatives, particularly the use of electric fencing systems (e.g., *Sistem Pager Elektrik Gajah,* SPEG) to deter large mammals such as elephants and tapirs. Educational programmes in schools aim to foster long-term awareness of biodiversity conservation. Although not species-specific, these initiatives indirectly promote tapir conservation (PERHILITAN 2021).

Under the MATCAP, partners such as Universiti Putra Malaysia (UPM) and the Malaysian Nature Society (MNS) conduct awareness and research activities. MNS supports conservation education through school-based nature clubs, while UPM encourages student research on various aspects of tapir biology and conservation.

RESEARCH

Despite being documented for over 200 years, research on the Malayan tapir remains limited, with only 57 scientific publications recorded as of 2023 (PERHILITAN 2021). Existing studies are often small-scale and fragmented. Key research gaps include human dimensions and roadkill mitigation, although recent studies have begun addressing tapir-vehicle collisions (Lim *et al.* 2022). Research priorities identified since the 2003 Malayan Tapir Conservation Workshop include population status, ecology, distribution, habitat use, threat reduction, and effective awareness programmes. These priorities continue to guide current and future conservation efforts (PERHILITAN 2021).

CONCLUSIONS

In 2016, the Malaysian government introduced the National Policy on Biological Diversity (NPBD) 2016–2025 to strengthen the country's efforts in conserving biodiversity (KATS 2019). This policy has since been updated to align with the Kunming-Montreal Global Biodiversity Framework 2030, which replaced the Aichi Biodiversity Targets 2010–2020. Under the revised NPBD 2022–2030, Malaysia is committed to achieving its biodiversity conservation targets by 2030. A key initiative in this effort is the Malayan Tapir Conservation Action Plan (MATCAP) 2021–2030, designed to guide and support the protection of the Malayan tapir in Peninsular Malaysia. MATCAP aims to create ecological and social conditions that allow the species to thrive in its natural habitat, while aligning with international and national policies, laws, and regulations. The plan emphasises habitat management, *ex-situ* management, communication, education, public awareness, and research, outlining 16 outcomes and 49 activities to be implemented through 2030. Progress will be continuously evaluated and adapted to ensure the successful conservation of the Malayan tapir in Peninsular Malaysia.

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CHAPTER 17

Asian elephants in Peninsular Malaysia

SALMAN SAABAN[1,3]* and WONG EE PHIN[2,3]*

Abstract: Peninsular Malaysia is considered as one of the strongholds for globally significant populations of wild Asian elephants (*Elephas maximus*), estimated around 1,223 – 1,677 individuals, that spread across seven states: Perak, Kelantan, Terengganu, Kedah, Negeri Sembilan, Pahang and Johor. In the past, wild elephants used to roam throughout Peninsular Malaysia, but at present only ~ 45% of the area still have wild elephants. The wild elephant populations are threatened by illegal killing (i.e. poaching, poisoning), human-elephant conflict, habitat lost and fragmentation that impedes elephant movement and result in vehicle collisions. Efforts by the Department of Wildlife and National Parks (PERHILITAN), academia, and non-profit organisations to manage threats to Asian elephants include collaboration and working with stakeholders on the ground to transform conflict to harmonious coexistence, and carry out education outreach, awareness, scientific research, and wildlife law enforcement. There are also wider efforts by other governmental agencies like the Forestry Department and PLANMalaysia to protect Peninsular Malaysia's remaining forest complexes and establish functional ecological linkages via the Central Forest Spine Masterplan. Continuous monitoring efforts on the ground and scientific research are needed to protect and elevate knowledge on Asian elephants' behaviour and ecology in the Sundaic region.

INTRODUCTION

There are only three extant species of elephants (Order Proboscidea, Family Elephantidae) globally, with two species in Africa, namely the African savanna elephant (*Loxodonta africana*) and African forest elephant (*Loxodonta cyclotis*), and one species in Asia, the Asian elephant (*Elephas maximus*). The Asian elephant is categorised into four recognised subspecies: the Sri Lankan elephant (*E. m. maximus*), the Indian elephant (*E. m. indicus*), the Sumatran elephant (*E. m. sumatranus*), and the Borneo elephant (*E. m. borneensis*). Historically, the Asian elephant's range covers the continent of Asia, from Turkey, Iraq and Iran in the West (Lister *et al.* 2013), and span across India, Indochina, southern China, and Southeast Asia (IUCN 2019). It is estimated that the Asian elephant has lost ~95% of its historical range and its wild populations are currently found across 13 countries in Asia, with transboundary shared populations (Sukumar 2003; Fernando and Pastorini 2011; IUCN 2019; Mahmood *et al*. 2021).

The Asian elephant (Figure 1) is listed as Endangered on IUCN Red List of Threatened Species, with an estimated number ~45,600 to 49,000 individuals globally (IUCN 2019). In Peninsular Malaysia, the population estimation is around 1,223 – 1,677 individuals distributed across 7 out of 11 states: Perak, Kelantan, Terengganu, Kedah, Negeri Sembilan, Pahang, and Johor (Saaban *et al.* 2011). Although this is considered a fairly acceptable number in terms of genetics for a long-term viable population, but it requires protecting connectivity between habitats to allow elephant movement and the acceptance of a harmonious human-elephant coexistence to minimise local extinction.

[1] Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN), Km. 10, Jalan Cheras, 56100 Kuala Lumpur, Malaysia.
[2] School of Biological and Environmental Sciences, Faculty of Science & Engineering, University of Nottingham Malaysia, Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia.
[3] Management & Ecology of Malaysian Elephants, University of Nottingham Malaysia, Jalan Broga, 43500 Semenyih, Selangor Darul Ehsan, Malaysia.
***Joint first and corresponding authors: salman@wildlife.gov.my; eephin@gmail.com**



Figure 1. A portrait of a male Asian elephant (Photo credit: K. Gukaaneswaran/MEME).

The IUCN SSC Asian Elephant Specialist Group (AsESG) monitors elephant ranging areas to assess the status of Asian elephants across range countries. In 2013 to 2015, a survey carried out in Peninsular Malaysia found a loss of 68% of elephant range in human-occupied areas within 40 years (one to two generations) (Tan 2016). A recent update of the elephant presences map with PERHILITAN and other stakeholders' data, expanded the 5km × 5km occupancy grid to include forested areas, found an overall estimation of ~45% area in Peninsular Malaysia that still harbour elephant presences (Salman Saaban *et al*., in review). Considering that, historically, the whole of Peninsular Malaysia has wild elephant presences, the reduction in roaming range is of concern. Currently, elephants are managed within dedicated Managed Elephant Ranges (MERs). These habitats are centred around three primary landscapes: the Belum-Temenggor, the Taman Negara-Greater Kenyir, and Endau-Rompin forest complexes (Department of Wildlife and National Parks 2023).

Globally, more effort is required to halt and reverse species extinction and the trend of wildlife population number loss as the biomass for wild mammals (including both terrestrial and marine) amount to just ~ 5% of the world's total biomass of mammals, compared to the

humans (~34%), cattle (~35%), pigs (~12%), buffaloes (~5%), goats (~3%), sheep (~3%), and horses (~2%) (Bar-On *et al.* 2018; Ritchie and Spooner 2025). As one of the world's biologically megadiverse countries, Malaysia harbours a rich diversity of wild species of flora and fauna, and has in the past and still much needed for the present and future, to shoulder important responsibilities towards the protection and conservation of Asian elephants, other wildlife, and their habitats.

Prehistoric elephants in Sundaic region or Sundaland

Genomic mapping of extinct and living elephants found exchange of genes between our living (modern) elephants and extinct ancestors such as the straight-tusked elephants (Genus *Palaeoloxodon*) and mammoths (Genus *Mammuthus*) (Palkopoulou *et al.* 2018). In Malaysia, most Proboscidea fossils recovered from archaeological sites were identified to be Genus *Elephas*, and although straight-tusked elephants' fossils were found in Thailand and Kalimantan, Indonesia but none were confirmed so far for Malaysia (Tshen 2013). Hence, the first discovery of a tooth belonging to *Stegodon* sp. (Order Proboscidea, Family Stegodontidae) at a limestone cave in Perak, deposited during the middle Pleistocene, has generated a lot of interest and excitement (Amiruddin *et al.* 2025). Further research is needed to identify the species and the paleoenvironment surrounding the *Stegodon*.

There has been prolonged debate on the state of environment during the Pleistocene in the Southeast Asia region, when the sea level is ~ 62 meter lower, and the land mass of Peninsular Malaysia is connected to Borneo, Philippines, Sumatra and Java islands, which is known as the Sundaic region or Sundaland (Woodruff 2010). Paleontology and paleoenvironment studies debated whether there was extensive grassland in the middle of the region known as the north-south savanna corridor (Bird *et al.* 2005; Louys and Roberts 2020), which was eventually taken over by rainforest, or was the region predominantly forest all along (Hamilton *et al*. 2024). Perhaps, a consensus would be that the environment is more heterogeneous than previously accepted, which then allowed the migration of hominin populations from the North into the region (Rabett 2017; Cheng *et al.* 2023). The repeated rising and lowering of sea level, and the expansion and recession of the forest during the Quaternary Period, spanning 2.6 million years ago, had influenced the landscape and biodiversity in Southeast Asia, especially in the Sundaland region (Woodruff 2010; Badam 2013; Sheldon *et al.* 2015).

Role of Asian elephants in the sundaic forest

The Asian elephant plays an important role in dispersing seeds of fruit trees (Figure 2), especially for large fleshy megafruits (width ≥ 40mm). In the recent decade, there has been studies in Peninsular Malaysia examining elephant's and other wildlife ecological role in dispersing seeds in the rainforest, especially in the Belum-Temengor Forest Complex in Perak (Terborgh *et al.* 2018; Ong *et al.* 2021, 2023; Tan *et al.* 2021). Long-term monitoring of fruit seeds in elephant dung by Management & Ecology of Malaysian Elephants (MEME) found that fruits in the rainforest are seasonal and sporadic sources of food for elephants and other wildlife (Tan *et al*. 2021). As generalists, Asian elephants in the rainforest and edge areas would consume leaves, bark and stems from monocots (i.e. grasses, palms and bamboos), pioneer plants, liana, and other plants (Yamamoto-Ebina *et al*. 2016; Terborgh *et al*. 2018; Ong 2021; Abdullah-Fauzi *et al*. 2022; Ong *et al.* 2023). By comparing herbivorous megafauna (> 500kg) from Pleistocene to the present day, to the presences of megafruit species across the larger tropical Asia region, the regional diversity of megafruit species is found to be positively related to megafaunal diversity in the area, both when considering extant megafauna species only and when including both extant and extinct megafaunal species (McConkey *et al.* 2022). Peninsular Malaysia is considered as one of the regions with high megafauna and high megafruit diversity (McConkey *et al*. 2022).



Figure 2. Fruit tree seedlings in Belum-Temengor forest germinating after dispersal by a wild elephant (Photo credit: MEME).

MANAGING THREATS TO ASIAN ELEPHANTS

Across the range countries, threats to Asian elephants include illegal killing, human-elephant conflict (HEC), habitat loss, and habitat fragmentation that impeded elephant movement and resulted in vehicle collisions with elephants. In Peninsular Malaysia, PERHILITAN has captured several poacher groups that specialised in hunting wild elephants and recorded cases of elephant poisoning, suspected due to retaliation caused by HEC. In terms of roadkill, annually the number of elephant-vehicle collisions fluctuates between zero to four cases. Research conducted using GPS satellite collars to monitor elephant movement at Gerik-Jeli highway found that roads bisecting forest can become a barrier to elephant movement (Wadey *et al*. 2018; Wong *et al.* 2018b). Although wildlife crossings can help facilitate the movement of elephants, wildlife may still cross directly over the road, and therefore it is important to instil awareness among drivers to slow down at wildlife corridors (Clements *et al*. 2014; Wong *et al.* 2018a; Ament *et al.* 2021).

Between 2015 and 2024, 175 elephant deaths were recorded (10 – 24 annually), with ~37% due to illegal killing, including poisoning and poaching. State of Perak registered the highest number of elephant fatality averaging 4.5 cases per year, followed by Johor with 4.3 cases per year, Kelantan 3.6 cases per year and others (Saaban *et al.* 2026). In the same period, HEC resulted in 19 human fatalities and 18 injuries, with PERHILITAN assisting victims and their families by facilitating compensation applications through the Social Welfare Department. There were 6,860 cases of HEC (2015 – 2024) with MYR65 million in losses, which averaged ~686 complaints annually (Saaban 2026). In 2024, the Ministry of Natural Resources and Environmental Sustainability expanded the HEC compensation scheme to cover crop and property damage (partially), and the scheme focused on independent smallholders and individual farmers.

As part of HEC mitigation measures, PERHILITAN will translocate elephants as the last resort in conflict areas to protected areas, and deploy other HEC mitigation measures such as trenches, electric fencing, and on-site guarding (Saaban *et al.* 2011; Department of Wildlife and National Parks 2023). Captive elephant management facilities are regulated by PERHILITAN under the Wildlife Conservation Act 2010 [Act 716] and the recorded number of captive elephants is 83 individuals (19 males and 64 females) spread across ten facilities including National Elephant Conservation Center (NECC) in Kuala Gandah, Pahang, other PERHILITAN managed facilities in Terengganu and Johor, and various zoos either managed by state local authorities or private. The captive elephants at NECC are trained to assist PERHILITAN in translocation of conflict elephants and are used for conservation education, awareness, and ecotourism. Recent research on AI-based surveillance systems using cameras, bioacoustics, and drones as early warning systems, are being explored to help alert nearby communities and workers in order to increase safety (Loo *et al*. 2024; Avicena *et al.* 2025). However, clear standard operating procedures and proper training are essential to ensure, once alerted of elephant presences, people do not approach the elephants on their own, as it may result in more injuries and fatalities.

MOVING TOWARDS COEXISTENCE WITH ELEPHANTS

Globally, there are interests to transform the narrative of HEC to human-elephant coexistence and examine the human-dimension of conflict using social sciences and psychology tools (IUCN 2023). Often, HEC is seen as a sensitive topic and ranks high in the concerns of affected stakeholders and government agencies. On the other hand, some communities living within the range of elephants or other wildlife roaming areas, may not view the presence of wildlife as conflict until being interviewed. Hence, the terminology of human -elephant coexistence or human-elephant interactions are often used to allow exploration of neutral and positive interactions between people and elephants without neglecting the negative interactions or the conflict aspect as well (Frank 2016; IUCN 2023). Very often, there needs to be consideration of potential human-human conflict that could emerge from past disputes or due to different goals between stakeholders resulting in disagreements (IUCN 2023).

In both Sabah (orang utans and elephants) and Peninsular Malaysia (elephants), efforts were made to work in collaboration with oil palm plantations to move towards biodiversity or wildlife-friendly plantations that foster safe human-wildlife coexistence (Saaban *et al.*, in review; Tan and Wong, in review). For Peninsular Malaysia, a coalition for Achieving Coexistence with Elephants (ACE) was formed in 2021 with a memorandum of cooperation signed among a few oil palm plantations, non-profits and academia (www.ace-coalition.com). The project focuses on the southern landscape of Peninsular Malaysia, mainly in the state of Johor. Five workshops (Tanjung Leman 27–30 March 2022, Kota Tinggi 7–9 February 2023 & 26 September 2023, Desaru 10–12 September 2024, and Semenyih 3 November 2025) were organised and conducted by MEME involving stakeholders within and outside the coalition from FELDA, FGV, SD Guthrie, Johor Plantation, Aramijaya, IOI Plantation, TH Plantations, Tradewind Plantations, MADOS, FIMA, Malaysian Palm Oil Board (MPOB), MPOGCF, Earthworm Foundation, WCS-Malaysia Programme, WWF-Malaysia, Seratu Aatai, Bring Back Our Rare Animals (BORA), Proforest, Satok Digital, PERHILITAN, Forestry Department and others. These workshops primarily discuss safety protocols, conflict mitigation measures, habitat connectivity, elephant behaviour and ecology, and emerging technologies such as AI for cameras, bioacoustics and drones to increase safety for people while monitoring elephant movement (Wong *et al.* 2026). Outreach materials such as safety posters for plantations and villages, human-elephant coexistence board games, a comic book and online modules were developed to support

harmonious human-elephant coexistence via having safe feeding grounds and movement passages for elephants (Tan *et al.* 2024, 2025). There is on-going effort to monitor elephant feeding behaviour and acoustics at one of the trial elephant foodbanks set up by FGV in Johor (Kasah *et al*. 2026) and a few other areas. Besides collaboration with MEME and ACE, PERHILITAN also supports the establishment of food banks and elephant corridors with other stakeholders such as MPOGCF, Earthworm Foundation, University Malaysia Kelantan and other universities and stakeholders in Johor, Terengganu and Pahang.

GOVERNANCE AND ACTION PLANS

The National Elephant Conservation Action Plan 2023-2030 (NECAP 2.0), developed by PERHILITAN with input from academia, NGOs, and the oil palm sector, sets out key strategies for elephant protection and conservation in Peninsular Malaysia. Its objectives include protecting habitats and connectivity, reducing HEC through coexistence, strengthening legislation and enforcement, expanding knowledge of elephant ecology and behaviour, and improving captive elephant management.

NECAP 2.0 interacts with other national policies such as the National Policy on Biological Diversity 2022-2030, National Forestry Policy, National Physical Plan (NPP4), Central Forest Spine Ecological Linkages Master Plan (PIRECFS 2022), Thirteenth Malaysia Plan (2026-2030), Rural Development Policy, National Agrofood Policy 2021-2030, National Agricommodity Policy 2021-2030, and National Construction Policy 2030. It also works in synergy with related initiatives, including the Malayan Tiger Crises Action Plan, Malayan Tapir Conservation Action Plan, and Integrated Khazanah Wildlife Enforcement Operations.



Figure 3. Continuous research and monitoring of elephants are needed to generate more findings that will help support harmonious human-elephant coexistence (Photo credit: MEME).

CONCLUSION

Protection and conservation efforts for elephants in Peninsular Malaysia requires working together with stakeholders and partners on the ground to secure coexistence and habitat connectivity, to allow elephants to move safely between feeding grounds while minimising risk of human-elephant conflicts. In effort to promote harmonious coexistence between people and elephants, we have to address the issue of safety for people and elephants on the roads, in agriculture areas and also in their natural habitat. There is a need to continuously conduct monitoring and increase scientific knowledge on behaviour and ecology of elephants in the Sundaic region, to support the on-going efforts on the ground.

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CHAPTER 18

Status, threats, and conservation strategies for Bornean elephants in Sabah

CHERYL CHEAH[1]*, ESTHER LONNIE[1] and PRIMUS LAMBUT[2]

Abstract: Once widespread, the Bornean elephant is now confined to fragmented landscapes in Central Sabah, Tabin, and the Lower Kinabatangan, with an estimated population of about 1,000 individuals. Habitat loss and fragmentation, driven by deforestation, agricultural expansion, and infrastructure development, remain the primary threats, alongside human -elephant conflict, poaching, and poisoning. The paper synthesises current knowledge on elephant ecology, distribution, and population trends, and highlights key conservation interventions, including ecological corridors, joint patrols, landscape-level conflict management, and community-based initiatives. A case study from the Tabin landscape demonstrates the effectiveness of multi-stakeholder collaboration in reducing conflict and improving coexistence. The manuscript concludes with policy recommendations to strengthen certification frameworks, integrate biodiversity safeguards into infrastructure planning, and enhance habitat connectivity to secure the long-term survival of Bornean elephants.

INTRODUCTION

The Bornean elephant—the smallest and perhaps the most elusive of all Asian elephant subspecies—roams only through the northeastern landscapes of Borneo. Once widespread across the island's lush lowland forests, they are currently confined mainly to Central Sabah, Tabin, and the Lower Kinabatangan, with a small population reaching into North Kalimantan. Their present distribution has been reshaped by deforestation, expanding agriculture, and infrastructure development, which have reduced and fragmented their habitats and pushed them into closer contact with people.

Today, only about a thousand Bornean elephants remain, their survival threatened by habitat loss, fragmentation, human-elephant conflict, and poaching. Yet amid these challenges, conservation partners, government agencies, plantation owners, and local communities are working together to manage human-elephant conflict, reconnect forest landscapes, strengthen patrols, and implement joint management strategies in their efforts to protect this iconic species and nurture a future where people and elephants coexist in a shared and resilient landscape.

Taxonomy

Bornean elephants are generally smaller, with distinct skull features compared to those from Sumatra and mainland Asia (McLean *et al.* 2024). Genetic analyses indicate they belong to an ancient lineage isolated for over 300,000 years (Fernando *et al*. 2003; Sharma *et al.* 2018). The Bornean elephant (*Elephas maximus borneensis*) is now recognised as a unique subspecies of the Asian elephant, distinct from its mainland relatives due to its physical and genetic characteristics (McLean *et al.* 2024).

[1] Sabah Landscapes Programme, WWF-Malaysia, Kota Kinabalu, Sabah, Malaysia.
[2] Sabah Wildlife Department, Sabah Wildlife Department, Wisma MUIS, Kota Kinabalu, Sabah, Malaysia.
***Corresponding author: ccheah@wwf.org.my**

Legal status and protection

The Bornean elephant was recently listed as Endangered on the IUCN Red List of Threatened Species, highlighting its dwindling numbers and small population size (McLean *et al.* 2024). In Sabah, the species is afforded the highest level of protection under Schedule 1 of the Wildlife Conservation Enactment 1997, which strictly prohibits hunting, capturing, or killing. Offences involving the killing or possession of elephant parts, such as tusks, skin, or bones, carry severe penalties, including fines ranging from RM50,000 to RM250,000 and imprisonment of six months to five years (Sabah Wildlife Department 2020).

DISTRIBUTION AND POPULATION SIZE

The Bornean Elephant is found only in the northeastern part of Borneo, spanning the border between Sabah, Malaysia, and North Kalimantan, Indonesia. In Sabah, long-term satellite tracking has revealed that these elephants primarily occupy three Managed Elephant Ranges (MERs): the Lower Kinabatangan, Tabin, and Central Sabah (Cheah *et al.* 2022; Sabah Wildlife Department 2020; Figure 1), with a smaller population extending into North Kalimantan (Sukmantoro *et al.* 2021).

Their distribution appears linked to the availability of essential minerals like kaolin clay, which they consume to detoxify plant matter (Payne *et al.* 2020). However, decades of human expansion and land-use change have greatly reduced and fragmented their habitat, confining elephants to smaller, isolated areas, resulting in the loss of more than 60% of their historical range over the past 40 years (Gaveau *et al.* 2014; Sabah Wildlife Department 2020). Today, their remaining habitat covers roughly 30,600 km^2, with only about 15,200 km^2 actually occupied by elephants (McLean *et al.* 2024).

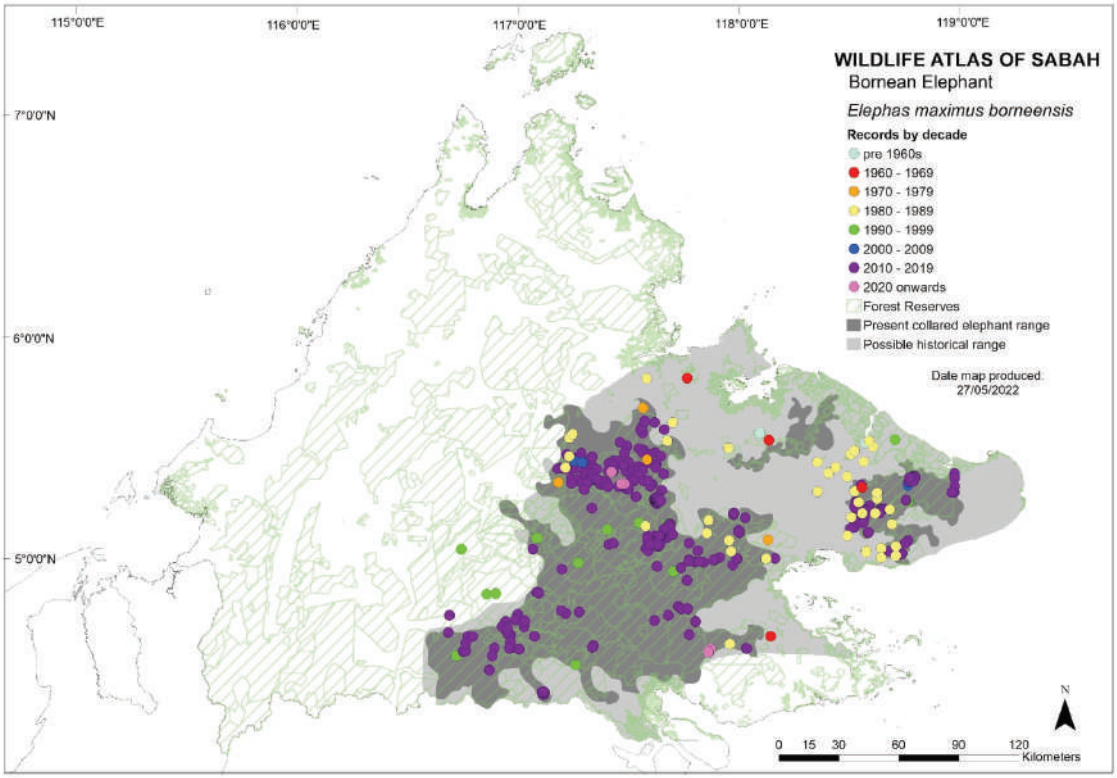

Figure 1. Probable historical range and present range of the Bornean Elephant in Sabah (Source: Cheah *et al.* 2022).

In the early 1990s, Payne and Andau (1991) provided the first population estimate of Bornean elephants in Sabah, suggesting between 500 and 2,000 individuals based on limited field data and questionnaire surveys. Since then, more robust survey methods, including distance sampling and dung count techniques, have produced more reliable estimates. The latest Red List assessment in 2023 estimated approximately 1,000 elephants remaining across their MERs, with a small transboundary group of about 12 individuals in Northeast Kalimantan (McLean *et al.* 2024). The assessment reports around 541 elephants in Central Sabah (Cheah and Yoganand 2022; McLean *et al.* 2024), 245 in Tabin (Andau 1997), and about 200 in the Lower Kinabatangan range (McLean *et al*. 2024). Although the early and current figures are not directly comparable due to differences in methodology, recent mortality data raise concern. Between 2010 and mid-2019, Sabah recorded at least 131 elephant deaths—a staggering loss that represents about 13% of the entire population in less than a decade (Sabah Wildlife Department 2020).

HABITAT AND ECOLOGY

Bornean elephants primarily inhabit low-lying areas where movement is less constrained, generally avoiding steep and rugged terrain. Studies by Evans *et al.* (2018) and de la Torre *et al*. (2022) indicate that they show a preference for secondary forests, forest gaps, regenerating areas, and newly established plantations. Interestingly, elephants are mostly found outside protected areas (PAs), often inhabiting landscapes along the peripheries (de la Torre *et al.* 2022). They primarily feed on grasses and bamboos from the Poaceae family, which thrive in riverine and open grassland habitats, along with palms and gingers (English *et al.* 2014). They are also known to consume young oil palm shoots, the pith of felled palms, and various cultivated fruits (Othman *et al.* 2019; Cheah *et al.* 2022). This adaptable yet opportunistic feeding behaviour often brings them into conflict with people. Bornean elephants have vast home ranges, averaging between 150 to 200 km^2 (Evans *et al.* 2020), reflecting their need for large, connected habitats to meet their ecological needs.

MAJOR THREATS

The Bornean Elephant Action Plan (2020 – 2029) highlights four major threats to the subspecies in Sabah: habitat loss and fragmentation, retaliatory killings linked to human -elephant conflict (HEC), poisoning, and poaching for ivory (Sabah Wildlife Department 2020). Habitat loss remains a significant concern. The ongoing Pan Borneo Highway, for example, cuts through key elephant habitat within the Central Sabah MER, further isolating sub-populations and heightening risks of vehicle collisions and poaching (Othman *et al.* 2019). Retaliatory killings often arise when elephants venture into oil palm landscapes.

Efforts to reduce such conflicts, like translocation or the installation of electric fences by individual plantation companies, often restrict elephant movements, exacerbating long-term conflict. Meanwhile, local communities lacking the means for costly preventive measures sometimes resort to killing elephants as an immediate solution. Poisoning may be deliberate or unintentional due to potential chronic exposure to agricultural chemicals in plantations where elephants forage (McLean *et al.* 2024). Poaching for ivory has become an increasing concern, with reports of tusks being smuggled from Sabah to Kalimantan, where they are prized as traditional wedding dowries among Indonesian Timorese communities (Sukmantoro and Suyitno 2023).

CONSERVATION INITIATIVES

Reducing further habitat loss and fragmentation

Government agencies, plantation owners, and conservation NGOs have collaborated to create ecological corridors in oil palm landscapes to facilitate elephant movement between fragmented habitats (Othman *et al.* 2019; Cheah *et al*. 2021). Sabah Softwoods Berhad (SSB) exemplifies this approach, setting aside 1,067 hectares in 2012 to connect the Ulu Kalumpang and Ulu Segama forest reserves. With WWF-Malaysia's support, SSB implemented strategic fencing to protect vulnerable areas while allowing elephant access elsewhere. This coexistence strategy effectively reduced conflicts and costs by more than 90% (Cheah *et al*. 2021, 2022).

Combatting poaching and smuggling

To curb elephant poaching, government agencies and NGOs in Sabah have initiated joint patrols and task forces to improve coordination and intelligence sharing. The Sabah Wildlife Department (SWD) has also established an intelligence unit to strengthen enforcement (Cheah *et al.* 2022) and launched a 10-Year Action Plan on Combating Wildlife Crime for Sabah (2024–2035) focused on law enforcement, interagency collaboration, and sustainable conservation to combat wildlife crime (Sabah Wildlife Department 2024). Furthermore, wildlife protection has been greatly strengthened through the use of the SMART Mobile application, enabling SWD to establish a standardised method to monitor poaching incidents and identify wildlife crime hotspots with greater accuracy.

Management of HEC at the landscape level

Landscape-level working groups comprising multiple stakeholders have been formed to implement joint strategies (Cheah *et al*. 2021: Othman *et al*. 2022). Achieving coexistence with elephants requires collaboration with the agricultural sector for improved land-use planning and strong community engagement to empower people to live alongside elephants and to become active stewards of conservation. As many plantations undergo replanting, coordinated electric fencing and spatial planning are vital, alongside community-based initiatives such as those established in Kinabatangan (Cheah *et al*. 2022).

CASE STUDY

A landscape approach to managing human-elephant conflict and fostering coexistence

In 2021, a multi-stakeholder working group was established in the eastern part of Sabah's Tabin Landscape to manage HEC through collaborative action. The group, comprising the Lahad Datu District Office, SWD, Sabah Forestry Department, other government agencies, plantation companies, community representatives, and WWF-Malaysia, focused on coordinating a joint electric fencing initiative among neighbouring plantations. This initiative has since reached 95% completion, with efforts now centred on fence maintenance to ensure long-term effectiveness.

At the same time, a community-based voluntary team was formed in Kg. Teburi, with technical support from SWD and WWF. The team is tasked with safely diverting elephants to forested areas and receives training from SWD and WWF to enhance communication and safety in the field. To support their work, siren fences were installed at key conflict hotspots, providing early warnings of elephant presence. Awareness programmes were also held to help local communities better understand elephant behaviour and adopt safer practices.

An annual perception survey conducted in Kg. Teburi has shown encouraging results. In 2024, community members reported a stronger sense of safety and a more positive outlook on coexistence, with 30% agreeing it is achievable—up from just 7% in 2023 (Nahun 2024). Some respondents credited the joint electric fencing initiative among plantations for reducing the frequency of elephants entering community areas. These outcomes demonstrate the value of a landscape approach and continued community engagement in fostering human-elephant coexistence in the Tabin Landscape.

CHALLENGES AND OPPORTUNITIES

Challenges

Investigating the cause of elephant deaths suspected to be from chronic poisoning remains a major challenge. The wide-ranging movement of elephants and the multitude of chemicals used in plantations make it difficult to pinpoint the source of toxins. Although cadmium was detected in elephant carcasses in 2021, authorities have yet to identify its origin (Vanar 2021).

The HEC situation is currently further complicated by the ongoing replanting phase in many oil palm estates, where newly established palms are vulnerable to elephant damage. Without proper land-use planning at the landscape level and proper maintenance of electric fences, conflicts are likely to intensify. A study by Othman *et al.* (2022) found that current plantation certification standards fall short in guiding companies on managing HEC effectively. In some cases, auditors interpret any elephant deaths on estates as non-compliance, potentially jeopardizing a company's certification status (Othman *et al.* 2022). Moreover, the high operational costs associated with preventing crop damage in newly replanted areas discourage plantation companies from accommodating elephants within their landscapes.

Meanwhile, infrastructure projects such as the Pan Borneo Highway, while promising socio-economic growth, also threaten key elephant habitats. Conservation experts are often consulted too late in the project cycle, as seen in Phase 1B of the highway through Tawai Forest Reserve; by the time advice was sought, critical mitigation measures could no longer be integrated due to finalised budgets and alignments.

Opportunities

Despite the growing challenges, there remain promising opportunities to balance biodiversity conservation with human development. A recent advance is the release of the *Handbook to Mitigate the Impacts of Roads and Railways on Asian Elephants* (Dodd *et al.* 2024). Launched during a multi-stakeholder workshop in Sabah (Cheah 2025), the handbook outlines detailed design guidelines for elephant-friendly infrastructure such as viaducts, overpasses and bridges. With these technical references now available, infrastructure planners and engineers can work hand in hand with conservation NGOs, research institutions, companies, communities, and multi-sectoral government agencies to strategically place wildlife crossings and enhance their effectiveness as safe elephant passages.

Conservation NGOs and plantations are also exploring innovative coexistence measures, such as habitat enrichment or "elephant food banks". One pioneering project by Bringing Back Our Rare Animals (BORA) established 20 hectares of nutrient-rich grass along the periphery of the Tabin Wildlife Reserve to attract elephants away from nearby oil palm estates. By providing supplementary food and minerals, such initiatives may help reduce crop damage by elephants.

Conservation-based tourism offers a promising pathway for coexistence. In the Lower Kinabatangan, elephants frequently feed along riverbanks at dusk, providing exceptional wildlife-viewing opportunities for visitors (Othman *et al.* 2019). When managed responsibly, such tourism can create local jobs and generate income to help offset losses from crop and property damage. However, clear guidelines and best practices need to be developed with the tourism industry to ensure the safety of people as well as to minimise disturbance to elephants and other wildlife.

POLICY RECOMMENDATIONS

Enhancing the role of certification bodies in managing HEC

The Roundtable on Sustainable Palm Oil (RSPO) and Malaysian Sustainable Palm Oil (MSPO) certification have guided the palm oil industry toward greater sustainability by promoting stronger environmental stewardship, social responsibility, and improved management systems. However, their effectiveness ultimately depends on robust implementation and enforcement. Despite more than a decade of certification, HEC continues to occur within certified areas, demonstrating that standards alone cannot resolve such complex challenges.

Nonetheless, these certification bodies remain critical in transforming industry practices. Through closer collaboration with NGOs and government agencies, they can strengthen compliance such as ensuring that oil palm plantation companies notify wildlife authorities before replanting or installing electric fences, as such activities can exacerbate the conflict situation. Compliance frameworks should also recognise proactive efforts by landowners to make their landscapes wildlife-friendly, such as restoring riparian areas, sealing open pits or any areas that may endanger elephants, storing chemicals safely, and following guidelines when encountering elephants. Additionally, training auditors to identify persistent HEC risks will help ensure plantations adopt wildlife-friendly practices and reduce conflict more effectively.

Embedding biodiversity safeguards in road infrastructure planning

For future infrastructure projects, it is crucial to embed the mitigation hierarchy within development policies to ensure roads and highways are elephant-friendly, climate-resilient, and cost-effective. Where avoidance of sensitive habitats is impossible, impacts must be minimised by realigning routes or incorporating wildlife-friendly designs such as viaducts and underpasses to mitigate the impacts. Cost-benefit analyses should be conducted at the feasibility study stage to ensure that environmental, climate change, social, and economic considerations are fully integrated. This is to ensure that a project's benefits truly outweigh its costs. Lessons from Phase 1B of the Pan Borneo Highway highlight the need for biodiversity safeguards to be included at the earliest planning and budgeting stages, not as an afterthought.

Connecting fragmented forests for long-term survival of elephants

Although Sabah retains more than 50% forest cover and aims for 30% Totally Protected Areas by 2025, many of these forests remain small and fragmented. Given the Bornean elephant's extensive range, and increasing drought risks due to climate change (Advani 2015), connecting these fragmented habitats through ecological corridors is vital to maintain genetic diversity and support climate adaptation. Strengthening habitat connectivity should therefore be a key conservation priority integrated into state policies. Private landowners can also play a pivotal role by setting aside land for corridors or providing access through riparian buffers (already a legal requirement) that link forest patches, ensuring the long-term survival of the Bornean elephant in a shared and changing landscape.

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CHAPTER 19

Sympatric large carnivores in peril? Assessing the conservation status of the tiger, leopard and clouded leopard in Peninsular Malaysia

D. MARK RAYAN[1]*, SHARIFF WAN MOHAMAD[1], CHRISTOPHER WONG CHAI THIAM[1], AZLAN MOHAMAD[2], ENG SUE YING[2], CHING FONG LAU[3], RAMACANDRA WONG[4], KANITHA KRISHNASAMY[4] and SIVANANTHAN ELAGUPILLAY[5]

Abstract: The Malayan tiger (*Panthera tigris*), Malaysia's national symbol, is now on the brink of extinction. With fewer than 150 individuals remaining, the Malayan tiger and Peninsular Malaysia's two other big cat species: the leopard (*Panthera pardus*) and clouded leopard (*Neofelis nebulosa*), continue to face persistent threats from poaching, prey depletion, habitat loss, fragmentation, and disease. The authors attempt to provide an overview of the status of these three large carnivores based on multiple sources of data including open-source information and where possible, over a 20-year period. The Malayan tiger population has dwindled from about 250 individuals in 2014 to less than 150 in 2022, whereas leopard numbers could be as low as 280. Although there are several site-level density estimates for clouded leopards, no national level population estimate has been published for this species. This paper discusses the major threats that affect these carnivores, describes pertinent ongoing conservation initiatives, and highlights key gaps while addressing the long-term conservation pursuits and recovery of Peninsular Malaysia's three large felid species.

INTRODUCTION

Southeast Asia has the highest rates of deforestation among the tropics (Sodhi *et al.* 2004) and around 21 – 48% of regional mammal species are predicted to be extinct by 2100 (Brook *et al*. 2003). Globally, large carnivores particularly have had substantial habitat range contractions and alarmingly show dwindling populations attributing to threats such as poaching, habitat loss/fragmentation, and prey decline (Wolf and Ripple 2017; Carter *et al.* 2019; Romero-Munez *et al.* 2020). The situation is dire, particularly for large cats in Southeast Asia (Gray *et al.* 2018, Petersen *et al.* 2020; Rostro-Garcia *et al.* 2024) and Peninsular Malaysia is no different (Kawanishi 2015; Rostro-Garcia *et al.* 2019; Gray *et al.* 2021).

Malaysia harbours a total of ten wild cat species, which are divided across Peninsular Malaysia (seven species) and the Bornean states of Sabah and Sarawak (five species), with some species overlap. In Peninsular Malaysia, the three largest wild cat species are the tiger (*Panthera tigris*), leopard (*Panthera pardus*), and clouded leopard (*Neofelis nebulosa*). Globally, tigers are listed as Endangered under IUCN's Red List and fall within Appendix 1 under the Convention on International Trade in Endangered Species (CITES). Both the leopard and clouded leopard are listed as Vulnerable and fall under CITES Appendix 1 as well. Globally, the current population trend for all three species has been noted to be decreasing.

[1] Wildlife Conservation Society (WCS) Malaysia, No. 7 Jalan Ridgeway, 93200 Kuching, Sarawak, Malaysia.
[2] World Wide Fund for Nature-Malaysia, No. 1, Jalan PJS 5/28A, Petaling Jaya Commercial Centre, 46150, Petaling Jaya, Selangor, Malaysia.
[3] Perak State Parks Corporation, No. 28A Jalan Lang Indah A/1, 30010 Ipoh, Perak, Malaysia.
[4] TRAFFIC Southeast Asia, Suite 3.04, Level 3, Dataran Hamodal (Block B), Jalan Bersatu, 13/4, 46200, Petaling Jaya, Selangor, Malaysia.
[5] Member of National Conservation Assured Tiger Standards (CATS) Malaysia & Hon. Member Global Tiger Forum (GTF). No. 3 Jalan 50, Taman Bukit Mewah 43000 Kajang, Selangor, Malaysia.
***Corresponding author: mrayan@wcs.org**

But what about locally? How are tigers, leopards, and clouded leopards faring in Malaysia? What are the current and emerging threats that these animals face? What are the key conservation initiatives relevant to these big cats in Malaysia and how have these panned out?

In this review, the latest information available on these big cats were synthesised by drawing upon open source and other available sources of information to address these questions, and conclude by highlighting the need to integrate science-based information, threat assessments and other key management perspectives so that a better understanding of the conservation status of Malaysia's three large felid species can be realised and meaningfully pursued for their long-term conservation and recovery.

PENINSULAR MALAYSIA'S THREE BIG CATS

Seven species of wild cats are found in Peninsular Malaysia – the tiger, leopard, clouded leopard, Asiatic golden cat (*Catopuma temminckii*), mainland leopard cat (*Prionailurus bengalensis*), marbled cat (*Pardofelis marmorata*) and flat-headed cat (*Prionailurus planiceps*). The tiger, leopard, and clouded leopard generally fall within the definition of large mammals, having a body weight of over 20 kg (Morrison *et al*. 2007; Jayadevan *et al.* 2020). Although clouded leopards fall within the lower range, their maximum size can exceed 20 kg (Francis 2019).

Malayan tiger (*Panthera tigris*)

Over the decades, national-level population 'guesstimates' of the Malayan tiger (Figure 1) have gradually grown more precise with the advances in scientific monitoring methods and analysis. In 1950s, Peninsular Malaysia was thought to have about 3,000 wild tigers (Locke 1954), which was revised to 600 – 650 individuals (Khan 1987), and later to around 500 tigers towards the early mid-2000s – a figure derived based on the possibility Malaysia had at least one tiger per 100 km^2; and its expected habitat range was about 50,000 km^2 (Kawanishi *et al*. 2003; DWNP 2008).



Figure 1. Malayan tiger (Source: WCS Malaysia).

Despite more than 20 years of camera-trap monitoring, there is still a startling paucity of published and statistically robust tiger density estimates for Malaysia. The first analogue camera-trap survey for tigers (1997 – 1999) across nine sites in Peninsular Malaysia (Lynam *et al.* 2007) yielded insufficient data for a capture-recapture analysis. The first publication using a robust Mark-Capture-Recapture (MCR) framework was from Taman Negara National Park (1.10 ± 0.52 to 1.98 ± 0.54 tigers per 100 km^2), spearheaded by a Japanese researcher, Kae Kawanishi (Kawanishi and Sunquist 2004). This was followed by the second published tiger population estimate in Gunung Basor Forest Reserve in Kelantan (2.59 ± SE 0.71 tigers per 100 km^2) by Rayan and Mohamad (2009).

In 2014, the lead author, through a collaborative effort via the Malaysian Conservation Alliance for Tigers (MYCAT), collated tiger density estimates from two sites in Perak (Rayan and Linkie 2015), and five different sites within Kelantan, Terengganu, Pahang and Johor from surveys conducted between 2010 – 2013 (unpublished). Three of the seven camera trap surveys were also reanalysed employing the newer established robust Spatially Explicit Capture-Recapture (SECR) framework to derive a more comparable and realistic density estimate across the sites. From this exercise, the compelling evidence indicated that there could only be 250 – 340 tigers remaining in Malaysia based on extrapolation of the available tiger habitats. This was the first nationwide extrapolated tiger estimate which incorporated actual robust densities estimates from several sites in Malaysia.

With the exception of Royal Belum State Park that had almost two tigers per 100 km^2, the average density estimate was close to 0.5 per 100 km^2, suggesting earlier assumptions of having at least one tiger per 100 km^2 and the corresponding guesstimate of 500 tigers nationwide were likely: (1) overestimated and erroneous from the start, (2) reflected genuine population decline over a decade or so, or (3) both. A joint press statement by the Department of Wildlife and National Parks (PERHILITAN) and MYCAT subsequently announced that Malaysia may have as few as 250 tigers remaining (WWF-Malaysia 2014), contributing to the revision of the Malayan tiger's IUCN status to Critically Endangered in 2015 (Kawanishi 2015).

Though the SECR framework is now used as the standard for estimating tiger population densities, only two known studies using such a framework have been published in Malaysia: one from Belum-Temengor (0.61 – 1.95 tigers per 100 km^2) in Perak (Rayan and Linkie 2015) and another from Kenyir (0.15 – 0.53 tigers per 100 km^2) in Terengganu (Lam *et al.* 2023). The report from the 1st National Tiger Population Survey (2016 – 2020) has yet to be published, but publicly announced official figures state that fewer than 150 tigers remain in Malaysia. Coupled with the fact that tiger densities are well below a threshold of one tiger per 100 km^2 (except for Royal Belum State Park), these findings paint a bleak scenario, but one that warrants greater scrutiny at the site-level.

There is limited published information on prey preference of tigers in Peninsular Malaysia. Early evidence from tiger scat samples in Taman Negara—albeit with a limited sample size of three – identified sun bear, cattle and pangolin as prey species (Kawanishi and Sunquist 2004), although these are unlikely the tigers' preferred or main prey species. A more recent publication by PERHILITAN used DNA metacoding to analyse tiger scats from five localities in the states of Perak, Kelantan and Terengganu (Gani *et al.* 2024). Surprisingly, no evidence of barking deer, wild boar or sambar deer was detected. From the six scat samples obtained from human-tiger conflict areas, the primary prey selection of tigers primarily consisted of livestock (86%) from the genus *Bos* (cattle), *Bubalus* (buffalo), *Capra* (goat) and *Gallus* (chicken). The remaining four scat samples were taken from a protected area and had predominantly medium-sized prey (90%) comprising the genus *Canis* (dogs) and *Capricornis* (serow). Tigers typically prey on large ungulate species such as wild boar and sambar deer (Hayward *et al.* 2012), and may also prey on other large ungulate species such as serow (>100kg) and even gaur (up to a tonne), although these species are less common and patchily distributed. Barking deer is one of the most common ungulate species detected based on camera-trapping rates, but their smaller size and agility may make them less energetically favourable prey. Tapirs would perhaps be an ideal size as they can weigh upwards of 300kg, but evidence of tiger predation on this species remains scarce at best.

Leopard (*Panthera pardus*)

Leopards are highly adaptable but now only occur in about 36% of their historical range in Malaysia (Rostro-García *et al.* 2016). Despite this, Peninsular Malaysia was recognised as one of only two remaining leopard strongholds in Southeast Asia, although the authors of this publication were cautious to state that this could change due to recent evidence of leopard poaching (Rostro-García *et al.* 2016).

Leopards in Peninsular Malaysia are predominantly melanistic (Kawanishi *et al.* 2010), while the spotted variant has only been recorded in a handful of localities including Endau Rompin, Ulu Muda and Lenggong (Mohamad *et al.* 2023). Within these localities, the spotted variant (Figure 2) is thought to be more common in the Endau Rompin Landscape based on camera-trapping data by WCS Malaysia.



Figure 2. Spotted leopard (Source: WCS Malaysia).

Peninsular Malaysia is estimated to have 282 – 847 leopards (Rostro-García *et al.* 2016), based on a total area of confirmed and potential distribution of 47,051 km^2 multiplied by an inferred density of 1 to 3 leopards per 100 km^2, whilst assuming 60% occupancy. A similar density range assumption pattern that was used for tigers has also been applied to leopards in this study, and so the figures might well be flawed with similar undertakings used for tigers previously. Therefore, this warrants cautionary interpretation on national-level figures.

Since the majority of leopards in Peninsular Malaysia are melanistic, distinguishing each individual using coat patterns is extremely challenging. However, it was discovered that the almost-indiscernible rosette patterns on melanistic leopards (Figure 3) become visible via infrared camera-trap images taken under low-light conditions. A novel camera -trapping study by Hedges *et al.* (2015) developed a modified camera-trap method that forces the usage of infrared flash during both day and night, allowing rosettes to be detected consistently. This study resulted in providing the first density estimate of melanistic leopards in Malaysia.

Using this method, several density estimates have been obtained using the SECR method, which ranges from 0.98 per 100 km^2 (Pasir Raja, Terengganu, to 2.64 per 100 km^2 in Taman Negara National Park (Rostro-Garcia *et al.* 2024), to 3.00 per 100 km^2 in the Kenyir Wildlife Corridor in Terengganu (Hedges *et al.* 2015). Leopard density estimates from another study (Lam *et al.* 2023), which did not use the forced infrared flash to enhance the leopard rosettes in Kenyir, Terengganu ranged from 2.53 – 2.74 per 100 km^2, was derived using a Space-to-Time Event (STE) framework rather than SECR. The STE approach assumes random camera-trap placement, a requirement lacking in their study design, which therefore warrants cautious interpretation of these estimates and limited direct comparison with SECR-based estimates.



Figure 3. Melanistic leopard (Source: WCS Malaysia).

Although leopards are agile climbers and often feed on primates, they appear to prefer medium-sized ungulate prey within the range of 10 – 40 kg, where available (Stein *et al.* 2025). Two ungulate species in Malaysia fall within this range: barking deer and wild pig. Some studies in India and Nepal have found wild pig to be a preferred leopard prey species, alongside barking deer, sambar deer, and hog badger in Thailand (as referenced in Rayan and Linkie 2016). However, there is extremely limited information on actual leopard prey preference in Malaysia and no published DNA analyses of leopard scat samples in Malaysia are currently available.

Clouded leopard (*Neofelis nebulosa*)

The clouded leopard (Figure 4) is believed to have a relatively wide distribution across Peninsular Malaysia. A recent habitat suitability assessment identified Malaysia as having the highest mean suitability for the species across its range, followed by Laos, India, and Cambodia (Abedin *et al.* 2024). Based on these findings, it was suggested for these countries to be prioritised for conservation of the species, amidst projected substantial habitat loss/ degradation from deforestation, land-use change, and climate change. Using detection/ non-detection camera trap data from Peninsular Malaysia, Tan *et al*. (2017) found that the habitat use of clouded leopard increased (i) further away from water bodies, (ii) in higher number of smaller fragmented forest patches, (iii) at higher elevations, and (iv) in sites with higher average forest change values. These findings suggest that the species might use recently disturbed forests or adapt well to changing landscapes.

Although there is no national-level population estimate for clouded leopards, several site-level density estimates using the SECR framework have been recorded and published. The first ever density estimates for the mainland clouded leopard, conducted in Belum -Temengor, Perak, reported densities of 3.46 ± SE 1.00 per 100 km^2 in Temengor Forest Reserve and 1.83 ± SE 0.61 per 100 km^2 in Royal Belum State Park (Mohamad *et al.* 2015). The estimated density of clouded leopard in Gunung Basor, Kelantan was 1.15 ± SE 0.35 per 100 km^2 (Razak *et al.* 2019) and in Kenyir, Terengganu ranged from 0.99 to 1.25 per 100 km^2 (Lam *et al.* 2023) across three different years.

Clouded leopards have been known to prey upon a variety of arboreal and terrestrial prey including hog deer, slow loris, brush-tailed porcupine, pangolin, squirrels, primates, muntjac and argus pheasant (Gray *et al.* 2021). In Belum-Temengor, clouded leopard habitat use was found to be highly influenced by the availability of small and medium prey species such as pig-tailed macaques, porcupine, mouse deer, and small carnivores (Mohamad *et al.* 2015).



Figure 4t. Clouded leopard (Source: WCS Malaysia).

Interspecific interactions among the three big cats

The Malayan tiger, leopard and clouded leopard overlap in distribution and habitat across Peninsular Malaysia (DWNP 2017). However, population dynamics among these sympatric carnivores remain complex, particularly regarding their spatial and temporal relationships. A prominent pattern of spatial avoidance by leopards in areas with high tiger abundance has been documented in India, where leopards are forced to occupy poor quality habitats outside protected areas, resulting in increased conflict with humans (Harihar *et al.* 2011). In areas where leopards are absent, clouded leopards exhibit stronger temporal avoidance of tigers (Sunarto *et al.* 2015). The smaller size difference and physical capabilities of leopard and clouded leopard are hypothesised to result in stronger avoidance between these two species (Sunarto *et al.* 2015).

Leopards and clouded leopards may occur at higher densities where densities of larger cat species such as tigers are lower (Harihar *et al.* 2011; Gray *et al.* 2021). This pattern was observed in Belum-Temengor, where it was found that the density of clouded leopards was almost two times higher and leopard relative abundances were almost five times higher in Temengor Forest Reserve than Royal Belum State Park (Mohamad *et al.* 2015; Rayan and Linkie 2016), where tiger density in Royal Belum State Park was three-fold higher than in Temengor Forest Reserve (Rayan and Linkie 2015). The higher ungulate prey base in Royal Belum likely supported greater tiger densities, which in turn may have suppressed leopard abundance and influenced fine-scale behavioural avoidance from leopards (Rayan and Linkie 2016). Similar tiger-mediated interactions have been documented in Nepal and India, where a bottom-up effect on tigers by large prey availability consequently exerted a top-down regulative effect on leopards and dholes (Seidensticker *et al.* 1990; Odden *et al.* 2010; Harihar *et al.* 2011; Mondal *et al.* 2012). However, such regulatory effects may diminish when tiger densities fall below one adult tiger per 100 km^2 (Rayan and Linkie 2016), which reflects the current scenario in Malaysia.

CURRENT AND EMERGING THREATS

Habitat loss/ degradation/fragmentation

Forest conversion

A report by RimbaWatch (2023) indicates that close to 2% of forest cover in Malaysia was lost between 2017 and 2021, declining from 18,332,583 ha to 17,983,338 ha. Timber plantations were identified as the main driver of deforestation during this period, accounting for 41.6% of total forest loss, followed by oil palm plantations (15.5%). In Peninsular Malaysia, forest loss was highly concentrated in Pahang and Kelantan, which collectively lost 158,627 ha, while Perak, Johor, Terengganu and Kedah each recorded losses between 7,000 and 9,000 ha between 2017 and 2021 (RimbaWatch 2023). Even more concerning, the report further

projected that Malaysia could lose over 2.3 million hectares of forest in the future due to timber plantations and oil palm plantations, potentially reducing the national forest cover to below the 50% committed threshold. Kelantan and Pahang are also projected to experience the highest future losses, overlapping with existing key strongholds of tigers, and likely leopards and clouded leopards, raising significant conservation concern.

Another key aspect that is often ignored in relation to habitat loss for big cats in Malaysia is that certain habitats are likely to harbour higher nutritional resources for big cat prey. Lowlands are especially important for most of these prey species. In Belum-Temengor, occupancy of key ungulates such as sambar deer, barking deer, and gaur was higher at lower elevations (Rayan and Linkie 2020). There also seems to be a larger concentration of saltlicks at lower elevations – from Belum-Temengor, out of the >70 saltlicks recorded, approximately 80% were situated below 500 m above sea level (WWF-Malaysia, unpublished data). In fact, about 45% of the saltlicks were at lowlands <300 m in elevation, despite limited remaining lowland habitat due to inundation from the construction of Temengor Dam back in the 1970s (Mohamad *et al.* 2023).

Forest degradation

Logging practices may not cause complete large scale forest loss but can significantly reduce and degrade habitat quality. About 60% of Peninsular Malaysia's Permanent Reserved Forests are production forests subject to logging, while the remaining 40% are classified as protection forests (Forestry Department of Peninsular Malaysia 2023). Secondary forests subjected to selective logging may still harbour many wildlife species and may theoretically result in an increase in ungulate density due to a presumed higher availability of browse material (Rayan and Mohamad 2009). However, selecting logging can severely degrade soil and river systems, at the same time lead to canopy disruptions, road expansion, and increased access for poaching, all of which likely outweigh the potential benefits from a presumed increase in browse materials for ungulates (Free Malaysia Today 2022). Consequently, prey densities and predator carrying capacity are often reduced in these impacted areas.

Forest degradation also threatens a more specific tiger prey resource – saltlicks. Under the Wildlife Conservation Act 2010 (WCA 2010), it is an offence to disturb salt licks, where hunting, trapping, building platforms and possession of weapons is prohibited within a 400 m radius from saltlicks. Saltlicks are not explicitly recognised under the *National Forestry Act 1984*, and although the Malaysia Criteria and Indicators for Sustainable Forest Management (Criterion 6.2) calls for the protection of rare, threatened and endangered species and their habitats, including saltlicks, management interventions remain insufficient. For example, the Special Area Plan for Royal Belum State Park designates only a 40 m buffer around saltlicks in production forests. Out of the 40 identified saltlicks, only one saltlick was formally classified as a High Conservation Value Forest (HCVF), with an area size of 0.002 ha. Such minimal buffering is likely insufficient for key species such as sambar deer (Rayan *et al.* 2013). Furthermore, saltlicks and their buffer areas are highly interdependent owing to their ecological functionality, and need to be managed as one. Without official recognition and incorporation into forest management plans, saltlicks remain vulnerable to disturbance from commercial logging and increased accessibility for poachers.

Forest fragmentation

Forest fragmentation isolates big cat individuals into smaller pockets of habitat, reducing genetic diversity, as well as increasing the risks of inbreeding and local extirpation. Large-scale linear infrastructure such as roads, highways and railways increasingly bisect the previously contiguous forest blocks, and restricts wildlife movement, dispersal, and gene flow between subpopulations (Laurance *et al.* 2009). Roads also provide easy access for humans intruding into remote forested areas, indirectly intensifying threats such as poaching, illegal encroachment, and resource extraction.

Roadkill incidents involving wildlife have emerged as a significant and increasing anthropogenic threat in Malaysia, particularly in regions where forest fragmentation and linear infrastructure intersect into key wildlife habitats. Between 2012 and 2024, PERHILITAN reported at least 5,554 wildlife roadkill incidents in Peninsular Malaysia, with more than 3,300 cases involving mammals. At least six adult Malayan tiger deaths were reported from vehicle collisions between 2023 – 2024 alone, compared to only one recorded case between 2008 – 2020 (Ten *et al.* 2021). Nine leopards were reported killed by vehicles between 2020 – 2024. Data on clouded leopard road kills were not published, but at least four records related to clouded leopard road collisions were found online, all from 2021 – 2024 (Astro Awani 2021a; Harian Metro 2023; Sinar Harian 2023; Bernama 2024).

Although the number of roadkill records for large cats are lower than those recorded for Malayan tapir (200 cases), wildlife mortality on roads has been increasingly prevalent. The death of breeding individuals is especially consequential for species that are now left with critically small numbers in the wild. For example, a female tiger that was struck by a lorry on the Gerik-Jeli Highway in November 2024, had raised four cubs to maturity over a year prior to the tragedy. The death of such an individual directly reduces reproductive output and may skew the local sex ratios, thereby disrupting the population and its social dynamics within a site.

Poaching and illegal trade

Poaching for illegal trade remains the most immediate threat to large felids in Peninsular Malaysia, particularly the critically endangered Malayan tiger. Despite intensified enforcement efforts in recent years, poaching for international trade and local markets (including traditional medicine, talismans, bushmeat and other products) continues to exert severe pressure on the already depleted populations of large felids and their prey species.

Analysis of seizure records involving tigers, leopards and clouded leopards in Peninsular Malaysia from 2006 – 2025 revealed there were 74 known cases over the 20-year period (Figure 5). These records were gathered from open-source media, government and partner records, and exclude cases involving zoos, captive facilities and those linked to human-wildlife conflict. It is therefore assumed that animals from these 74 cases were poached from wild populations in Peninsular Malaysia to supply illegal trade.

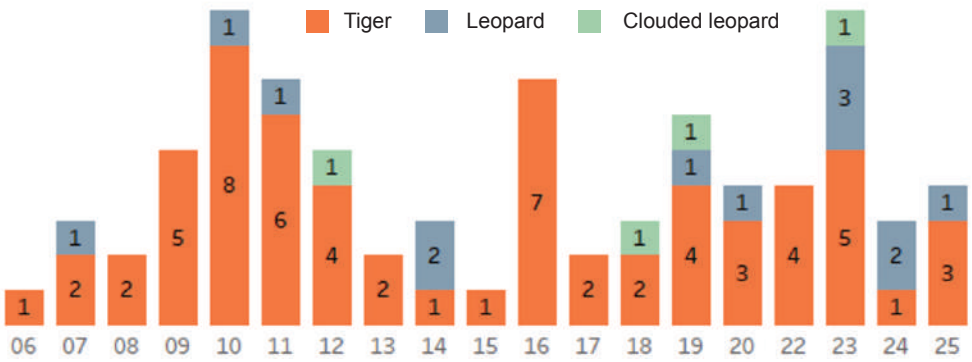

Figure 5. Seizures involving tigers, leopards and clouded leopards in Peninsular Malaysia from 2006 – 2025.

The majority of the incidents involved tigers (86%), followed by leopards (18%) and clouded leopards (4%), with several seizures involving multiple species and therefore, these percentages are not additive. Seizure data does not necessarily reflect the true scale of poaching, as they reflect only intercepted cases and are heavily influenced by enforcement effort and detection probability. The actual magnitude of such illegal activity is thus likely

underestimated. Records do not always indicate subspecies level, particularly for tigers. Nonetheless, even relatively small numbers are deeply concerning for Malaysia, where the national wild population is estimated to be fewer than 150 individuals.

These 74 incidents involved minimum estimates, with 116 equivalent big cats that entered the illegal trade chain; 77% involved tigers (n = 90), 19% leopards (n = 22) and 4% clouded leopards (n = 4). The estimation approach follows Wong and Krishnasamy (2025), with adaptations to also account for leopards and clouded leopards. Trafficking volumes experienced significant fluctuations over the two decades analysed, with an average of six big cats confiscated per year, with peaks exceeding 10 – 25 individuals in certain years (notably in 2015), while 11 years recorded only 0 – 3 individuals, likely reflecting under-detection (Figure 6). Recent trends suggest increased trafficking of leopards alongside reduced tiger seizures, potentially indicating substitution of tigers with leopard and other felids, although further data are needed to confirm this pattern in Malaysia.

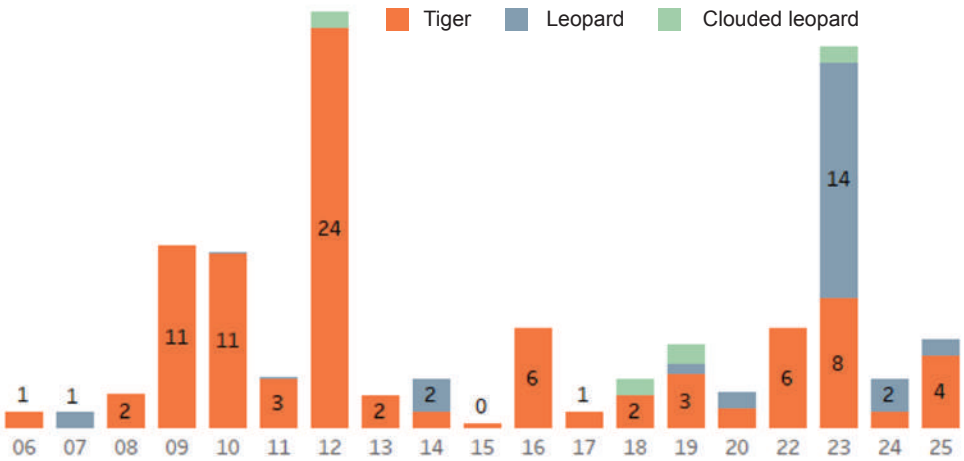

Figure 6. Estimated volume of confiscated big cats from 2006 – 2025.

In terms of tigers, leopards, and clouded leopards that have been seized by the authorities, about 978 individual commodity items (whole animal and its bodily parts) were confiscated over a 20-year period. The most commonly seized parts were claws and teeth, accounting for 402 and 161 items confiscated, respectively (Table 1). Leopard claws and teeth accounted for an increasingly larger share of confiscated body parts in recent years, suggesting a possible partial substitution of leopards for tigers within the trade networks.

Table 1. Big cat parts confiscated from 2006–2025.

	Tiger	Leopard	Clouded leopard	TOTAL
Claw	133	230	39	402
Teeth	114	44	3	161
Body parts (Other)	105	60		165
Bone	97			97
Skin (whole)	34		1	35
Skin (piece)	33			33
Meat	17	14		31
Head and skull	22	1		23
Individual - Dead	18	4		22
Individual - Live	5	2	1	8
Skeleton	1			1

` At the State level, Kedah recorded the largest number of big cats confiscated (36 equivalent animals), despite ranking 5th in seizure incidents (7 cases), largely due to the major 2012 wildlife bust in Kedah involving at least 22 tigers. In this case, a 29-year old Malaysian man was found with eight tiger skins, 22 tiger bone pieces including whole skulls, six African elephant tusks, and an antelope horn. Pahang state recorded the highest number of seizure incidents involving big cats (16 cases), involving at least 32 animals (Figure 7 and 8). While tiger seizures were actively pursued across the peninsula, leopard and clouded leopard seizures were concentrated in fewer states (Figure 9).

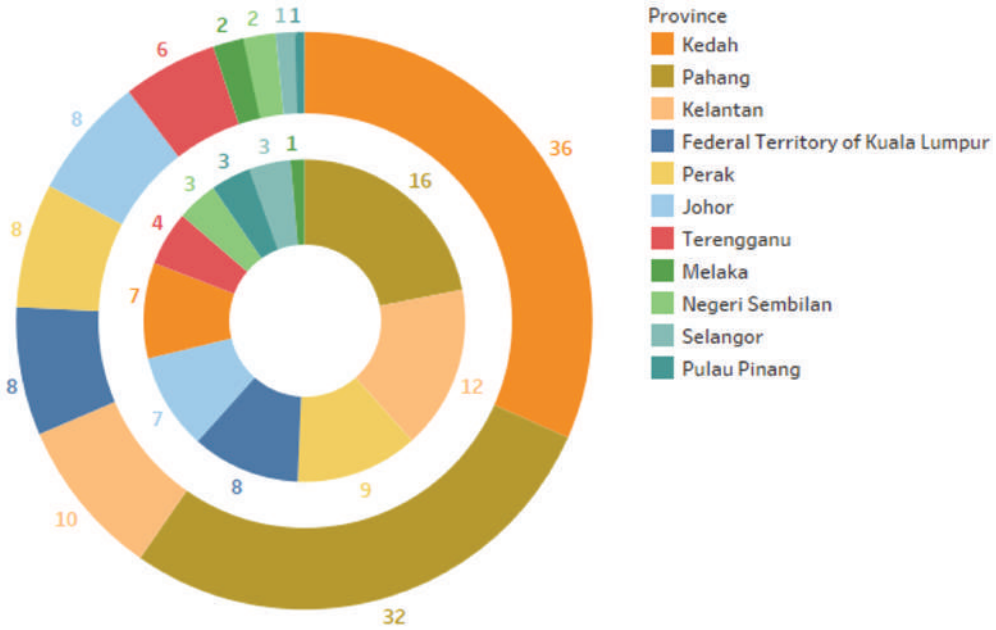

Figure 7. Distribution of seizures and volumes confiscated by state from 2006 – 2025. (Inner ring: seizure incidents; Outer ring: individuals confiscated).

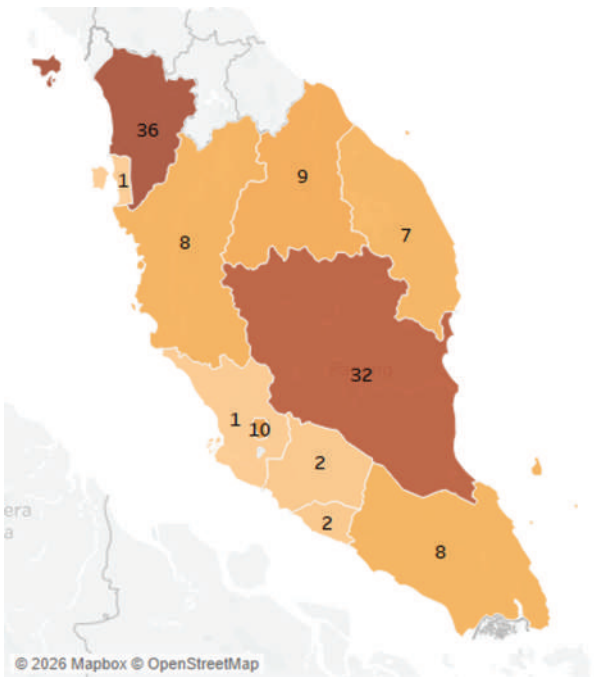

Figure 8. Confiscated big cat individuals by state from 2006 – 2025.

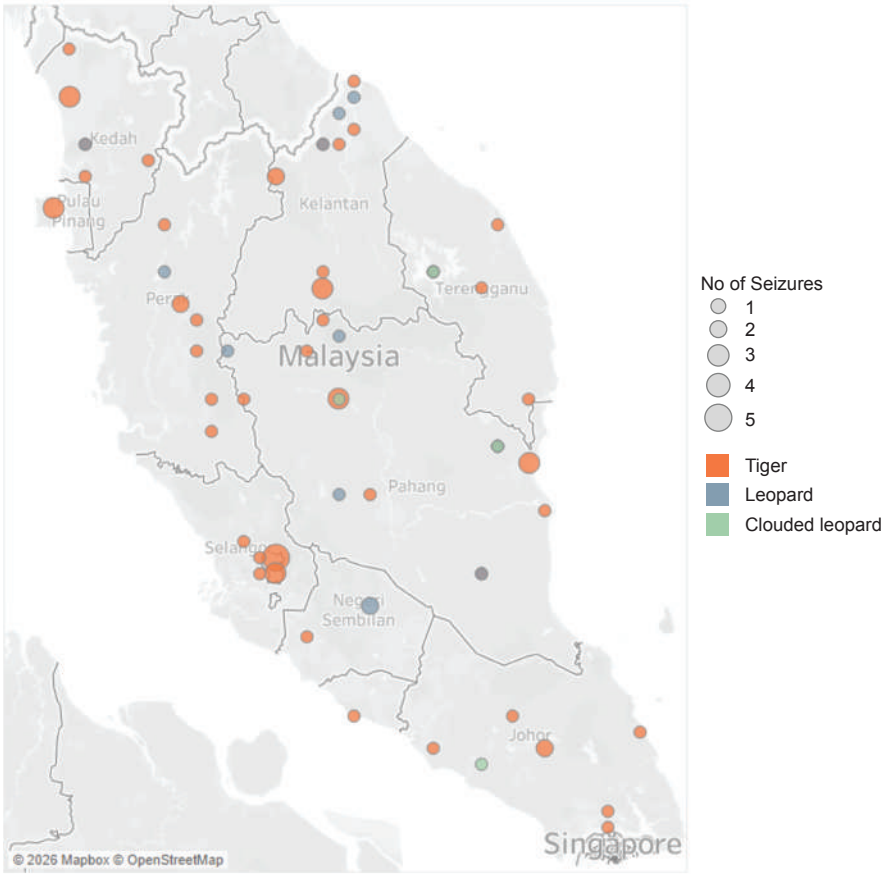

Figure 9. Big cat seizure hotspots in Peninsular Malaysia from 2006 – 2025.

Of the 74 cases analysed, at least 60 cases resulted in the arrest of 130 individuals. Available prosecution records indicate that 68 individuals were charged with violating relevant wildlife protection laws, which resulted in monetary fines for 40 individuals and jail sentences for at least 35 individuals.

Since WCA 2010 came into force, jail sentences for wildlife crimes have ranged from one month to ten years, with an average of 40 months and a median of 27 months. Monetary fines ranged from RM350 to RM1.56 million, averaging at RM230,000 with a median of RM15,000. Penalties varied considerably depending on the specific factors such as number of suspects charged, variety of species and parts involved, nature of the charges, with few extreme outliers that heavily impact the average.

For several suspects, judicial proceedings may still be ongoing though in many of these cases, the outcome is unknown to the authors. Apart from Malaysians (about 52%), cases also show the involvement of Vietnamese, Indonesian, Thai, Cambodian, Burmese and Chinese nationalities, reinforcing the fact that big cat poaching and trafficking is impacted by international trafficking syndicates, and likely facilitated by Malaysians.

In Malaysia and across many other Southeast Asian countries, many poachers deploy wire cable snares to target large mammals and commercially target valuable species such as tigers, leopards, and sun bears (Belecky and Gray 2020). However, snares are inherently indiscriminate and frequently entrap non-target species, resulting in severe depletion of the key prey species such as sambar deer, serow, barking deer and other ungulates that sustain carnivore populations. In addition, some snares are not checked by

the poachers, resulting in the snared wildlife, including tigers being left to die. In Belum-Temengor, snaring is believed to have contributed to >50% decline in tiger population (Says 2019). Prior to this, WWF-Malaysia recorded a dramatic increase in snares, particularly linked to Indochinese poachers. However, this declined after intensified patrolling and reduced movement during the COVID-19 pandemic.

PERHILITAN's annual reports showcased that over 4,300 snares were removed from forests across Peninsular Malaysia between 2019 and 2024 (Table 2). Although it is unclear if these were all active snares or if they include remnants, the actual number of snares deployed is likely far higher than the figures reported, as many more would have gone undetected. While many cases involved foreign poachers and are often associated with organised wildlife trafficking syndicates (Lam *et al.* 2023), local involvement was also found to be significant, and they too were implicated in more than 50% of the seizure incidents analysed. This is a serious cause for concern as the narrative on poaching over the past two decades has been largely confined towards Indochinese poachers. This needs an in-depth assessment to investigate local poachers and their network of underlying syndicates. The blatant disregard by local poachers in exploiting wildlife is best shown from the recent case of a tiger that was snared and found in the trunk of a car in Johor (The Straits Times 2025).

Table 2. Number of snares removed across Peninsular Malaysia by the *Operasi Bersepadu Khazanah* and Community Ranger programs between 2019 and 2024.

Year	Snares removed by *Operasi Bersepadu Khazanah*	Snares removed by Community Rangers
2019	218	-
2020	672	128
2021	303	456
2022	440	594
2023	270	559
2024	400	260
Total	**2,303**	**1,997**

Source: Annual reports of PERHILITAN

Prey loss

Key prey species for the three large felids in Peninsular Malaysia include sambar deer, bearded pig, wild boar and barking deer, with some overlaps based on prey preferences and predator-prey mass ratio. However, habitat loss, poaching, and disease outbreaks have severely threatened the prey population.

Prey depletion is driven by both local hunting for consumption and trade (New Straits Times 2026a), as well as illegal poaching by organised Indochinese syndicates (MYCAT 2012). Due to the decline in sambar deer population, the Malaysian government has imposed a hunting moratorium in 2009 as a measure for population recovery (Kawanishi *et al.* 2014) and has proposed upgrading the species to Totally Protected under the WCA 2010. Even then, the bigger problem still lies with in having enough enforcement capacity to intensively detect and effectively deter poaching activities.

Disease outbreaks, particularly the African Swine Fever (ASF), have recently caused substantial decline in the wild pig population in the country (WCS Malaysia, unpublished data; WWF-Malaysia, unpublished data; PSPC, unpublished data). In the southern region, the effect is more apparent on bearded pigs (WCS Malaysia, unpublished data). ASF was first detected in Malaysia in Sabah in February 2021, before spreading into Sarawak in July 2021 (World Animal Health Information System 2023). At the end of 2021, the first ASF

case was detected in Peninsular Malaysia – from wild boar carcasses found in Batang Padang District, Perak. Subsequently, cases were detected exponentially in the wild, in which 85 cases of wild boar and five cases of bearded pigs, were reported dead (World Animal Health Information System 2023).

Camera-trap surveys in Belum-Temengor and Endau Rompin showed a sharp decline in detecting the presence of wild boar and bearded pig after 2021 (WCS Malaysia, unpublished data; WWF-Malaysia, unpublished data). To highlight the severity of the disease, data from Endau Rompin showed a decline of 99% for bearded pigs and 81% for wild boar between 2021 and 2023, which also correlates with increased tiger attacks on cattle (Malay Mail 2025). Despite these downward trends, signs of breeding in both pigs and tigers in Endau Rompin were observed during camera trapping surveys in 2024, with fewer reported cases of human-tiger conflict in 2024 – 2025.

During the ASF outbreak in Royal Belum State Park in 2022, the wild boar population crashed within a short period of two months, where carcasses were largely spotted during November and December. Samples collected from two carcasses in December 2022 tested positive for ASF. There were also earlier reports of wild boar carcasses from adjacent Temengor Forest Reserve discovered in September 2022, followed by reports from Bang Lang National Park in southern Thailand later during the end of the same year. These anecdotal observations demonstrated how the highly contagious and deadly ASF virus infected the wild boar population across a vast contiguous forest landscape. Wildlife monitoring through camera trapping in Royal Belum State Park and adjacent forests revealed that the population of wild boar in the area suffered a 99% decline between 2021 and 2025 (WWF-Malaysia, unpublished; Perak State Parks Corporation, unpublished). Two and a half years after the outbreak first started, the wild boar population has still not shown any positive signs of recovery.

PERHILITAN annual reports (2019 – 2024) indicated a 9% decline (225 cases) of wild boar conflict cases in 2022 and a 44% decline (1,000 cases) in 2023 (Figure 10). Across six states with the highest recorded cases of wild boar and tiger conflicts; the decline in wild boar conflicts appeared to coincide with the increase in tiger and leopard conflict cases (Figure 11). There was no available published data for 2022. Although there is the potential for over- or under-estimation of wildlife conflict reports and the trend is not proof of a direct causal effect, the data does indicate a correlation between the decline of wild boar and increase of big cat-human conflict which warrants further scrutiny.

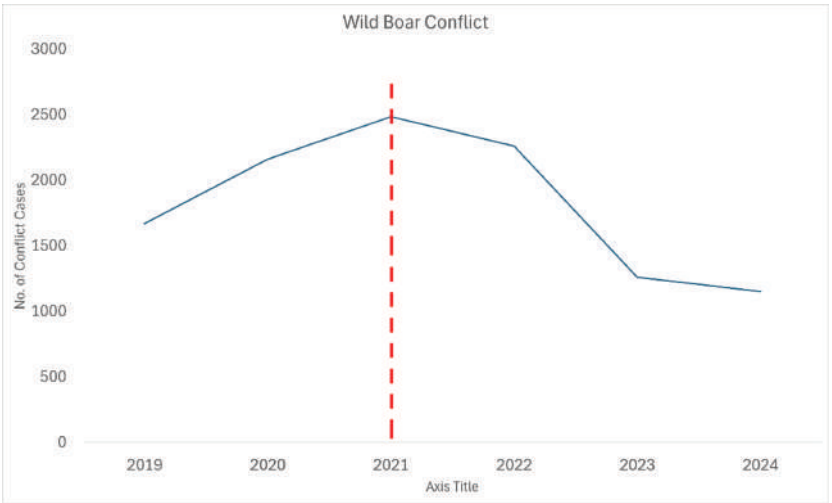

Figure 10. Reports of wild boar conflict in Peninsular Malaysia before and after African Swine Fever was first detected in 2021 (indicated by the red line).

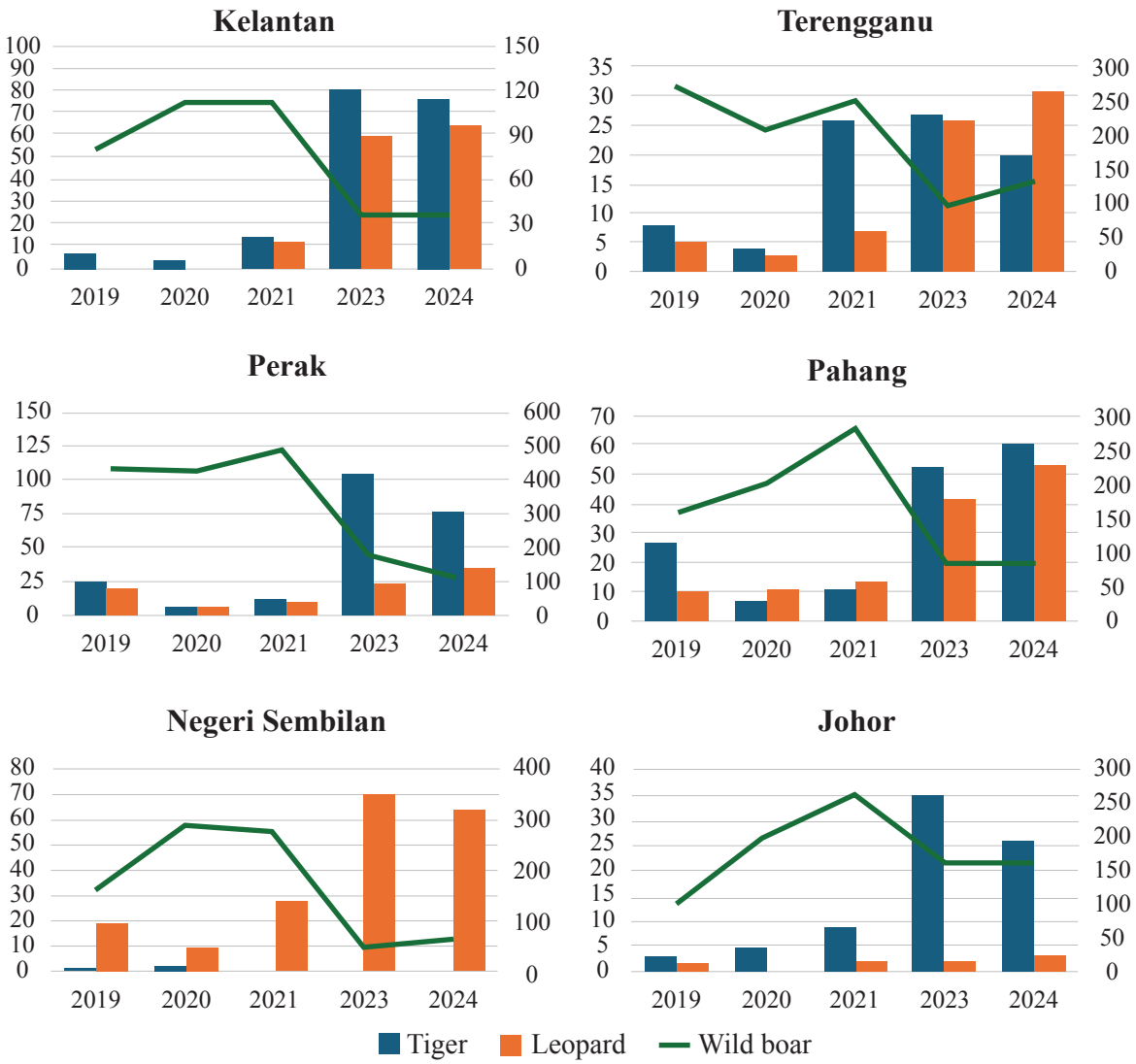

Figure 11. Cases showing the trend of conflicts involving tigers, leopards, and wild boar in Kelantan, Terengganu, Pahang, Perak, Negeri Sembilan and Johor two years before and after African Swine Fever was first detected in 2021.

ASF is probably the best known and devastating disease affecting swines. Apart from this, wild boar is also susceptible to other diseases such as the classical swine fever, Aujeszky's disease, and porcine circoviruses and parvoviruses (Nisavic *et al.* 2021). Other tiger prey species such as gaur and sambar deer are susceptible to diseases as well. From captive gaur research in Malaysia, some of the recorded infectious diseases include brucellosis, foot and mouth disease, lumpy skin disease and cowpox (Rosli *et al.* 2023). However, there is an absence of substantial published data of infectious diseases amongst local wildlife, and how such diseases impact wild populations.

Diseases directly impacting the three big cat species

Over the past two decades, several diseases have been recorded directly affecting tigers, leopards and clouded leopards. Avian influenza H5N1 has caused the death of captive tigers, leopards and clouded leopard in Thailand (Keawcharoen *et al.* 2004; Dudley 2012); whilst sporadic reports of SARS-CoV-2 (Covid-19) have been detected in tigers and

leopards (Forbes 2021; Independent 2022). In this millenia, Malaysia has experienced four waves of H5N1 outbreaks in 2004, 2006, 2007 and 2017 (Wan Norulhuda and Tariq 2018), but no published reports on the detection of H5N1 or even the recent SARS-CoV-2 was reported for tigers, leopards or clouded leopards in Malaysia.

Canine Distemper Virus (CDV) is a highly contagious disease with a high mortality rate that affects domestic dogs and all families of terrestrial carnivores. CDV affects the central nervous system, resulting in disorientation in the affected animals (Deem *et al.* 2000; Gilbert *et al.* 2020, 2023). The first confirmed case in Malaysia involved a tiger in Terengganu in July 2019, where a tiger was sighted roaming around Kampung Besul unfazed by the presence of humans. Following that, CDV cases in tigers began to emerge in Mersing, Johor (New Straits Times 2020), Gua Musang, Kelantan (New Straits Times 2022), and the most recent case at Chemor, Perak (Perak Department of Veterinary Services 2026). CDV has also been detected in a clouded leopard in Perak (Astro Awani 2021), while no confirmed cases have been reported for leopards in Malaysia. Aside from CDV, other domestic animal diseases such as feline parvovirus and feline immunodeficiency virus have been reported for wild tigers, but these viruses have not been documented in Malaysia (Lazarus *et al.* 2025).

Human-wildlife conflict

Human-wildlife conflict (HWC) refers to negative interactions between humans and wildlife, often perceived as threats to human activities including livelihoods, livestock, and safety. Such interactions often lead to mitigation responses and in severe cases, retaliatory killing or removal of wildlife (Ten *et al*. 2021; South China Morning Post 2024; New Straits Times 2025a; New Straits Times 2026b). Rapid land-use changes such as deforestation, agricultural expansion, and infrastructure development driven by human population growth are widely recognised as key factors influencing the occurrence and trends of HWC (Shevade *et al.* 2017; Morales-González *et al*. 2020). This is further exacerbated by prey declines linked to ASF outbreaks (Luskin *et al*. 2020), which may push large carnivores toward livestock and edge habitats, increasing conflict incidence (Braczkowski *et al*. 2018; Lubis *et al.* 2020).

Compiled data from PERHILITAN's annual reports and published materials from 2005 to 2024 illustrate incident trends of HWC with Malayan tigers, leopards, and clouded leopards (Figure 12). Incidents classified as conflicts are not limited to livestock depredation and wildlife attacks towards humans, but also include pugmark reports and direct sightings (Ten *et al.* 2021; DWNP 2005–2024). It is also not known whether each HWC genuinely involved the three big cat species, or whether some sightings were misidentified. Data obtained for years 2014, 2018, and 2022 were incomplete due to inaccessibility to or the lack of HWC details in those annual reports.

Human-wildlife conflict data (DWNP 2005–2024) indicates that tigers consistently represent the highest number of carnivore conflict cases in Peninsular Malaysia, with more than 1,700 reported cases between 2005 and 2024. A notable peak occurred in 2005 (133 cases), followed by a recent surge in 2023 (316 cases) and 2024 (264 cases) (Table 3, Figure 11). Despite a decline in the tiger population (Ten et al. 2021), the number of human-tiger conflict incidents remains relatively high. At the State level, Pahang recorded the highest human-tiger conflict with 553 cases, accounting for nearly one-third of the total reports. In 2023 and 2024, there was an upsurge in annual case numbers recorded in Kelantan (80 and 76 cases) and Perak (105 and 76 cases), compared to Pahang (53 and 61 cases).

Leopards account for the second highest number of human-carnivore conflict in Peninsular Malaysia, with 1,095 reports since 2005 – 2024 (Table 4). Human-leopard conflict has become increasingly frequent, particularly due to the adaptability of the species to human-modified landscapes. Table 4 and Figure 11 shows that leopard conflict incidents occur consistently across Peninsular Malaysia and have increased substantially in recent years, with recorded 238 cases in 2023 and 266 in 2024. Negeri Sembilan consistently recorded the most cases of leopard conflict, apart from 2019, where it had the same number of incidents as Perak (19 cases). Negeri Sembilan's leopard conflicts total to almost 30% of the cases nationwide since 2005.

Clouded leopard conflict with humans has historically been reported to be less frequent compared to tigers and leopards in Peninsular Malaysia. Records between 2005 and 2024 show relatively low numbers of incidents, totaling 249 cases within this period (Table 5). Kedah recorded the highest number of conflicts, contributing to almost 40% of the reported cases. Mainland Penang too, recorded a case in 2008, while no cases of clouded leopard conflict were recorded in Federal Territory of Kuala Lumpur since 2009, except for one recent report that emerged in 2023. Recent data indicates an increasing trend in the Peninsular, with 43 cases recorded in 2023 and 47 in 2024. Although it is still comparatively lower than tigers and leopards, this increase may suggest escalating interactions between clouded leopards and human activities along the forest-edge environments.

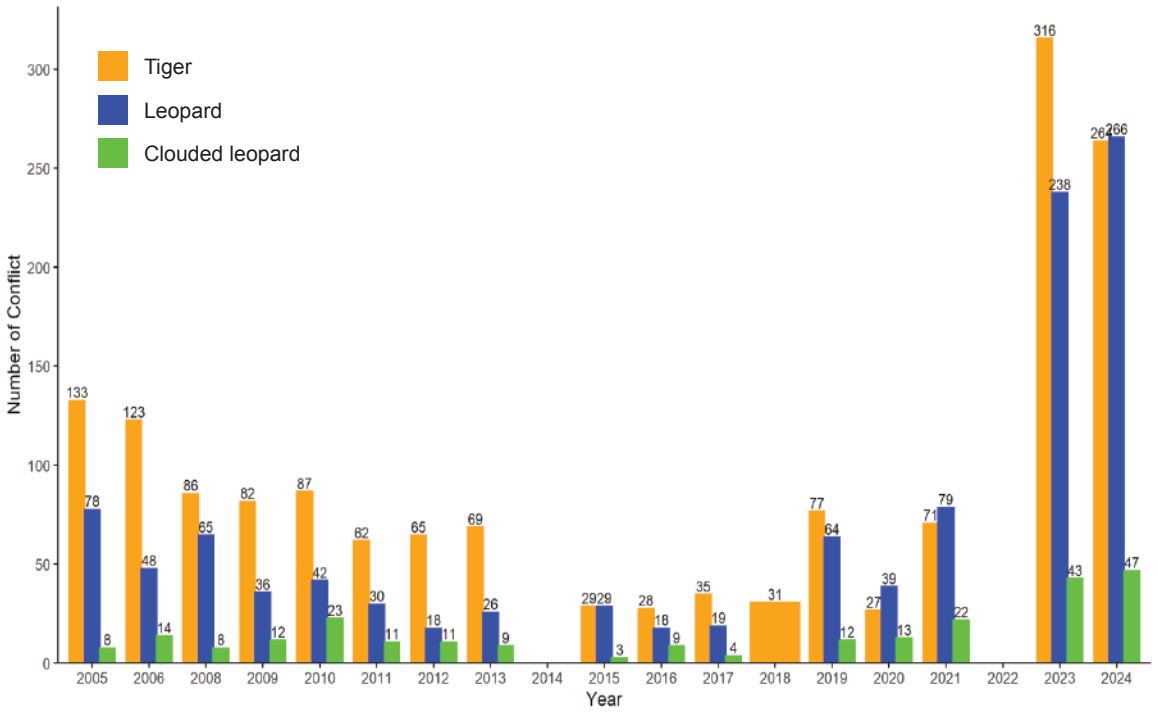

Figure 12. Conflict cases between humans and tigers, leopards and clouded leopards in Peninsular Malaysia from 2005 to 2024.

Table 3. Human-tiger conflict incidences in Peninsular Malaysia from 2005 – 2024, by state.

Year	JHR	KDH	KTN	PNG	NSN	PHG	MLK	PRK	PLS	SGR	TRG	WLY	Total	%
2005	13	5	15	1	6	52	2	16	0	3	19	1	133	-
2006	9	8	10	0	4	41	2	27	1	4	15	2	123	–7.5
2007	NA	16	NA	NA	NA	127	NA	19	NA	NA	NA	NA	162	+31.7
2008	11	11	11	0	2	30	1	8	0	4	8	0	86	–46.9
2009	21	3	5	0	3	23	1	9	1	4	12	0	82	–4.7
2010	4	7	10	0	0	30	1	22	0	0	13	0	87	+6.1
2011	3	5	6	0	0	24	0	18	1	0	5	0	62	–28.7
2012	3	6	8	0	0	19	1	9	1	2	16	0	65	+4.8
2013	8	3	11	0	0	25	0	13	0	3	6	0	69	+6.2
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	38	–44.9
2015	4	2	3	0	0	8	0	5	0	3	4	0	29	–23.7
2016	4	7	2	0	0	9	0	5	0	1	0	0	28	–3.4
2017	2	0	11	0	0	6	0	5	0	1	10	0	35	+25.0
2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	31	–11.4
2019	3	3	6	0	2	27	0	25	1	2	8	0	77	+148.4
2020	5	0	3	0	2	7	0	4	0	2	4	0	27	–64.9
2021	9	NA	13	NA	1	11	NA	11	NA	NA	26	NA	71	+163.0
2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2023	35	9	80	0	1	53	0	105	0	6	27	0	316	-
2024	26	3	76	0	0	61	0	76	0	2	20	0	264	–16.5

Abbreviations: JHR – Johor, KDH – Kedah, KTN – Kelantan, PNG – Penang, NSN – Negeri Sembilan, PHG – Pahang, MLK – Malacca, PRK – Perak, PLS – Perlis, SGR – Selangor, TRG – Terengganu, WLY – Federal Territory of Kuala Lumpur, NA – No Data, % - percentage of change (increase/decrease) from previous year. Note: 2014, 2018 and 2022 data are not available from PERHILITAN annual reports. The total number of HTC cases for 2014 and 2018 were taken from Ten *et al.* (2021).

Table 4. Human-leopard conflict incidences in Peninsular Malaysia from 2005 – 2024, by state.

Year	JHR	KDH	KTN	PNG	NSN	PHG	MLK	PRK	PLS	SGR	TRG	WLY	Total	%
2005	4	14	5	0	15	15	0	9	0	7	2	7	78	-
2006	5	1	1	0	13	9	2	8	1	2	5	1	48	–38.5
2007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2008	9	9	1	1	20	16	1	3	0	2	3	0	65	-
2009	0	2	4	0	7	13	0	4	0	4	1	1	36	–44.6
2010	4	4	3	0	16	9	0	3	0	1	2	0	42	+16.7
2011	4	1	3	0	9	5	0	5	0	1	2	0	30	–28.6
2012	1	2	3	0	4	1	0	4	1	1	1	0	18	–40.0
2013	1	3	2	0	9	6	0	3	0	1	1	0	26	+44.4
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2015	1	4	3	0	7	5	1	2	0	3	3	0	29	-
2016	0	2	4	0	9	1	0	1	0	0	0	1	18	–37.9
2017	0	3	1	0	6	3	0	4	1	0	1	0	19	+5.6
2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2019	2	4	1	0	19	10	0	19	0	4	5	0	64	-
2020	0	2	1	0	10	11	1	4	2	5	3	0	39	–39.1
2021	2	2	11	-	29	13	1	9	1	4	7	-	79	+102.6
2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
2023	2	1	59	-	72	42	-	24	-	12	26	-	238	-
2024	3	3	64	-	66	54	3	35	1	6	31	-	266	+11.8

Abbreviations: JHR – Johor, KDH – Kedah, KTN – Kelantan, PNG – Penang, NSN – Negeri Sembilan, PHG – Pahang, MLK – Malacca, PRK – Perak, PLS – Perlis, SGR – Selangor, TRG – Terengganu, WLY – Federal Territory of Kuala Lumpur, NA – No Data, % - percentage of change (increase/decrease) from previous year. Note: 2007, 2014, 2018 and 2022 data are not available from PERHILITAN annual reports.

Table 5. Human-clouded leopard conflict incidences in Peninsular Malaysia from 2005 – 2024, by state.

Year	JHR	KDH	KTN	PNG	NSN	PHG	MLK	PRK	PLS	SGR	TRG	WLY	Total	%
2005	0	5	0	0	2	0	1	0	0	0	0	0	8	-
2006	0	1	0	1	8	0	0	1	3	0	0	0	14	+75.0
2007	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2008	0	1	0	1	4	0	0	1	0	1	0	0	8	-
2009	0	5	0	0	0	0	1	1	3	1	0	1	12	+50.0
2010	1	14	1	0	0	0	0	4	1	1	1	0	23	+91.7
2011	0	6	0	0	0	0	0	1	1	2	1	0	11	–52.2
2012	0	8	0	0	0	1	0	2	0	0	0	0	11	0.0
2013	3	4	1	0	0	1	0	3	0	0	0	0	9	–18.2
2014	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2015	0	1	2	0	0	0	0	0	0	0	0	0	3	-
2016	0	1	1	0	1	2	0	4	0	0	0	0	9	+200.0
2017	0	1	1	0	1	0	0	0	0	1	0	0	4	–55.6
2018	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2019	0	1	1	0	5	1	0	2	0	2	0	0	12	-
2020	3	6	1	0	0	0	0	3	0	0	0	0	13	+8.3
2021	0	9	2	0	0	4	0	6	0	0	1	0	22	+69.2
2022	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	-
2023	1	13	15	0	1	1	0	10	1	0	0	1	43	-
2024	1	20	10	0	1	2	1	7	0	5	0	0	47	+9.3

Abbreviations: JHR – Johor, KDH – Kedah, KTN – Kelantan, PNG – Penang, NSN – Negeri Sembilan, PHG – Pahang, MLK – Malacca, PRK – Perak, PLS – Perlis, SGR – Selangor, TRG – Terengganu, WLY – Federal Territory of Kuala Lumpur, NA – No Data, % - percentage of change (increase/decrease) from previous year. Note: 2007, 2014, 2018 and 2022 data are not available from PERHILITAN annual reports.

CONSERVATION INITIATIVES, POLICIES AND FRAMEWORKS

There is an absence of dedicated action plans or initiatives specifically for leopards and clouded leopards in Peninsular Malaysia. As such, we describe below the best currently available strategies aimed at conserving tigers, which to a large extent indirectly mitigates the underlying threats, issues and challenges besetting large carnivores in Malaysia.

Action plans and high-level government coordination

Malaysia has adopted and implemented the National Tiger Conservation Action Plan 2008 – 2020 (DWNP 2008) for almost 15 years. After years of advocacy by NGOs, the inaugural National Tiger Survey of which the scientific framework was developed and designed by the author and several co-authors of this paper, was spearheaded and undertaken by PERHILITAN and NGO partners between 2016 to 2020. However, the outcome of the systematic countrywide survey using thousands of camera traps at a cost of RM18 million in government funding was bewildering: the Malayan tiger population had plunged to less than 150 individuals in the wild.

The Malaysian government and NGO partners recognised that the Malayan tiger was in a state of peril. Proactive measures to ensure its long-term survival must address the major issues of management/protection of the species habitat, resource mobilisation and funding gaps (DWNP 2024). In response, the Ministry of Natural Resources and Environmental Sustainability (NRES) adopted nine Strategic Actions to Save the Malayan Tiger in 2021 and subsequently, formulated the Malayan Tiger Crisis Action Plan 2022-2030.

The implementation of these actions is being monitored by a high-level National Tiger Conservation Task Force (MyTTF), chaired by the Prime Minister of Malaysia (NRES 2024), and supported by the National Tiger Implementation Working Group (MyTWG) – chaired by the Minister of NRES, and the Technical Committee (JTMyTTF) – chaired by the Director General of PERHILITAN (DWNP 2023, 2024). As a result, Malaysia has undertaken several significant and sustained law enforcement and management efforts on the ground to protect the Malayan tiger, which also contributes to the conservation of other wildlife and their habitats.

The formation of this high-level task force has been a major victory for many stakeholders, especially the NGOs involved in tiger and wildlife conservation. Despite this progress, certain challenges remain. Since 2018, six Ministers have overseen wildlife-related portfolios and four since the formation of MyTTF. The frequent changes in the government have also seen several changes in the name and focus of the Natural Resources Ministry. Therefore, establishing a permanent Secretariat consisting of representatives from the government and NGO representatives would be much needed to ensure comprehensive policy papers are brought to the attention of MyTTF for decision making. Additional gaps include the infrequent meetings per year, lack of NGO representation within these committees, particularly those working on tiger protection efforts on the ground, and insufficient attention given to state level issues such as forest conversion, all of which may reduce the effectiveness of this task force.

Motivating State governments with financial incentives

Under the Malaysian Constitution, land and forest management falls under State jurisdiction. As a result, most of the Malayan tiger habitats are managed by the respective State Forestry Departments. In contrast, Taman Negara National Park, established in 1939, is managed by the Federal Government through PERHILITAN. However, State governments have generally been reluctant to upgrade more forested areas for tiger habitats to national protected areas due to concerns over potential loss of revenue and lack of capacity (DWNP 1996; Elagupillay 2004).

To motivate the State Governments to protect tiger habitats, the Federal Government introduced the Ecological Fiscal Transfer (EFT) funding mechanism, which provides financial incentives for conservation. The scheme has supported the States in designating 15,000 ha of new protected areas (NRES 2024). To ensure the State governments use the EFT financial grants to prioritise tiger habitats in a sustainable manner, EFT funding should be incorporated into the 5-year Malaysia Plans, with stronger monitoring frameworks that incorporate big cats and its prey as key performance indicators in the use of the funds.

Initiatives to counter the illegal wildlife trade and poaching

In 2022, the Royal Malaysian Police established the Wildlife Crime Bureau, strengthening investigative capacity and intelligence coordination nationwide. By institutionalising wildlife crime enforcement within the national policing framework, Malaysia has elevated offences involving wildlife to the level of serious organised crime. To complement and assist the Wildlife Crime Bureau in gathering evidence in the field, PERHILITAN expanded its Special Protected Area Response Team (SPARTA) in 2023 and enhanced the capacity of the National Wildlife Forensic Laboratory (DWNP 2024). Based on the recent successes in the arrests and prosecution of several prominent wildlife crime cases, many involving big cats, the formation of the Wildlife Crime Bureau has helped in Malaysia's efforts to combat organised wildlife crime. Joint investigations between multiple agencies have increased in recent years and should be encouraged further, although there is a need for more in-depth post-arrest investigations to identify the entire network of people involved in each case.

To address limited enforcement capacity on the ground, the government allocated RM80 million in 2025 to deploy over 2,500 Community Rangers across protected areas and forest reserves in Malaysia, including critical big cat habitats within the Central Forest Spine

landscape. The Community Ranger programme is led by PERHILITAN and supported by various other government agencies and NGOs. The programme was initiated in 2020 with just 150 rangers and has since annually increased both in allocation and personnel. Members of local and Orang Asli communities are recruited to assist enforcement personnel to conduct patrols, dismantle snares, detect encroachments, and gather vital ground intelligence in remote forest areas (NRES 2025).

Under the current arrangement, funding for the Community Ranger programme is allocated annually by the Ministry of Finance to NRES and PERHILITAN. As a result, ranger contracts typically end in December and are only renewed in January or February once new funds are approved and administrative processes are completed. This creates temporary staffing gaps during which key tiger habitats may become more vulnerable to poaching and encroachment. To ensure sustainability and continuity, the programme would benefit from being incorporated into the 5-Year Malaysia Plan. So while this initiative is great, mechanisms should be developed to convert Orang Asli ranger positions from short-term contracts into permanent and formally institutionalised roles.

Malaysia also launched *Operasi Bersepadu Khazanah* (OBK) in 2019 as the country's first joint taskforce to combat wildlife crime. Jointly helmed by the Royal Malaysian Police, PERHILITAN and Royal Malaysian Customs, it involves the participation of various law enforcement agencies including Forestry Departments, Malaysian Border Control and Protection Agency, Immigration Department, Perak State Parks Corporation, Johor National Parks Corporation, with NGOs included as observers in meetings. Through this initiative, integrated patrols combining wildlife authorities, police and enforcement agencies have intensified action against poaching and trafficking networks. Between 2021 and 2024, these operations resulted in 427 arrests of poachers and encroachers, with 73 foreign nationals apprehended, and RM150 million worth of wildlife-related assets seized (NRES 2024).

To address several weaknesses in legislation, significant amendments were made to the WCA 2010, which were passed by Parliament in February 2022. The amendments introduced stricter protections and heavier penalties involving totally protected species, including the Malayan tiger, leopard and clouded leopard. This includes minimum fines for offences involving juvenile and female tigers, leopards and clouded leopards, as well as penalties per wildlife part or derivative, resulting in higher cumulative fines for multiple items. Maximum penalties now reach up to RM1 million in fines and imprisonment of up to 15 years (DWNP 2024). The new law is not fully enforced in entirety, as only 44 sections of the 2022 Amendment were enforceable in January 2023, while other regulations and schedule amendments (including changes to species protection status) are pending approval.

On 19th February 2026, three foreign nationals were fined RM128.9 million and sentenced to a combined 65 years of imprisonment for possession of nearly 1,000 parts of protected wildlife species, including 54 tiger parts, 273 leopard parts and 20 clouded leopard parts, as well as four snares (Bernama 2026). This conviction reinforces a strong legal deterrent against wildlife crime, which requires continued momentum towards enforcement.

International practices, standards and collaboration

Realising the need to enhance the management of tiger habitats, Malaysia has adopted the Conservation Assured | Tiger Standards (CA|TS), a global certification system that sets benchmarks for protection, habitat management, community involvement, and wildlife monitoring for tiger conservation areas. Royal Belum State Park, a major tiger habitat, became the first CA|TS approved site in Southeast Asia in 2023. Taman Negara National Park and Endau Rompin National Park subsequently registered for this scheme in 2025, where both parks are undergoing rigorous assessment and management enhancement (International Big Cats Alliance 2026).

Malaysia has also been an active participant of the Global Tiger Forum and recently became an official member of the International Big Cats Alliance (Ministry of Foreign Affairs Malaysia 2026). With the increasing commitment of Malaysia to global standards and in line with '*Think Globally, Act Locally*', more resources will be allocated by the government and local and international funding sources for the conservation of the Malayan tiger. Together with strengthened enforcement outcomes, these developments indicate increased national commitment to conserving Malaysia's big cat species and implementing both global and national frameworks including the Global Tiger Recovery Programme 2.0 and Malaysia's Malayan Tiger Crisis Action Plan 2022 – 2030.

Prey release program

PERHILITAN has implemented several captive-bred prey release programmes over the years, with sambar deer being the most frequently-released prey species. Since 2010, at least 24 gaur, 13 banteng and seven barking deer have been released according to PERHILITAN's annual reports. At least 132 sambar deers (63 males and 69 females) were released across various sites from 2014 – 2026 (Table 6). However, it remains to be seen how well the animals fared after release as post-release monitoring has generally been limited.

Table 6. Documented sambar deer releases in Peninsular Malaysia.

Year	Month	Wildlife Conservation Centre	Release site	No. of Individuals (Male: female)	Method of Release
2014	June	Gua Musang	Taman Negara Pahang, Sg Relau	14 (8:6)	Soft release
2015	April	Gua Musang	Taman Negara Pahang, Sg Relau	9 (5:4)	Soft release
	June	Sungkai	Taman Negara Pahang, Kuala Tahan	5 (1:4)	Hard release
	July	Sungkai	Taman Negara Pahang, Kuala Tahan	4 (2:2)	Hard release
	November	Sungkai	Amanjaya Forest Reserve, Perak	2 (0:2)	Soft release
2016	March[a]	Sungkai	Tembat Forest Reserve, Terengganu	4 (3:1)	Hard release
	May[a]	Sungkai	Tembat Forest Reserve, Terengganu	6 (3:3)	Hard release
	October[b]	Sungkai	Taman Negara Pahang, Sg Relau	5 (1:4)	Soft release
2017	July	Gua Musang	Taman Negara Pahang, Sg Relau	9 (5:4)	Soft release
	October	Sungkai	Taman Negara Pahang, Sg Relau	6 (1:5)	Hard release
2018	October	Sungkai	Taman Negara Pahang, Sg Relau	6 (3:3)	Hard release
2019	May[c]	Sungkai	Taman Negara Pahang, Sg Relau	6 (3:3)	Hard release
	May[d]	Gua Musang	Taman Negara Pahang, Sg Relau	1 (0:1)	Hard release
2020	August	Sungkai	Taman Negara Terengganu, Sg Terenggan	5 (5:0)	Hard release
	October	Sungkai	Gunung Basor Forest Reserve, Kelantan	4 (4:0)	Hard release
2021	March	Not stated	Gunung Basor Forest Reserve, Kelantan	8 (4:4)	Hard release
	October[b]	Sungkai	Royal Belum State Park, Perak	10 (5:5)	Hard release
	November	Not stated	Taman Negara Pahang, Sg Relau	2 (1:1)	Hard release
2022	August[b]	Sungkai	Royal Belum State Park, Perak	8 (3:5)	Hard release
2023	May[e]	Sungkai	Royal Belum State Park, Perak	6 (3:3)	Hard release
	October	Not stated	Taman Negara Terengganu	4 (1:3)	Not stated
	October	Not stated	Taman Negara Pahang	2 (0:2)	Not stated
2024	October	Sungkai	Taman Negara Terengganu	2 (0:2)	Hard release
	October	A'Famosa Safari Wonderland	Taman Negara Terengganu	2 (0:2)	Hard release
2026	February	Taiping Zoo	Royal Belum State Park, Perak	2 (2:0)	Hard release
			TOTAL	**132 (63:69)**	

Notes:
[a] All sambar deer were fixed with VHF-radiotelemetry collars.
[b] Four sambar deer were fixed with VHF-radiotelemetry collars.
[c] Five sambar deer were fixed with VHF-radiotelemetry collars, and one male sambar deer fixed with a GPS-satellite collar.
[d] One female sambar deer was fixed with a GPS-satellite collar.
[e] Three sambar deer were fixed with VHF-radiotelemetry collars.
Sources: 2014 – 2020: Badmanathan *et al.* (2022); 2021 – 2024: PERHILITAN annual reports; 2026: Perak State Parks Corporation, unpublished data.

Between 2021 and 2023, PERHILITAN released 24 sambar deer into Royal Belum State Park (Perak State Parks Corporation, unpublished). Of the 24 individuals, 11 were fixed with VHF-radiotelemetry collars (Table 6). Two months after the 2023 release, a survey over six nights was carried out at the release sites which detected eight collared sambar deer, of which three were from the 2021 release, three from the 2022 release, and two from the 2023 release. At least four fawns were also observed with the released females. Some individuals remained near the release sites and nearby Orang Asli villages to feed on crops such as cassava leaves (Perak State Parks Corporation, unpublished). There were limitations with the radio collar to detect how far the released sambar deer had travelled. However, the longest recorded distance travelled was obtained via an opportunistic observation where a released male sambar deer was detected about 11.5 km apart between two observations (Perak State Parks Corporation, unpublished). One male sambar deer was killed by a tiger 658 days after its release, whilst another female was photographed surviving a tiger attack with visible claw marks on its back. Two more sambar deer were released into Royal Belum State Park in 2026, where the stock was provided by Taiping Zoo (Table 6).

In general, the number of released animals is still relatively small to produce significant outcomes, particularly when compared to more targeted programmes implemented in Thailand (WWF Foundation 2023). PERHILITAN is currently exploring the involvement of private breeders to increase sambar deer stock production for future releases, although details are not publicly available. Moving forward, there is a critical need for greater investment in optimising breeding conditions for captive animals so that a larger cohort of animals can be released, ideally via soft-release approaches. Post-release monitoring using satellite collars is also essential to assess the survivorship, movement and habitat use of released animals to enhance our understanding on best practices to improve future augmentation efforts.

Malayan Tiger Conservation Centre

The Malayan Tiger Conservation Centre is an 80-hectare site in Lanchang, Pahang, that costs about RM40 million and was established to support the captive breeding of Malayan tigers, with the long-term aim of rehabilitation and eventual rewilding (Bernama 2025). While the initiative may have been an immediate response to try to stem the rapid decline of wild tigers, the practicality of breeding, rewilding and eventually releasing tigers into the wild requires careful evaluation and may not be a viable and successful option to increase tiger numbers in the wild. In fact, even if a tiger was able to be rewilded, released and survives, it may be disruptive to the existing social organisation and population dynamics of tigers within a site or landscape and should only be explored in areas where tigers are no longer there and where the underlying threats that caused local extinction of tigers (such as poaching, habitat loss/degradation and lack of prey) have been addressed. It is critical that these factors be given due consideration before any decision is made towards releasing tigers into the wild.

Other state level initiatives

In 2023, Malaysia established its first tiger reserve—the Al-Sultan Abdullah Royal Tiger Reserve—in Pahang, spanning 1,340 km2. Adjacent to Peninsular Malaysia's largest protected area, Taman Negara National Park, this extension effectively increased the national park's area by 30% (CNN 2026). Strong royal support from the Crown Prince of Pahang serves as a clear example of how political will can aid biodiversity conservation within the country.

Within Perak State, stakeholders are coming together to develop a Perak Tiger Conservation Plan aimed at tiger recovery efforts, which includes supporting patrolling and monitoring of tigers, as well exploring financial mechanisms to sustain these efforts over the long term (The Edge 2025). In Johor, State authorities are discussing plans to establish a state-level conservation committee to coordinate responses towards threats faced by biodiversity that would include tigers, leopards and clouded leopards, and translating these discussions into potentially targeted conservation actions for their recovery.

KEY RECOMMENDATIONS

Further science-based assessments to understand the conservation status of the three sympatric carnivores

For tigers, sufficient data already exist to establish baselines at national, state, landscape, and site levels. The priority now should be to move beyond national population estimates and focus on site- and landscape-level analyses that examine population dynamics in relation to prey availability, poaching pressure, habitat loss and fragmentation, human-tiger conflict, disease, and road mortality. Particular attention should be given to how social organisation and demographic structure within the tiger sub-population respond to these pressures. The low tiger densities (<1 tiger per 100 km^2), coupled with nationwide prey declines, suggest a trajectory similar to that reported in Thailand, where reduced tiger reproduction rate and low cub survival impedes the potential for population recovery even in connected landscapes (Steinmetz *et al.* 2025). A shift towards assessing site-specific demographic components of growth, survival, reproduction, dispersal, recruitment and threats is therefore essential, but is currently severely lacking. Administratively, the management and decision-making is possibly more straightforward at the State-level, but conservation assessment should focus on site-specific subpopulations or broader landscape units, which often extend across several states.

Existing data from the National Tiger Survey and other recent surveys need to be analysed to gain a better understanding of the population and distribution of leopards, clouded leopards, prey and possibly other species. For clouded leopards, population-level analysis and density estimation is possible due to the presence of natural markings to identify individuals as opposed to melanistic leopards. This would enable a nationwide assessment of the species with no additional fieldwork required, although it would take a significant amount of effort to extract the species records, identify individuals, verify the information, and analyse the data. Some caveats also have to be made as the camera trap spacing and locations were optimised for tiger detections, and clouded leopards are known to be at least partly arboreal. Therefore, any densities derived would likely have to be recognised as conservative estimates due to the lower detection probabilities. It would be even more challenging to produce density estimates for leopards due to the predominantly melanistic form found within Malaysia without standardised use of infrared-enhanced imaging. However, it would be extremely feasible to produce an updated distribution map or occupancy estimates as an alternative indicator of the conservation status for leopards, clouded leopards, other large mammal species and even prey in Peninsular Malaysia from the National Tiger Survey data and other recent surveys. While the National Tiger Survey (completed in 2020) provides an important baseline, more recent updated data would be required to assess their current conservation status.

There is also a dearth of information on the preferred prey of these three large cat species in Malaysia. Existing information is largely opportunistic or inferred from studies in other regions. Even though Malaysia may share some habitat and species similarities with neighboring countries, especially Indonesia, the biodiversity and conditions are not quite the same. Targeted dietary studies using DNA metabarcoding of scat samples are needed to generate reliable prey profiles, so that informed management decisions can be made in terms of prey recovery. To support this, a standardised scat collection protocol should be established across agencies and NGOs, with samples processed through the forensics laboratory of PERHILITAN. This would enable a consistent national dataset on prey preference profile of the three large cat species, and improve understanding of prey availability and recovery needs across different landscapes. In addition, interspecific interactions between the carnivore guilds and how these regulate prey would need to be assessed to better understand ecological functionality and recovery over the longer term.

Threat reduction actions

Habitat loss, degradation and fragmentation

Over the years, habitat loss and degradation have significantly altered big cat landscapes in Peninsular Malaysia, contributing to declines in habitat size, quality and connectivity. Future land-use decisions—such as road expansion, forest conversion and mining, including for rare earth elements—will be critical in determining the long-term viability of tigers and other wildlife. And so, there is a need to harmonise land use plans at the Federal and State level, including the upcoming 5th National Physical Plan, with district and local plans to designate critical wildlife habitats as 'no-go zones' and minimise conversion, fragmentation and land use change within these areas. Knowledge at the Federal level must be effectively integrated into local plans, and State-level decision-makers should be briefed on the critical values of these forest complexes to ensure their continued protection.

In Peninsular Malaysia, the Malayan tiger, leopard, and clouded leopard occupy overlapping forest habitats. The global effort in mapping the Tiger Conservation Landscapes (TCLs) since the 1990s up to 2023 (Dinerstein *et al*. 1997; Sanderson *et al.* 2006; Sanderson *et al.* 2023) provides useful information on the tiger distribution alongside satellite-derived habitat data, incorporating landscape, connectivity, human pressure and other ecological characteristics. TCLs represent a good starting point for big cat landscape-wide assessments and analysis for Malaysia, especially when data is scarce for leopards and clouded leopards. However, Malaysia lost 29% of area within its TCLs between 2001 and 2020 (Sanderson *et al*. 2023). Current estimates indicate around 55,000 km^2 of suitable tiger habitat remaining in Peninsular Malaysia (Tiger Conservation Landscapes - Global Forest Watch 2019).

An overlay of TCLs with protected areas and lowland dipterocarp forests in Peninsular Malaysia (Figure 13) shows that only 25% of these areas are protected, which includes both protected areas and portions of Permanent Reserved Forests under a specific class of protection. Hence, approximately 75% of tiger habitats remain unprotected and at risk of conversion or degradation. Lowland dipterocarp forests—comprising around 35% of TCLs—should be prioritised for protection due to their importance for both big cats and their prey, as well as their high susceptibility to agriculture or monoculture forest plantations.

This issue is especially important as 60% of Permanent Reserved Forests are classified as production forests and constitute close to 75% of tiger habitats. Despite their designation, these natural forests can still be converted into timber plantations while remaining classified as forest cover. Intensively-logged production forests have been known to be reclassified or labelled as 'poor forests' (*hutan miskin*) and converted into monoculture plantations such as latex-timber clones. These conversions reduce their natural capacity to support prey and consequently big cats. In terms of degradation caused by selective logging, although the annual allowable cut of timber in Permanent Reserved Forests was reduced from 1,165,300 ha to 890,000 ha under the 13th Malaysian Plan (The Star 2026), stricter enforcement of Reduced Impact Logging guidelines is needed to reduce collateral damage from logging. In addition, control over encroachment via logging roads, and reducing poaching within concessions need to be enforced.

Greater attention is needed to safeguard natural saltlicks before embarking on the creation of artificial saltlicks, which is increasingly being applied as habitat enrichment intervention. Natural saltlicks are critical resources for ungulates, yet their protection remains weak and severely neglected. Degradation and hunting in and around saltlicks can negatively impact the occupancy of ungulates and ultimately lower the carrying capacity for large carnivores over time. Saltlicks should be formally recognised as High Conservation Value within Forest Management Plans with a protection buffer of at least 400 m following WCA 2010, though a minimum of 2 km would be ideal to increase the likelihood for a species such the sambar deer to occupy a site within the vicinity of a saltlick (Darmaraj 2012).

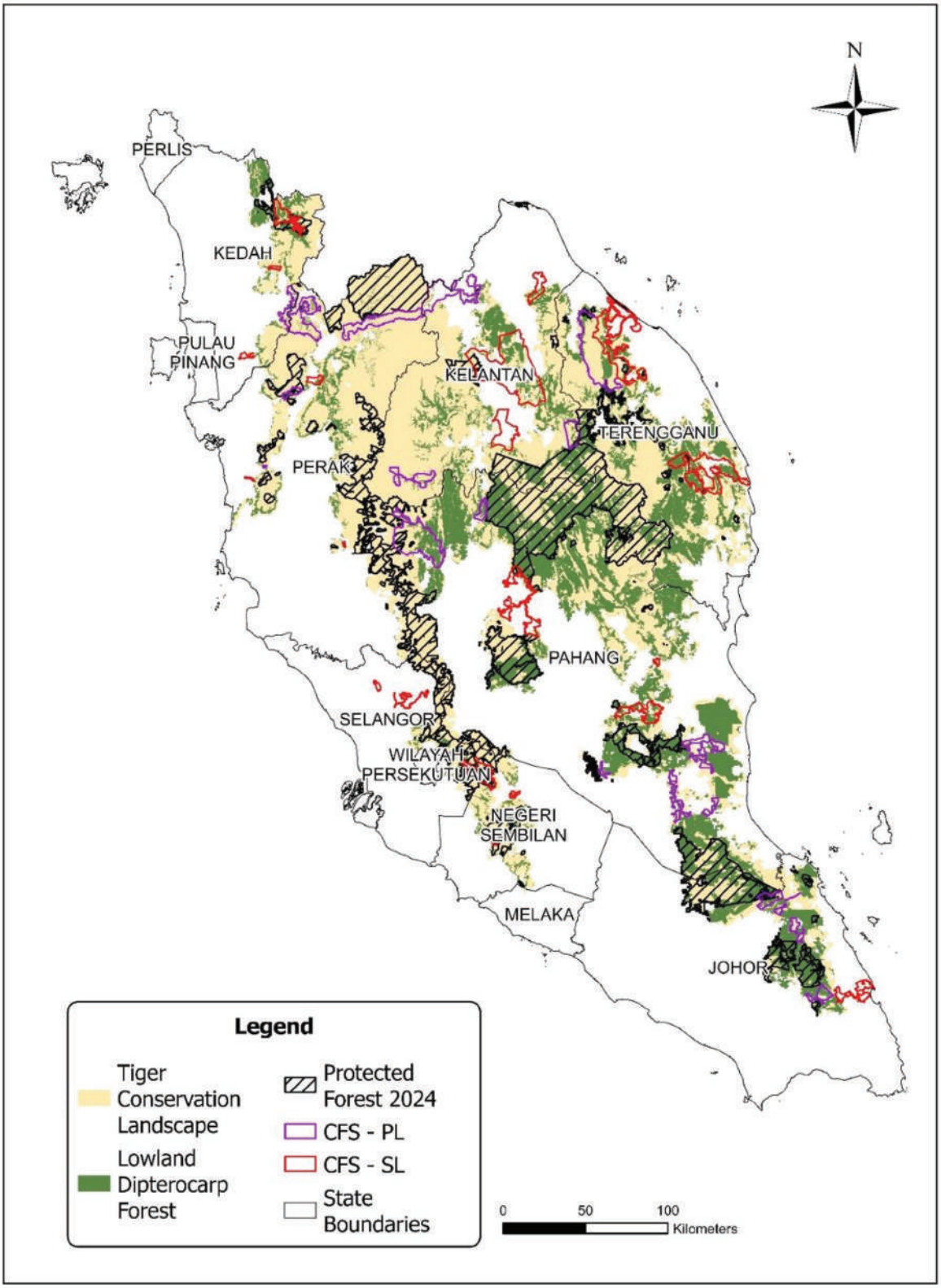

Figure 13. A map that shows linkages as per the Central Forest Spine Master Plan and lowland areas that needs to be legally protected, restored and monitored for tigers, leopards, and clouded leopards as an initial basis for conservation planning. Source data: WWF-Malaysia.

In addition, degraded areas such as log yards could be rehabilitated into grass pastures, while areas infested with false staghorn ferns (*Dicranopteris linearis*) should be weeded out and planted with fig trees and other prey browse plants as means of increasing food availability for ungulates. Such practices would need to be embedded within the silviculture practices of sustainable forest management for Peninsular Malaysia.

In addressing habitat fragmentation and lack of connectivity threatened by linear infrastructure and other land used development, Malaysia has the Central Forest Spine (CFS) Master Plan for Ecological Linkages, a Federal planning spatial blueprint that identifies Ecologically Sensitive Areas and ecological linkages. Although the plan has recently been revised, its implementation in development plans at the State level remains inconsistent as land matters fall under the State jurisdiction. As a result, despite existing plans and policies for conservation planning; monitoring, implementation, and enforcement remain severely lacking. Whilst much effort is needed to secure primary and secondary ecological linkages, there is an imminent risk of the larger forest blocks being converted into other land uses, undermining the very purpose of the Master Plan. For example, about 185,413 ha of forest reserves in Peninsular Malaysia were cleared for forest plantations between 2012 and 2020, of which 68% had not been replanted, with the largest affected area in Pahang and Kelantan (Macaranga 2022).

New linear infrastructure such as roads crossing the CFS could further fragment the habitat, making them vulnerable for conversion into agriculture or other development. Sustained financing support mechanisms are therefore needed to help States retain critical tracts of forest to maintain the forest contiguity. The establishment of the national Ecological Fiscal Transfer (EFT) mechanism is an important step to incentivise States to preserve their forest, but funding levels and governance mechanisms need to be strengthened to ensure that existing natural forests are not converted to other land uses or degraded. Although this mechanism is promising and allocations have increased annually, there remains a substantial funding gap to support the scale of action required for effective biodiversity conservation nationwide.

The State governments' commitment to retain forest cover is critical. Efforts should be expedited to operationalise mechanisms to aid or enable States to leverage approaches such as REDD+, Climate Change Funds, and Nature-Based Solutions, not only to preserve natural forest and its ecosystem services, but also to safeguard the habitat for big cats and broader biodiversity. The implementation of the CFS Master Plan will need stronger financial support of mechanisms such as EFT, the Malaysia Forest Fund's Forest Conservation Certificates and Forest Carbon Offsets, and other emerging Nature-Based Solutions. Together these efforts can be maximised to protect, restore, and connect big cat habitats that will benefit Malaysia's biodiversity as a whole.

Although current roadkill numbers for big cats are not critically high, this threat is expected to grow as the road networks and traffic volume increase, especially near wildlife habitats. Whilst wildlife crossings such as underpasses and overpasses can be useful to enable safe passages, the location, length-spread and intensity of applying such structures need to be more strategically and extensively implemented to minimise road-induced big cat mortality. Other measures include mandatory speed limiters for commercial heavy vehicles and AI-assisted speed cameras to enable "point-to-point" detection with hefty fines for non-compliance as a deterrent. Ultimately, road use intensity, as well as placement and alignment of roads near critical big cat habitats will strongly influence wildlife roadkills. A clear Federal and State directive requiring all future linear infrastructure to avoid bisecting contiguous forest patches would significantly reduce habitat fragmentation and infrastructure -related mortality of big cats.

In terms of forest contiguity and size, the greater Taman Negara-Banjaran Titiwangsa landscape is the largest in Peninsular Malaysia and likely harbours a significant portion of the nation's big cats. However, it would be counter intuitive to neglect efforts for big cat conservation efforts in other key landscapes, such as the Bintang Range in the north and Endau-Rompin in the south despite their fragmentation. Endau-Rompin (~4,000 km^2) is the only tiger landscape in Malaysia that harbours bearded pigs which reinforces its ability to sustain a high tiger density at carrying capacities and therefore warrants increased investment and sustained efforts. Tigers have been recorded to venture from Endau-Rompin to as far as Tasik Chini, suggesting movement through plantations, secondary forests, and human -dominated areas. Enabling safe passage through ecologically functioning corridors or even smaller forest patches that serve as 'stepping stones' is much needed and would greatly enhance the connectivity and genetic exchange of tigers and other big cats. Given the likely low genetic diversity in Malayan tigers among the surviving tiger subspecies, even partially isolated populations like those in Endau-Rompin play a critical role in contributing to the future persistence of tigers in Peninsular Malaysia (Allberry *et al*. 2024). This accentuates the need to shift the narrative that fragmented landscapes are less important; instead, they warrant equal government attention and investment to ensure the long-term survival of the big cats.

Illegal wildlife trade and poaching

Despite sustained government and conservation efforts, continued seizures of tigers, leopards, and clouded leopards in Peninsular Malaysia still persist, which indicates that current responses remain insufficient. The recorded cases in this paper likely represent only a small proportion of actual poaching and trafficking activity, given the covert and organised nature of the crime. The true scale is likely to be substantially higher, underscoring the urgency to intensify and recalibrate enforcement strategies.

Central to addressing big cat poaching is a decisive investment toward intelligence -led investigations that operate across the full criminal chain, from poaching in forested landscapes to domestic and transnational trafficking networks. Too often, enforcement efforts conclude at the point of seizure or arrest of low to mid-level actors. This approach delivers only short-term disruption, as organised criminal networks can quickly replace intermediaries. More lasting impact will require systematically identifying and dismantling the broader networks, including recruiters, financiers, transporters, coordinators, and end buyers. Without this, Malaysia's big cats will remain persistent targets.

Whilst it is critical to dismantle poaching syndicates, it is equally important to understand the motivations behind local poaching and how it forms part of an intertwined web of criminal networks. At the source site, the authorities need a better understanding on why individuals become involved in poaching so that measures can be taken to prevent or reduce this pathway. This can include multiple initiatives ranging from addressing the communities' basic needs, to making it difficult for poaching to occur, and increasing the likelihood of being caught as a means of deterrence. A strong deterrent requires better law enforcement such as deploying more patrol rangers, as well as improving patrol skills, frequency and coverage using the latest technology to detect incursions early.

Efforts on the ground must also be strengthened in high-risk poaching areas. The suggested benchmark of ten rangers per 100 km^2 implies that, across roughly 50,000 km^2 of forest available in Peninsular Malaysia, at least 5,000 rangers would be needed to monitor, detect and potentially deter poachers effectively. Beyond ranger numbers, it is equally important to assess ranger capacity, coverage and intensity of patrolling as well as site-specific threat intensity and variation levels. In addition, intelligence gathered from anti-poaching operations should be integrated into broader investigation efforts, linking field-based evidence with trafficking networks operating beyond protected areas and moving big cats and their parts into demand centres.

Given that big cat trafficking is driven by high profits and relatively low perceived risk, integrating financial investigation into enforcement efforts is critical. Authorities should consistently apply a "follow-the-money" approach to uncover dubious financial flows underpinning poaching and trade. Malaysia already has a strong legal foundation through WCA 2010 and the International Trade in Endangered Species Act 2008, with wildlife crime being recognised as a predicate offence under Malaysia's Anti-Money Laundering, Anti-Terrorism Financing and Proceeds of Unlawful Activities Act 2001 (AMLA). This allows authorities to seize assets and impose fines of up to RM5 million. However, this tool remains underutilised. Actively pursuing financial investigations alongside wildlife offences would enable asset seizures, disruption of profit streams, and expose higher-level actors who enable trafficking without directly participating in it.

Judicial outcomes are also central to deterrence. Strong custodial sentences and substantial financial penalties should be consistently pursued and imposed in offences involving tigers, leopards, and clouded leopards, to reflect the severity of the crime and reinforce deterrence. Strong sentencing sends a clear signal that wildlife crime carries serious consequences. These efforts should be supported by improved data collection and analysis to better understand poaching trends, enforcement gaps, and network structures specific to tigers and leopards. On the whole, addressing this threat requires a multi-pronged and coordinated approach from the government, transnational agencies, NGOs, local communities, and the general public.

Prey loss

There is enough evidence to indicate declines in prey due to poaching, habitat loss and diseases are negatively impacting big cat abundance and distribution in Malaysia. To support recovery, a comprehensive strategy is needed to increase wild prey populations by improving habitat quality, food availability, and mineral resources, alongside strengthening captive breeding and release programmes for key prey species.

At the site level, a proper evaluation on the current status of prey needs to be carried out so that a systematic assessment to determine whether interventions such as prey habitat enrichment and/or large prey (e.g., sambar deer and bearded pigs) supplementation are required, and the intensity of such interventions. Selected areas could be designated as prey recovery zones, where habitat restoration and enrichment are carried out by increasing the availability of high-quality forage for prey species, establishing mineral licks and grasslands (Bhumpakphan 1997; Steinmetz *et al*. 2010), and intensifying protection against poaching. However, it is critical to consistently monitor and document the efforts applied and its resulting outcomes to assess its impact on recovery of prey for replicability across different sites in Peninsular Malaysia.

Considering the severe decline of large prey in most of Peninsular Malaysia's forests, there is a need for an immediate start-up of breeding programs for large prey (e.g., bearded pigs, sambar, gaur or even banteng). As a crisis intervention, the release of captive spayed Javan deer or feral buffalo in areas where prey availability is low could also be considered. Currently no zoos in Peninsular Malaysia hold the bearded pig subspecies (*Sus barbatus oi*) found in Endau Rompin for breeding and reintroduction into the wild, which raises concerns for its long-term conservation if local populations decline further. It should be noted however, that Singapore Zoo maintains a small captive population and are keen to support future prey augmentation efforts, however.

Lack of prey availability forces tigers to expand their home ranges (Simcharoen *et al.* 2014), increasing the likelihood of human-wildlife conflict at forest edges and in agricultural landscapes. The severe depletion of wild pig including bearded pigs in the south of Peninsular Malaysia due to ASF has likely resulted in the increased death or removal of a

number of wild tigers due to: (1) tigers expanding home ranges and repeatedly preying on livestock (and even humans) as an alternative food source, which are subsequently captured or killed in a retaliatory manner, and (2) greater movement across fragmented landscapes in search of food, increasing the risk of vehicle collisions. Although a direct causal link between ASF and these incidences is difficult to establish, there has been a dramatic increase of human-tiger conflict cases and roadkill incidences involving tigers since the disease first spread in Peninsular Malaysia in 2022. This trend is particularly evident than in Perak, where at least 11 tigers have been reported captured or killed since 2023, in which five tigers were removed by PERHILITAN due to conflict with humans, three were killed by vehicles, one was shot dead by villagers, and two more found dead due to unknown causes (Perak State Parks Corporation, unpublished).

Wild boar is the most prolific breeder amongst the big cats' prey species, and its population decline has likely contributed to increased human-tiger conflicts, as well as reduced tiger breeding success and cub survival due to insufficient food for nursing females. For example, no new tiger breeding signs have been recorded in Royal Belum State Park since the ASF outbreak (WWF-Malaysia, unpublished; Perak State Parks Corporation, unpublished). Prolonged outbreaks are expected to further suppress wild pig populations and reduce the number of breeding big cats, unless prey populations are actively restored through captive breeding, release programmes, and habitat enrichment.

A combination of measures is needed to detect outbreaks and trigger timely management responses to manage future ASF outbreaks. These include improving biosecurity and regulating human movement from domestic pig-producing communities into forest edges and interiors to limit spillover; establishing early warning systems via improving surveillance on carcass detection that integrates ranger patrol and local community reporting; and ensuring safe disposal of carcasses at burial sites. Recovery measures should also include instituting temporary hunting bans until populations stabilise, *ex situ* breeding and introducing release programs in the wild for severely impacted sites.

Diseases directly impacting the three big cats

Among the pathogens reported in wild tigers, only CDV has been clearly associated with mortality that contributes to population declines in the big cats. In Malaysia, a follow-up study to the first detected case of CDV in tigers found CDV RNA in three common tree shrews (*Tupaia glis*), suggesting the potential role of small mammals as a carrier of the disease (Lazarus *et al*. 2025). Elsewhere, studies in Russia indicate that multiple wild carnivores may maintain CDV circulation in Amur tigers, although in other areas unvaccinated and free-roaming domestic dogs (Canis familiaris) are considered major CDV reservoirs (Gilbert *et al.* 2023). Hence, there is a critical need for more targeted studies to identify local CDV reservoir species, transmission routes, and CDV hotspots affecting Malayan tigers and other big cats, for the development of disease management and prevention systems. Surveillance of CDV via the collection of blood and preservation of serum should be mandatory and routinely incorporated into tiger handling protocols particularly in conflict mitigation, rehabilitation, or post-mortem examination (Gilbert *et al.* 2023).

Vaccination is the best means of mitigating CDV risk to big cat populations. Where domestic dogs are the primary source of CDV, vaccination can significantly reduce CDV transmission. However, this is ineffective if the infection is contracted through direct contact with wild animals that naturally maintains the virus in an ecosystem, as vaccines cannot be delivered to wildlife at the scale that is necessary to eliminate the virus. The development of oral baiting approaches to vaccinate wild tigers may be an option that needs to be explored (Gilbert *et al.* 2023).

Human-wildlife conflict

Human-tiger/leopard/clouded leopard conflict—arising from livestock depredation, sightings near settlements and plantations—frequently leads to the legal removal of the animal by authorities, or retaliatory killings, with potentially significant consequences on local populations, especially within a site that has high forest-edge interfaces. Human-wildlife conflict mitigation remains very reactive and heavily focused on compensation for livestock depredation or death of humans, as opposed to tackling the underlying issues of habitat loss, fragmentation, and lack of prey. While some farmers use physical barriers like paddocks to reduce livestock losses, these are not widely implemented or standardised, limiting their overall effectiveness.

Malaysia has two wildlife conflict compensation mechanisms, one of which is the Property and Crop Damage Compensation Assistance Initiative (Bantuan Kerugian Harta Benda dan Tanaman Akibat Serangan Hidupan Liar), which covers losses and damages to agricultural crops, property, and livestock caused by wildlife. The assistance is generally provided as a one-off payment based on verified losses, with RM 10 million allocated in 2024 (Ministry of Finance 2023). The second is the Wildlife Attack Victims Assistance Trust Fund (Tabung Bantuan Mangsa Serangan Binatang Buas), which provides support for injury or death cases relating to wildlife encounters and attacks. Established under the *Financial Procedure Act 1957* [Act 61] and managed by the Social Welfare Department, the fund provides a relatively small compensation of up to RM20,000 for cases involving death or permanent disability.

However, both schemes face limitations. Extended delays for payments, partial coverage and low levels of compensation value, are likely to be main challenges in implementing financial aid for economic losses and support for victims of wildlife attacks. Though these form an important component of national strategies to manage human-wildlife conflict, there is a clear need for strengthening these programs, alongside long-term preventive strategies such as improved land-use planning, ensuring habitat protection, and sustained community engagement, these are essential prerequisites in managing human wildlife conflict beyond today.

CONCLUSION

Based on our review of the conservation status of the three large cats in Peninsular Malaysia, more information, policies, and initiatives exist for tigers compared to leopards and clouded leopards, reflecting the tiger's national prominence and critically endangered status. Although there are encouraging population estimates for the latter two species, more robust assessments—like those for the Malayan tiger—are needed to properly monitor their conservation status across priority landscapes. As all three species co-occur in the forests of Peninsular Malaysia, most tiger-focused initiatives will also benefit the other two species and broader wildlife conservation. Over the years, Malaysia has stepped up efforts to stem wildlife decline, but there is a need to evaluate effectiveness of these initiatives and identify gaps that need immediate attention. This includes deep-dive assessments of the National Tiger Task Force, Operasi Bersepadu Khazanah, the Community Ranger Programme, and EFT to better conserve forests and biodiversity. The National Tiger Task Force should focus on urgent key measures described in this paper, while developing adaptive mid- and long-term strategies that could be sustained over a longer period, ensuring it does not become a tick-box exercise. Ultimately, stronger political will at both State and national levels, with immediate action on prey recovery and habitat loss, coupled with adequate sustainable financing is critically needed to ensure that Malaysia's three large sympatric cats stand a chance to not only survive, but recover over the next few decades.

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CHAPTER 20

The status of butterfly conservation in Peninsular Malaysia

CHOOI-KHIM PHON* and LAURENCE G. KIRTON

Abstract: A prior overview of the state of butterfly conservation in Peninsular Malaysia written 35 years ago identified two main threats: destruction of natural habitats and human exploitation. It recommended the protection of representative habitats and geographical zones, as well as measures to prevent over-exploitation. This paper reviews the current status of butterfly conservation in Peninsular Malaysia with respect to those recommendations. Currently, species distributions and habitat requirements remain partially known. Conservation status assessments have only recently begun. Forest loss continues, while gaps in the protection of important geographical areas remain. Some progress has however been made in establishing state parks, high conservation value forests and geoparks. Sites known to have high species diversity and rare or narrowly distributed taxa should be designated as Important Butterfly Areas. About 30 butterfly species are listed as being protected by law, but most are abundant and widespread, while some species that need protection are unlisted. There is therefore a need to review the list. Malaysia exports the greatest share of species protected under CITES. In addition, foreign collectors are known to collect large numbers of rare species for exchange or sale, which can adversely affect populations. Measures are needed to prevent over-collecting while encouraging responsible collecting for taxonomic study and habitat data. Climate change is an urgent but little-studied threat to butterfly species. Other anthropogenic impacts include clearing of understorey vegetation in recreational forest areas and clearing of roadside and wayside nectar plants, often using herbicides.

INTRODUCTION

Butterflies are beautiful and fascinating insects and are among the most studied insect groups in Peninsular Malaysia. A comprehensive account of the butterflies of Peninsular Malaysia was first published in 1934 (Corbet and Pendlebury 1934) with new editions published in 1956, 1978, 1992 and 2020. A stand-alone update to the fourth edition was published in 2006 (Eliot 2006). The book provides detailed morphological descriptions, keys and plates along with a checklist showing species and subspecies distributions across different subregions, islands, elevations and forest types. Several other less comprehensive books on Peninsular Malaysian butterflies or their early stages are also available, written by Morrell (1960), Fleming (1975a, 1975b, 1983), Yong (1983), Kirton (2020) and Goh (2024).

The taxonomy of butterflies in the Peninsula has been well studied in comparison to many other insect groups, despite the low number of taxonomists working on the subject. The number of additional species recorded from the Peninsula, which comprised new species described as well as new distributional records, numbered about 100 in the two approximately 20-year periods between the first, second and third editions of Corbet and Pendlebury (1934, 1956, 1978) (Table 1). In contrast, they numbered less than 30 (with some uncertainties) in the approximately 30-year period between the fourth and fifth editions (Corbet and Pendlebury 1992, 2020). This suggests the fauna is now relatively well documented.

Entomology Branch, Forest Research Institute Malaysia (FRIM), 52109 Kepong, Selangor.
***Corresponding author: phonchooikhim@frim.gov.my**

Table 1. Number of butterfly species recorded in each edition of the book, '*The Butterflies of the Malay Peninsula*' (Corbet and Pendlebury 1934, 1956, 1978, 1992 and 2020).

Year of publication	Number of years	Number of species recorded	Number of species added
1934		801	-
1956	22	898	97
1978	22	1,008	110
1992	14	1,031	23
2020	28	1,051	20
TOTAL	**86**		**250**

The first articles on conservation issues affecting butterflies in the Peninsula were published in 1961 and highlighted the need to protect island populations (Stubbs 1961) and small, localised populations of butterflies (Russell 1961). Some of the island populations were so different from mainland populations as to be named as subspecies. Subsequently, a more comprehensive overview of butterfly conservation in Peninsular Malaysia published 35 years ago identified two major threats to butterfly populations (Kirton 1991): destruction of natural habitats and human exploitation. To mitigate these threats, conservation of unique natural habitats was recommended, as well as permanent protection of a balanced representation of different habitats and geographical zones that support characteristic faunas. In addition, effective measures against human exploitation were advocated. This paper reviews the current status of butterfly conservation in Peninsular Malaysia with respect to those recommendations. The paper also examines the extent to which butterfly conservation has featured in research over the years, and new developments that either threaten or aid butterfly conservation in the Peninsula.

Development of baseline information on butterflies

Butterfly conservation requires baseline information such as comprehensive checklists and accurate distribution data. Priority regions and forest types identified in the previous overview of butterfly conservation in Peninsular Malaysia included Kedawi, the offshore islands of Peninsular Malaysia (as highlighted also by Stubbs 1961), highland regions, mangroves, peat swamps, and limestone outcrops (Kirton 1991). More than half of the 188 publications on butterflies in Malaysia in the past 35 years focused on diversity, assemblages, and distribution (Figure 1). Despite that, substantial gaps remain in our knowledge of the geographical distribution of butterfly species and their habitat requirements.

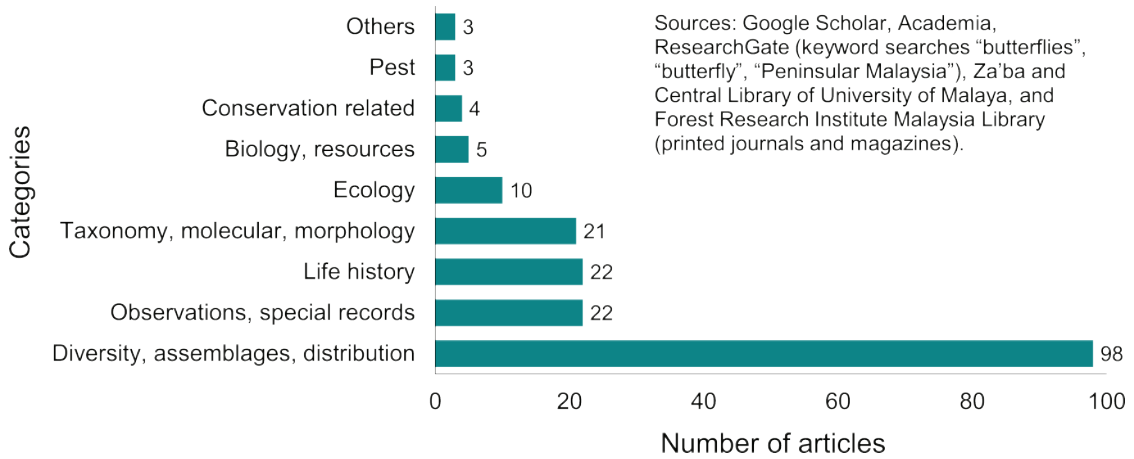

Figure 1. Numbers of published articles on butterflies in Peninsular Malaysia classified by subject between the years 1991 and 2025.

Some progress has been made for Kedawi. A preliminary checklist has been compiled for the Perlis State Park near Gunung Perlis (Noack 2002). Butterflies found on the Langkawi Islands are also indicated in the distributional checklist provided for Peninsular Malaysia in Corbet and Pendlebury (2020), but much forest loss has occurred on the main island of Langkawi since the lists were first compiled by Corbet and Pendlebury in 1956 and 1978 and by J.N. Eliot in 1992. More recent material from Langkawi, collected between 2012 and 2016 by Gary Ruben, is now deposited in the Forest Research Institute Malaysia (FRIM) Entomological Reference Collection, providing valuable baseline data. Progress has also been made for limestone areas. FRIM has recently completed butterfly inventories in selected limestone outcrops across Selangor, Perak, Perlis, Kelantan, and Pahang (Phon 2025).

Of the 188 articles on butterflies published between 1991 and 2025, only four had conservation as the primary objective (Figure 1). These articles stemmed from two studies. The first was conducted between 1996 and 2001 on the Swamp Tiger (*Danaus affinis*) at Kuala Selangor Nature Park, as a collaborative effort between the Malaysian Nature Society (MNS) and FRIM. It documented host plants, life history, habitat requirements, nectar sources, and population trends (Kirton and Azmi 1996, Kirton and Azmi 2004, Cheang 2005). The second was a study on the Rajah Brooke's Birdwing (*Trogonoptera brookiana*), which began around 2010. This work examined the population trends of the species (Phon *et al.* 2017), its geographical distribution and its preferred nectar plants, besides addressing taxonomic uncertainties on subspecies occurring in the eastern regions of Peninsular Malaysia (Phon *et al.* 2019).

The publications of naturalists have also been very useful in providing baseline information to support butterfly conservation in Malaysia. For example, the life histories of 191 butterfly species have been documented by Goh (2024), and useful observations on the biology and ecology of butterflies have been published by Liew (e.g., Liew 2025).

Conservation status assessments for butterflies

National-level butterfly conservation status assessments were proposed in the last review of butterfly conservation in Peninsular Malaysia (Kirton 1991). Implementation of assessments aligned with IUCN criteria and categories have only begun recently, starting with assessments of endemic species (C.-K. Phon, in prep.). The assessments await formal review.

Conservation status assessments require data on distributions and abundance. A substantial proportion of specimen data held in institutional collections has yet to be digitised or made publicly accessible, which poses a constraint to comprehensive assessments. Many naturalists now share their observations through online platforms, providing researchers with valuable locality records for numerous species. Such records represent an important data source for conservation status assessments. Advances in digital technology have certainly greatly increased the availability of butterfly occurrence data through online platforms such as GBIF and iNaturalist. However, conducting rigorous conservation status evaluations requires taxonomic and analytical expertise. Records from these sources need careful taxonomic verification and critical evaluation of reliability.

Habitat protection for butterflies

As of 2020, Malaysia retained approximately 55% of natural forest cover, equivalent to about 18 million hectares (Global Forest Watch 2025). However, forest loss continues to occur. For example, there has been extensive land-use change in the Cameron Highlands between 1984 and 2020, as Figure 2 illustrates. The ridges and summits of certain mountains in the highlands are ecologically important for butterfly hill-topping, a behaviour in which butterflies congregate at these elevated sites to enhance mating success. However, large swathes are often cleared of vegetation for electrical transmission lines and pylons. Heavy machinery is used, damaging the soil and landscape. Observations by local naturalists

indicate a decline in butterfly abundance at the summit of Gunung Jasar in Cameron Highlands, a well-known hill-topping site that deserves permanent protection. The establishment of transmission lines and pylons just below its summit and the loss of habitat in the lower slopes and valleys of the Cameron Highlands may be contributing factors to the decline in hill-topping on this mountain peak, others being over-exploitation by dealers and foreign collectors and the effects of climate change.



Figure 2. Extensive land-use change in Cameron Highlands between 1984 and 2020 shown in satellite images from Google Earth (2025).

Despite much forest loss, some progress has been made towards the conservation of natural habitats within different geographical zones since the last review of the status of butterfly conservation in Peninsular Malaysia (Kirton 1991). Several forest areas have been designated as state parks, high conservation value forests (HCVFs) or geoparks. Although these areas were not necessarily established to specifically cover representative geographical zones or habitat-types, they nonetheless play an important role in conservation.

However, in Peninsular Malaysia, conservation areas have differing levels of protection and are administered by multiple government agencies. The Department of Wildlife and National Parks (DWNP) oversees 35 protected areas, including national parks, wildlife reserves, wildlife sanctuaries, Ramsar sites, and wetlands (PERHILITAN 2025). The Forestry Department manages permanent forest reserves, HCVFs, eco-parks, recreational forests and certain state parks (JPSM 2025). Permanent forest reserves may still be degazetted for logging, agriculture or development. For example, 406.22 ha of Bukit Cherakah Forest Reserve in Selangor was recently degazetted for development (Selangor State Government 2022), which is being challenged by non-governmental organisations in court. Illegal activities further exacerbate the problem of protecting permanent forest reserves. Some state parks are administered by state-level statutory bodies, such as the Royal Belum State Park under the Perak State Parks Corporation and Endau Rompin National Park in Johor under the Johor National Parks Corporation. Geoparks, which are areas designated for their geological significance, lack any legal protection. Currently, approximately ten geoparks are recognised at the national level (Chew 2026), with two designated as UNESCO Global Geoparks in Malaysia (Global Geoparks Network 2025).

Gaps in the conservation of important geographical areas continue to exist and pose a concern for the conservation of many butterfly species. Localities that are already known to support high species diversity, rare taxa or populations that have very restricted distributions should be designated as Important Butterfly Areas in which to focus conservation efforts.

Some species that inhabit narrow ecological niches are particularly vulnerable to habitat loss and should be prioritised in conservation planning. For example, *Tongeia potanini*, which is currently known only from limestone outcrops in parts of Perak and Kelantan, warrants urgent conservation attention. Another clear example is the central-western subspecies of the Rajah Brooke's Birdwing, *Trogonoptera brookiana albescens*, a large and magnificent butterfly that has become a national icon. There continues to be no permanently protected areas within the range of this butterfly. It is a subspecies with complex ecological requirements because of the habit of males of congregating in large numbers at geothermal springs and seepages along the banks of certain rivers, a behaviour called puddling. Puddling sites are ecologically critical, as male birdwings obtain essential minerals and nutrients from them that are vital for physiological functioning and reproductive success.

Ulu Geroh in Perak is one such site where numerous male Rajah Brooke's Birdwings congregate densely at just a few small locations along the river. It is a spectacular phenomenon that attracts ecotourists and provides income to local indigenous guides. The vulnerability of these puddling sites is illustrated by an incident in December 2009, when an old-pipeline salvage project along the riverside at Ulu Geroh almost obliterated the puddling sites. The threat was ultimately mitigated through timely intervention involving local villagers, the media, MNS, parliamentarians, the Forestry Department, FRIM and DWNP (Phon *et al*. 2011). The site recovered and birdwings returned to puddle.

Effective measures against human exploitation of butterflies

At present, about 30 butterfly species in Peninsular Malaysia are protected under the First Schedule of the Wildlife Conservation Act (2010). Many of these species are popular with collectors and traders, but most of them are relatively abundant and widespread species that tolerate some forest degradation. They are also mainly from the families Papilionidae and Nymphalidae. In contrast, some butterfly species that have restricted distributions or occupy specialised habitats are heavily collected but not protected, such as certain *Delias* species of the family Pieridae that are found only on mountain tops. Therefore, there is a need to review the national list of protected species so that protection is given to species that truly need it. It is envisaged that future lists will be guided by national conservation assessments as these gradually become available.

Species in Peninsular Malaysia that are protected internationally under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) continue to be exported from the country (Table 2). Most specimens are sourced directly from wild populations. Butterfly ranching, in which butterflies are sourced from natural habitats that have been enhanced to increase wild populations should be encouraged and developed. This would help meet trade demands while reducing pressure on wild populations. Neighbouring countries such as Indonesia have begun implementing this (UNEP-WCMC 2012).

Exploitation of Malaysian butterflies occurs not only through formal trade mechanisms, but also by foreign collectors who engage local assistance to collect and bring back large numbers of specimens to their own countries for exchange and sale (pers. obs.). Rare species are often targeted. Although private collecting on a small scale is unlikely to have a significant impact on butterfly populations, sustained collecting of specific rare and localised species by multiple collectors can reduce populations, a concern also expressed by Russell (1961). Together with other population pressures such as habitat loss, this can be

detrimental to the survival of species. While responsible collecting within existing regulatory provisions, whether by local or foreign collectors, should be encouraged for the purpose of obtaining specimens for taxonomic study and data for conservation assessments, there is a need to prevent over-collecting of localised and rare species. This may require both improved legislation and stricter application of existing laws.

Table 2. Numbers of CITES-protected species exported from Malaysia, and Malaysia's percentage share of the world export of these species between the years 2017 and 2020 (CITES Secretariat and UNEP-WCMC 2023).

Species	2017	2018	2019	2020	Share of Export (%)
Trogonoptera brookiana	20	27	0	1,018	98.3
Troides aeacus	40	0	0	200	100.0
Troides amphrysus	28	0	9	14	72.5
Troides cuneifera	20	0	0	0	100.0
Troides helena	118	90	137	414	45.5

Anthropogenic impacts on butterflies

Anthropogenic impacts, that is, environmental changes caused directly or indirectly by humans, have a greater effect on butterfly populations than is generally realised. Over the years, methods of managing roads, rural landscapes, agricultural plantations, and parks and recreational areas situated in forests have changed to the detriment of butterfly populations. Many forest recreational areas such as camping and glamping grounds have been established in recent years, sometimes with little regulatory oversight. Little or no attention is given to planning such spaces in a way that preserves or encourages invertebrate wildlife. Undergrowth is usually cleared from the forest, leaving only tall trees, while natural vegetation at the sides of rivers is almost entirely removed. Sometimes cement is used to make pools or landings.

Roads through forested areas are now built larger and wider, cutting through hills instead of strictly following the hillside contours, resulting in drastic alterations to the landscape. Such large roads also require stabilisation of slopes by concrete and cement -work or by planting exotic grass species. As a result, native vegetation is lacking in the gaps between the bisected forests, making them uninhabitable barriers to dispersal. Even where roads are small, the clearing of wayside herbaceous growth has become more intensive and is often aided by herbicides. As a result, roadside nectar plants on which butterflies depend as a regular source of sustenance are largely eliminated (pers. obs.). Increasing numbers of vehicles using the roads also result in numerous road-kills of crossing butterflies (Muñoz *et al.* 2015).

Forest paths used as hiking trails are also sometimes intensively managed by clearing wide swathes of vegetation. On the mountain peaks and ridges where butterflies congregate to establish territories and seek mates, trees and low vegetation are often slashed down by hikers to provide views or to create platforms for photography. This could potentially have a great impact on butterfly and other insect populations that depend on these habitats for hill-topping as part of their reproductive behaviour.

Widespread pesticide usage in agricultural areas is also threatening butterfly populations (Quandahor *et al.* 2024). In Peninsular Malaysia, many forests border agricultural landscapes, and butterflies from these adjacent forests enter the edges of agricultural plantations seeking nectar and may be inadvertently poisoned. Pesticides and effluents from industries also contaminate rivers, destroying puddling sites along riverbanks. However, siltation is a bigger problem in upstream rivers due to logging, agriculture and development that occur along the watershed.

Light pollution is yet another anthropogenic impact that is detrimental to butterflies because many butterflies are crepuscular, being active at dawn and dusk and hence being readily attracted to light. Insects that are attracted to light often become prey to birds and lizards, putting pressure on their populations (Owens and Lewis 2018).

Climate change is an increasingly urgent threat to butterfly conservation. Rising temperatures, altered rainfall patterns, and prolonged droughts are among the effects of climate change that affect butterflies. Rising temperatures are expected to shift butterfly distributions along elevational gradients (Habel *et al.* 2023). Lowland species may begin to populate higher elevations, while species confined to mountain tops face an increased risk of extinction.

The impacts of anthropogenic pressures on butterflies remain poorly studied, both locally and globally. In Peninsular Malaysia, studies on the effects of climate change on butterflies are scarce due to the need for long-term datasets that require continuous research and funding commitments.

CONCLUSION

The last review of the status of butterfly conservation in Peninsular Malaysia written 35 years ago emphasised the importance of conserving unique habitats and a balanced representation of different habitats from different geographical zones, as well as effective measures to prevent over exploitation. Despite some progress being made, many important habitats and geographical zones in the Peninsula remain unprotected or poorly protected. Even our knowledge of the geographical distribution of butterfly species and their habitat requirements remain limited, and very few studies have been conducted on the conservation of butterflies. At the same time, recent advances in digital photography and digital online platforms are providing researchers with valuable locality records for numerous species. We recommend that localities known to have high diversity, rare taxa or geographically restricted populations be designated as Important Butterfly Areas that receive priority for conservation efforts. In particular, we propose that the conservation of Malaysia's most well-known butterfly, the Rajah Brooke's Birdwing, *Trogonoptera brookiana*, be given greater attention, as the central western race is distributed in forest areas that lack adequate protection. Targeted over-collecting of localised and rare species is a threat that also needs to be addressed. A review of the national list of protected species is greatly needed so that the species listed are those that truly need protection. National conservation assessments are also needed, as they can guide the selection of protected species. Greater attention to anthropogenic impacts in butterfly populations is also needed. Planning of reserves, parks, roads, recreational areas and hiking trails should take into account the preservation of wayside plants and the understorey vegetation so as to minimise impact on invertebrate populations. Greater study is needed on these aspects of butterfly conservation as well as the effects of other anthropogenic threats such as climate change.

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CHAPTER 21

Fireflies of Malaysia across 150 years (1875–2025)

WAN FARIDAH AKMAL JUSOH[1]*,
B. NADA[2] and FATHAN A. MUHARRARAN[1]

Abstract: Fireflies, known locally as *kunang-kunang* or *kelip-kelip*, have long captivated the human imagination through their bioluminescence, earning a cherished place in Malaysia's natural heritage as drivers of public engagement, ecotourism, and conservation. Yet, significant gaps in scientific understanding persist due to uneven knowledge across species, habitats, and regions. This chapter provides a brief overview of firefly research in Malaysia spanning the last 150 years, and presents its first official species checklist, documenting 78 species across three subfamilies and 21 genera. Tracing taxonomic activity from the late 1800s to the present, we identify three key phases, with surges in species naming during the 1910s – 1940s and 2000s – 2010s, while noting that nearly two-thirds of described species have received no further study since their original description. Based on current knowledge, Malaysia's fireflies can be categorised by four distinct signalling systems: roving flashers, glow-worms, dark (pheromone-based) species, and stationary synchronous flashers. They occupy diverse habitats from mangrove and riverine wetlands to montane forests and depend on distinct microhabitats at different life stages, making them sensitive indicators of ecosystem health. Primary threats include habitat loss, light pollution, pesticide contamination, and unregulated tourism, with four *Pteroptyx* species now classified as Vulnerable on the IUCN Red List. We also highlight critical gaps, including the absence of standardised survey protocols and limited data on solitary forest-dwelling species, and review ongoing conservation actions, including Malaysia's forthcoming Mangrove Firefly Conservation Action Plan.

INTRODUCTION

Fireflies are best known for their bioluminescence, a chemically produced light used for communication, warning, and courtship. The flashing fireflies inspire curiosity, advances scientific discovery and makes them powerful ambassadors for conservation (Lewis *et al.* 2024). As a "gateway bug" (Lewis as cited in Sidik, 2023), fireflies promote public engagement, generate ecotourism income and draw attention to broader declines in insect populations (Lewis *et al.* 2021). Their inclusion in educational programs motivates conservation action across all ages (Muharraran *et al.* 2024).

This paper provides a brief overview of firefly study in Malaysia, beginning with the first species described in 1875. It summarises key discoveries on their diversity, behaviour, and habitat preferences, while highlighting the main threats they face today and ongoing conservation actions. A central feature of this paper is Malaysia's first official checklist of firefly species, which we hope will deepen an understanding of fireflies and inspire continued research on taxonomy, ecology, and conservation needs.

Fireflies

Fireflies are beetles, not flies. They belong to the beetle family "shining light" (Lampyridae in Latin). The life cycle of fireflies comprises egg, larva, pupa, and adult stages. Although adult fireflies are conspicuous, much of their life cycle remains concealed. Eggs are deposited in moist, dark environments such as soil, moss, or leaf litter. Larvae may persist for months

[1] School of Science, Monash University Malaysia, Jalan Lagoon Selatan, Bandar Sunway, 47500 Subang Jaya, Selangor, Malaysia.
[2] Forest Research Institute Malaysia, Jalan Frim, Institut Penyelidikan Perhutanan Malaysia, 52109 Kepong, Selangor, Malaysia.
***Corresponding author: wanf.ajusoh@monash.edu**

or even years in humid, shaded habitats, preying on snails and slugs. Pupation occurs in damp soil or decaying wood for one to three weeks. Adults are short-lived, primarily devoted to courtship and seldom feed. This strong dependence on specific microhabitats at different life stages makes fireflies highly sensitive to environmental change, and thus valuable indicators of ecosystem health (Lewis *et al.* 2024).

Fireflies are a well-known and a cherished part of Malaysia's natural landscape, commonly referred to as *kunang-kunang* or *kelip-kelip* by locals. The term *api-api* can also mean firefly (Dewan Bahasa dan Pustaka 2005), though it is rarely used for insects and is more often used to describe mangrove trees of the genus *Avicennia*. Despite their visibility, scientific understanding has developed unevenly across species, habitats, and regions, so there are still significant gaps in what we know about, where they live and how they survive.

Two common names and four signalling systems

Whether you know them as *kunang-kunang* or *kelip-kelip*, fireflies hold a special place in Malaysia's natural heritage—not because of their physical appearance, but for the way they light up the night with their unique flashes. What truly sets these insects apart are their fascinating signalling systems: roving flashers, glow-worms, dark (pheromone-based) species, and stationary synchronous flashers (Lewis 2009).



Figure 1. In Malaysia, fireflies are generally known as either *kunang-kunang* (solitary firefly) or *kelip-kelip* (congregating firefly). *Kunang-kunang* can be further divided into three signalling systems, for instance: **(a)** *Pygoluciola*, the roving flasher; **(b)** *Lamprigera*, the glow-worm firefly; and **(c)** *Lucidina*, the dark firefly. *Kelip-kelip* usually refers to the bent-winged firefly, such as **(d–e)** *Pteroptyx tener*, congregating on mangrove trees. Photo credits: (a, c) Nicholas HL Tan, (b) Tan Wei Jack / Monash University Malaysia. Photos (d-e) Forest Research Institute Malaysia.

Firefly species of Malaysia

Firefly taxonomy has progressed through many phases, each contributing to current scientific understanding. McDermott's 1966 global catalogue of Lampyridae established a foundational taxonomic framework that informed subsequent research. The launch of the Lampyridae of the World Database in 2024 (Keller 2024) signalled a modern resurgence, providing updated and expanded information on these beetles. At present, about 2,635 species are described worldwide, ~380 of them in Southeast Asia across ~46 genera (Keller 2024; Lewis *et al.* 2024).

Taxonomic activity in Malaysia shows three phases: early exploration (late 1800s – 1930s), mid-century refinement (1930s – 1950s), and a modern resurgence in the 2000s to the present, driven by ecological interest and conservation needs. Naming surged during the 1910s – 1940s and again in the 2000s – 2010s under Lesley Ballantyne and collaborators, with Peninsular Malaysia contributing most species (Ballantyne *et al.* 2019) (Figure 2).

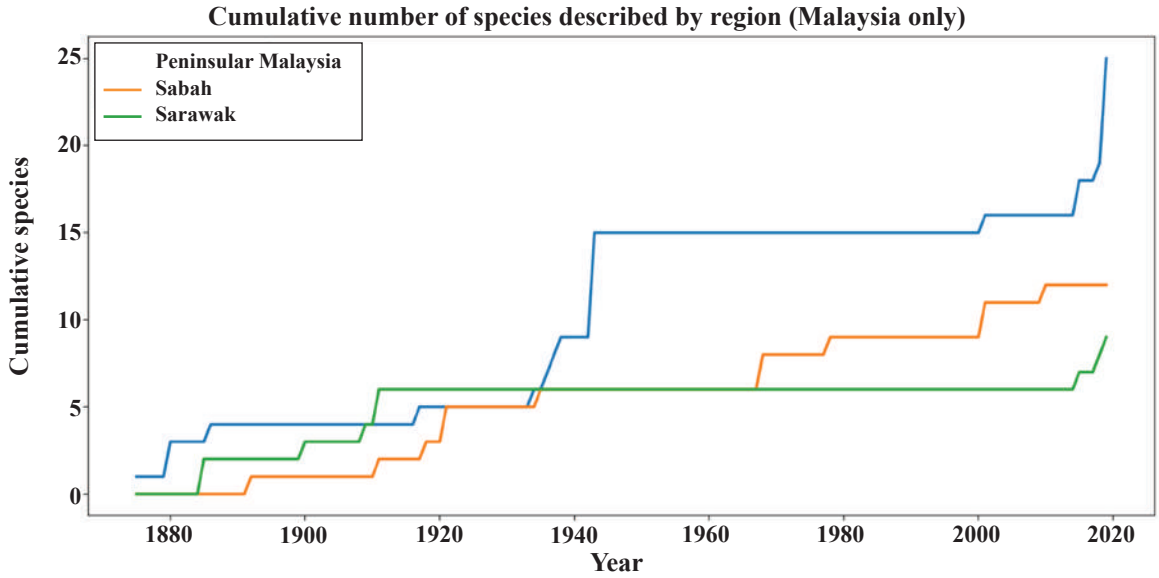

Figure 2. Cumulative number of firefly species from 1875 to 2025 based on historical and occurrence data. Peninsular Malaysia accumulates the most names overall; Sabah shows steady gains while Sarawak has a consistent but smaller trajectory.

In total, Malaysia currently has 78 firefly species distributed across three subfamilies. Two genera remain *incertae sedis* (Martin *et al.* 2017), meaning their exact classification is still uncertain (Table 1). The majority of species are found in Luciolinae (all flashing; 35 species) and Ototretinae (mostly dark; 31 species), with the remainder in Lampyrinae (Table 1). However, the true species diversity in Malaysia is likely higher than 100, as some historical records correspond to colonial-era administrative regions that do not match modern boundaries. Additionally, references to "Borneo" can include areas in Malaysia, Indonesia (Kalimantan), and Brunei.

Of these 78 species, approximately 48 were first discovered and described in Malaysia, making them the type localities for those species. The earliest, *Anadrilus indus* Kirsch, 1875, was collected in colonial Malacca and designated as the type species of *Anadrilus* by monotypy. Unfortunately, the original type specimen has been lost, leaving the taxon *incertae sedis* (Janisova and Bocakova 2013). Another genus with unresolved classification is *Lamprigera* (the so-called "giant fireflies"). Although popular and quite well known in Malaysia, the latest classifications place *Lamprigera* closer to Luciolinae, yet it shows little morphological similarity to that subfamily. This uncertainty highlights the need for broader and deeper sampling to resolve its classification.

The species list also revealed that nearly two-thirds of Malaysia's firefly species have not been studied since their original descriptions, and the original type specimens remain unlocated and are likely scattered across European museums. For many of these species, information is limited to outdated morphological descriptions and, in rare cases, brief notes on collection localities. However, not all species are lost to history. Recently, the first live sighting of *Pteroptyx gombakia* was confirmed in Kuala Lumpur, about 40 km from its original collection site in "Gombak Valley," where it was first discovered in 1921. This rediscovery not only confirms the species' continued existence but also marks the first record of a bent-winged firefly genus, *Pteroptyx*, in a non-mangrove forest, which was previously believed to be the exclusive habitat for this genus (Tan and Jusoh 2025).

Table 1. List of firefly species of Malaysia in alphabetical order by subfamily from 1875 to 2025. Type locality (T) is Malaysia, meaning it is the specific place where a newly discovered species was first found and scientifically described. Species under *incertae sedis* is indicated by an asterisk.

Subfamily	Genus	Species	Author, Year	Type locality
Lampyridae	*Anadrilus**	*indus*	Kirsch, 1875	T
incertae sedis	*Lamprigera**	*nitens*	Olivier, 1885	T
Lampyrinae	*Diaphanes*	*moultoni*	Olivier, 1909	T
	Lucidina	*angusticollis*	Pic, 1944	
	Lucidina	*flabellata*	Pic, 1944	
	Lucidina	*malaccana*	Pic, 1917	T
	Lucidina	*testaceipes*	Pic, 1944	
	Pyrocoelia	*atriventris*	Pic, 1938	T
	Pyrocoelia	*collaris*	Gorham, 1892	T
	Pyrocoelia	*consobrina*	Olivier, 1886	T
	Pyrocoelia	*fumigata*	Gorham, 1880	T
	Vesta	*pectoralis*	Pic, 1944	
Luciolinae	*Abscondita*	*berembun*	Nada, 2019	T
	Abscondita	*jerangau*	Nada, 2019	T
	Abscondita	*pallescens*	(Gorham, 1880)	
	Colophotia	*brevis*	Olivier 1903	
	Colophotia	*praeusta*	(Eschscholtz, 1822)	
	Curtos	*atripennis*	Pic, 1934	T
	Curtos	*flaviceps*	Pic, 1927	
	Kuantana	*menayah*	Ballantyne, 2019	T
	Luciola	*chapaensis*	Pic, 1923	
	Luciola	*jengai*	Nada, 2019	T
	Luciola	*maculipennis*	Olivier, 1913	
	Luciola	*niah*	Jusoh, 2019	T
	Luciola	*tiomana*	Ballantyne, 2019	T
	*Luciola**	*lata*	Olivier, 1883	
	Medeopteryx	*fraseri*	Nada, 2019	T
	Pteroptyx	*asymmetria*	Ballantyne, 2001	T
	Pteroptyx	*balingiana*	Jusoh, 2018	T
	Pteroptyx	*bearni*	Olivier, 1909	
	Pteroptyx	*decolor*	Olivier, 1911	
	Pteroptyx	*galbina*	Jusoh, 2015	T
	Pteroptyx	*gelasina*	Ballantyne, 2001	T
	Pteroptyx	*gombakia*	Ballantyne, 2015	T
	Pteroptyx	*malaccae*	(Gorham, 1880)	T
	Pteroptyx	*sayangia*	Ballantyne, 2015	T
	Pteroptyx	*tener*	Olivier, 1907	
	Pteroptyx	*testacea*	(Motschulsky, 1854)	
	Pteroptyx	*valida*	Olivier, 1909	
	Pygoluciola	*dunguna*	Nada, 2018	T

	Pygoluciola	*guigliae*	(Ballantyne, 1968)	T
	Pygoluciola	*hamulata*	(Olivier, 1885)	T
	Pygoluciola	*kinabalua*	(Ballantyne and Lambkin, 2001)	T
	Pygoluciola	*nitescens*	(Olivier, 1903)	
	Pygoluciola	*stylifer*	Wittmer, 1939	
	Pygoluciola	*wittmeri*	(Ballantyne, 1968)	T
	Pyrophanes	*semilimbata*	(Olivier, 1883)	
Ototretinae	*Brachypterodrilus*	*atricolor*	(Pic, 1943)	T
	Brachypterodrilus	*pallidipes*	Pic, 1918	T
	Drilaster (Drilaster)	*albicornis albicornis*	(Olivier, 1911)	T
	Drilaster (Drilaster)	*albicornis lateobscura*	(Pic, 1921)	T
	Drilaster (Drilaster)	*atriceps*	(Pic, 1921)	T
	Drilaster (Drilaster)	*borneensis*	(Olivier, 1907)	
	Drilaster (Drilaster)	*brevecostatus*	(Pic, 1939)	
	Drilaster (Drilaster)	*curtus*	(Pic, 1937)	T
	Drilaster (Drilaster)	*gravidus*	(Olivier, 1900)	T
	Drilaster (Drilaster)	*lateralis*	(Pic, 1921)	
	Drilaster (Drilaster)	*latipennis*	(Pic, 1943)	
	Drilaster (Drilaster)	*limbatus*	(Pic, 1925)	
	Drilaster (Drilaster)	*minutus*	(Pic, 1925)	
	Drilaster (Drilaster)	*niger*	(Pic, 1936)	T
	Drilaster (Drilaster)	*nigriceps*	(Pic, 1943)	
	Drilaster (Drilaster)	*pendleburyi*	(Pic, 1943)	T
	Drilaster (Drilaster)	*subapicalis helodiformis*	(Pic, 1921)	T
	Drilaster (Drilaster)	*subapicalis subapicalis*	(Pic, 1911)	T
	Drilaster (Drilaster)	*testaceicollis*	(Pic, 1921)	T
	Drilaster (Drilaster)	*testaceolineatus*	(Pic, 1936)	
	Drilaster (Drilaster)	*varicornis*	(Olivier, 1911)	T
	Drilaster (Loksadodrilus)	*subvittatus*	(Pic, 1943)	
	Emasia	*dentata*	Bocáková and Janišová, 2010	T
	Flabellototreta	*angustata*	Pic, 1935	T
	Flabellototreta	*inhumeralis*	Pic, 1925	
	Ototretadrilus	*maai*	Wittmer, 1978	T
	Stenocladius (Stenocladius)	*ater*	Pic, 1943	T
	Stenocladius (Stenocladius)	*basipennis*	Pic, 1943	T
	Stenocladius (Stenocladius)	*borneensis*	Pic, 1943	
	Stenocladius (Stenocladius)	*obscuripes*	Pic, 1943	T
	Stenocladius (Stenocladius)	*testaceus*	Pic, 1943	T

Habitats and ecological requirements

Fireflies in Malaysia inhabit a diverse range of environments, including mangrove and riverine wetlands, rice paddies, streams, marshes, grasslands, and forests at various elevations (Lloyd 2002; Nada *et al.* 2023). Congregating, synchronous displays are most linked to mangroves and are especially characteristic of the genus *Pteroptyx* (Jusoh *et al*. 2018; Wong 2022). However, both behaviour and habitat vary; not all *Pteroptyx* species are synchronous (e.g., *P. bearni*, *P. valida*), nor are they all limited to mangroves (e.g., *P. gombakia*) (Jusoh *et al.* 2018; Tan and Jusoh 2025). Many species occupy different habitats during different stages of their life cycle. For example, adult *Pteroptyx tener* court on mangrove trees, but females lay eggs farther up the riparian zone, and larvae develop along muddy banks where they prey on snails (Nada and Kirton, 2004). Within mangrove ecosystems, *Rhizophora* provides moist, shaded sites for oviposition; areas dominated by *Nypa fruticans* and *Metroxylon sago* support larval prey; and open-canopied *Sonneratia caseolaris* serves as a main tree for displays (Jusoh *et al*. 2010; Nada and Kirton 2004). The choice of display tree is influenced by proximity to water, leaf architecture, availability of sap or nectar, presence of larval prey, and structural stability (Jusoh *et al.* 2010).

A key ecological distinction is that only firefly larvae, not adults, exhibit aquatic or semi-aquatic behaviours. These larvae inhabit soil and leaf litter along riverbanks and pond margins and may briefly enter water while foraging. In contrast, truly aquatic fireflies have larvae that remain submerged and possess gills (Fu *et al.* 2012; Riley *et al.* 2021). For instance, the semi-aquatic *Pygoluciola dunguna* larvae crawl along sandy edges of shallow streams, indicating riparian rather than a fully aquatic lifestyle (Nada and Ballantyne 2018). Although truly aquatic firefly larvae have not yet been documented in Malaysia, they may be discovered as sampling expands.

For solitary fireflies, diversity in Peninsular Malaysia is largely shaped by habitat shifts associated with elevation, with forest type and canopy closure exerting the strongest influence (Nada *et al.* 2023). These species tend to be confined to specific elevational bands, leading to high species turnover between forest types. The cryptic nature and low density of fireflies complicate efforts to establish robust statistical links, but it is clear that habitat structure along elevation gradients is a primary driver of community composition. Worryingly, while many solitary firefly species still persist in urban areas, including Kuala Lumpur's green parks, they face ongoing threats (Mbugua *et al.* 2019; Muharraran *et al.* 2026).

THREATS TO FIREFLIES

The main threats to fireflies are habitat loss and degradation, light pollution, pesticide and insecticide exposure, water pollution, and unregulated tourism (Lewis *et al.* 2020, 2024). In Southeast Asia, habitat loss leads, closely followed by light and water pollution and pesticides. Surveys in Kuala Selangor suggest that over half of residents perceive local declines, citing insecticide use, tourism pressure, habitat loss, and water quality as leading concerns (Nadriah *et al.* 2020).

Mangrove fireflies are under pressure. On 27th of June 2024, the IUCN Firefly Specialist Group classified four congregating firefly species: *Pteroptyx bearni*, *P. malaccae*, *P. tener*, and *P. valida* as Vulnerable under the IUCN Red List (IUCN 2024). Formerly abundant in Southeast Asia's mangrove forests, these species, which can all be found in Malaysia, face severe threats from habitat loss and degradation. In fact, Malaysia has experienced substantial mangrove degradation through deforestation, reclamation, and pollution, with annual losses estimated in the thousands of hectares (Omar 2024; Islam *et al.* 2024). Such changes threaten *Pteroptyx*, which depend on specialised mangrove habitats (Nada and Kirton 2004; Jusoh and Hashim 2012). In the Rembau-Linggi estuary, land-use change coincided with nearly a 50% decline in *Pteroptyx* within two years (Jusoh and Hashim, 2012). Agricultural and industrial conversions introduce pollutant runoff that accelerates declines; oil palm and shrimp aquaculture runoff has been linked to lower *P. bearni* numbers and depressed water quality in the Cherating River (Lewis *et al.* 2020; Faudzi *et al*. 2021).

Pesticide contamination is a critical, cross-stage hazard. In the Selangor River, pesticide levels have exceeded thresholds deemed safe for freshwater biota (Leong *et al.* 2007). Such exposures can be directly lethal to eggs, larvae, pupae, and adults, and indirectly harmful by diminishing or poisoning larval prey (Pisa *et al.* 2015; Wang *et al.* 2022). Heavy motorboat traffic compounds impact by introducing oil pollution and generating waves that erode banks and dislodge display trees (Lewis *et al.* 2021).

Artificial light at night (ALAN) disrupts mate signalling by reducing contrast and detectability of flashes, curtailing activity windows, and immobilizing larvae (Gaston *et al.* 2013; Mbugua *et al.* 2019; Elgert *et al.* 2021; Owens *et al*. 2022). For *Lamprigera* sp., males have a narrow ~40-minute twilight window to locate females; bright lighting further compresses

that opportunity (Muharraran *et al.* 2024). In Bukit Kiara, larvae move away from illuminated zones, and in Cherating, reduced *P. bearni* populations have been associated with shrimp pond spotlights and nearby lights (Mbugua *et al.* 2019; Faudzi *et al.* 2021; Muharraran *et al.* 2026).

Climate change adds emerging risks. Prolonged heatwaves threaten moisture -dependent life stages, while sea-level rise can squeeze coastal wetlands, especially where human infrastructure blocks landward migration (Schuerch *et al.* 2018; Reed *et al.* 2020; Tangang 2025). Some Southeast Asian *Pteroptyx* congregate on *Sonneratia caseolaris*, a low-salinity species vulnerable to saltwater intrusion, which could in turn reshape local firefly assemblages.

EVIDENCE GAPS AND MONITORING NEEDS

Despite global renown for synchronous congregations, Malaysia still lacks comprehensive data on distribution, population dynamics, and long-term trends (Jusoh *et al.* 2010; Lewis *et al.* 2024). Most studies concentrate on a few rivers and focal sites, leaving many mangrove creeks and inland systems under-documented. Solitary and forest-dwelling species are particularly data-poor beyond select elevational transects (Nada *et al.* 2023).

A major bottleneck is the absence of standardised, habitat-specific survey protocols that enable comparisons across space and time. Establishing consistent methods for both congregating and solitary groups would strengthen trend detection and allow national-scale syntheses (Lewis *et al.* 2021). Malaysia already holds valuable datasets from long-term monitoring, elevational and recovery studies, and conservation projects; curating and integrating these across institutions would provide stronger baselines, reduce duplication, and sharpen policy planning (Nada *et al.* 2012). Taxonomic and genetic baselines are likewise needed to resolve cryptic diversity and support accurate field identifications (Jusoh *et al.* 2020).

Citizen and community science can bridge geographic and resource gaps when coupled with training and expert validation (Lewis *et al.* 2021). In urban parks such as Bukit Kiara, structured protocols allow volunteers from Friends of Bukit Kiara to monitor solitary fireflies (Friends of Bukit Kiara 2025). In riverine and mangrove systems, local communities and tour operators contribute long-term observations that track change and threats, as in the Selangor River programme (LUAS 2025). Trained volunteers and students are especially valuable for remote or high-elevation surveys (Nada *et al.* 2023). Ensuring data quality through training, photographic vouchers, and detailed metadata makes these efforts interoperable with professional datasets.

CONSERVATION ACTIONS

Over the past two decades, Malaysia has demonstrated leadership in firefly conservation, initiating the Selangor Declaration after the 2010 International Firefly Symposium (revised in 2014; Lewis *et al.* 2024), which ultimately led to the formation of the Fireflyers International Network (FIN) and the IUCN SSC Firefly Specialist Group (FSG) in 2018.

At the national level, firefly habitats are indirectly protected through legislation and policies governing permanent reserved forests, mangroves, river reserves, and environmentally sensitive areas. Research on solitary fireflies in Malaysian forests has shown that key habitat features such as canopy closure, leaf litter depth, presence of water bodies, and proximity to primary forest strongly influence firefly diversity and recovery following disturbance (Nada *et al.* 2023). These findings reinforce the importance of forest protection policies that maintain structural complexity rather than focusing solely on forest cover extent.

Local-level protection has been most explicit and operational in Selangor, where long-term research and monitoring directly informed policy outcomes. The gazettement of sections of the Selangor River as a Protection Zone under the Lembaga Urus Air Selangor (LUAS) Enactment, followed by the development of the Action Plan on Conserving the Fireflies of Selangor River 2022 – 2030 (Khoo *et al*. 2022), represents one of the clearest examples in Malaysia where sustained scientific evidence translated into enforceable conservation measures. The Action Plan integrates river basin management, land-use control, habitat rehabilitation, sustainable ecotourism, and stakeholder roles into a single implementation framework (LUAS 2025). Research along the Selangor River also demonstrates that maintaining natural riverbank vegetation behind display trees is vital for supporting larval, prey, and egg-laying populations (Nada 2011). Solely planting the *Berembang* tree, *Sonneratia caseolaris*, without broader habitat restoration, is insufficient to sustain firefly populations.

For forest-dwelling and solitary fireflies, protection in both natural and selectively logged forests is vital. Research indicates that once-logged forests can recover firefly diversity if structural complexity is preserved, whereas repeatedly logged forests exhibit poorer recovery. Moreover, numerous firefly populations persist outside protected areas and remain vulnerable (Nada 2023). Integrating firefly habitat requirements into environmental impact assessments, river and forest management, and urban planning is essential for their long-term survival (Lewis *et al.* 2024). There is also the need to integrate firefly requirements into forest management and restoration policies (Nada *et al.* 2023).

Looking ahead, Malaysia is set to achieve a conservation milestone. Wong (2022) published the Congregating Firefly Zones (CFZ) in Malaysia which established the basis for future firefly research in Malaysia. This pioneer work led to the planning of Malaysia Mangrove Firefly Conservation Action Plan, launched on the 28th of October 2025, and may result in the world's first national firefly conservation strategy. If this plan succeeds, it will help protect a key part of Malaysia's natural heritage and set an example for other countries in Southeast Asia. As Liani (2025) says, "*It takes a village to keep fireflies flashing.*" There is still a lot to do, especially in finding new species and helping populations recover, but there is a flash of hope for the future. Shine on!

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CHAPTER 22

Malaysia's land snails: Diversity, endemism, and the state of conservation

THOR-SENG LIEW[1]*, GOPALASAMY REUBEN CLEMENTS[2], JUNN KITT FOON[3,4], MOHD ZACAERY KHALIK[5,6] and MOHAMMAD EFFENDI BIN MARZUKI[5]

Abstract: Malaysia is recognised as a global biodiversity hotspot, but invertebrates remain largely overlooked in the national conservation discourse. We show that land snails are the country's most endangered terrestrial animal group. This is driven by high rates of narrow -range endemism within isolated limestone hills and highland forest ecosystems. Of the 970 land snail species recorded in Malaysia, 40 are currently listed as threatened according to the IUCN. Notably, the 28 species classified as Critically Endangered nearly equal the combined total of critically endangered mammals, birds, and reptiles in Malaysia. The severity of this crisis is underscored by the confirmed global extinction of *Plectostoma sciaphilum* following the complete quarrying of its only known habitat. Facing threats from limestone extraction industry and climate change, the conservation of these overlooked invertebrates requires a multifaceted approach comprising systematic biodiversity documentation, the application of the IUCN Red List of Ecosystems to prioritise limestone hills for protection, and immediate in-situ and/or ex-situ interventions to prevent further extinctions.

INTRODUCTION

Malaysia is known as one of the 17 megadiverse nations and one of the 36 biodiversity hotspots—places on Earth that are both biologically rich and highly threatened (Myers *et al*. 2000). In Malaysia, several large, charismatic, and popular animals have been used as flagship species to highlight conservation issues and to implement conservation action, such as protecting a specific habitat or ecosystem in Malaysia (KATS 2019). While these popular animals represent a broader cause of conservation, many other, less popular animals, especially invertebrates, are typically overlooked in conservation discourse. Furthermore, some of these less-popular animals, particularly many endemic invertebrates with limited distribution ranges, are obligate to small, isolated, and scattered ecosystems such as limestone hills or highland forests, especially mountaintops. Consequently, these unique endemic species and ecosystems that support them are often neglected. When some of these ecosystems are also important in providing irreplaceable raw materials for humans (e.g., limestone hills providing raw material for cement), a conservation crisis can escalate dramatically to a point where it becomes almost impossible to mitigate the degradation of the habitats and prevent the extinction of fauna and flora.

Invertebrates are often overlooked in nature conservation discussions, a pattern reflected in the reports: '*Nature Conservation in Western Malaysia*' (1961) dedicated a chapter only to butterflies, and subsequent report ('*State of Nature Conservation in Malaysia 1991 and 2025*) still focus on only a few taxa (e.g. butterflies, moths, fireflies, and land snails)

[1] Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Kota Kinabalu, Sabah, Malaysia.
[2] Zoological Society of London, London, UK.
[3] School of Science, Western Sydney University, Hawkesbury Campus, Richmond NSW 2753, Australia.
[4] Australian Museum Research Institute, Australian Museum, Sydney NSW 2010, Australia.
[5] Institute of Biodiversity and Environmental Conservation, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.
[6] Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia.
***Corresponding author: thorseng@ums.edu.my**

(Figure 1A). This neglect is not deliberate, but stems from the lack of knowledge driven by the sheer hyper-diversity of the group. The largest phylum, Arthropoda, is estimated to be 22 times more species-rich than all vertebrates combined, and Mollusca is 1.5 times richer (Mora *et al.* 2011; Li and Wiens 2023). Hence, the taxonomy of most invertebrate taxa is still far from complete, and their distribution and ecology remain largely unknown.

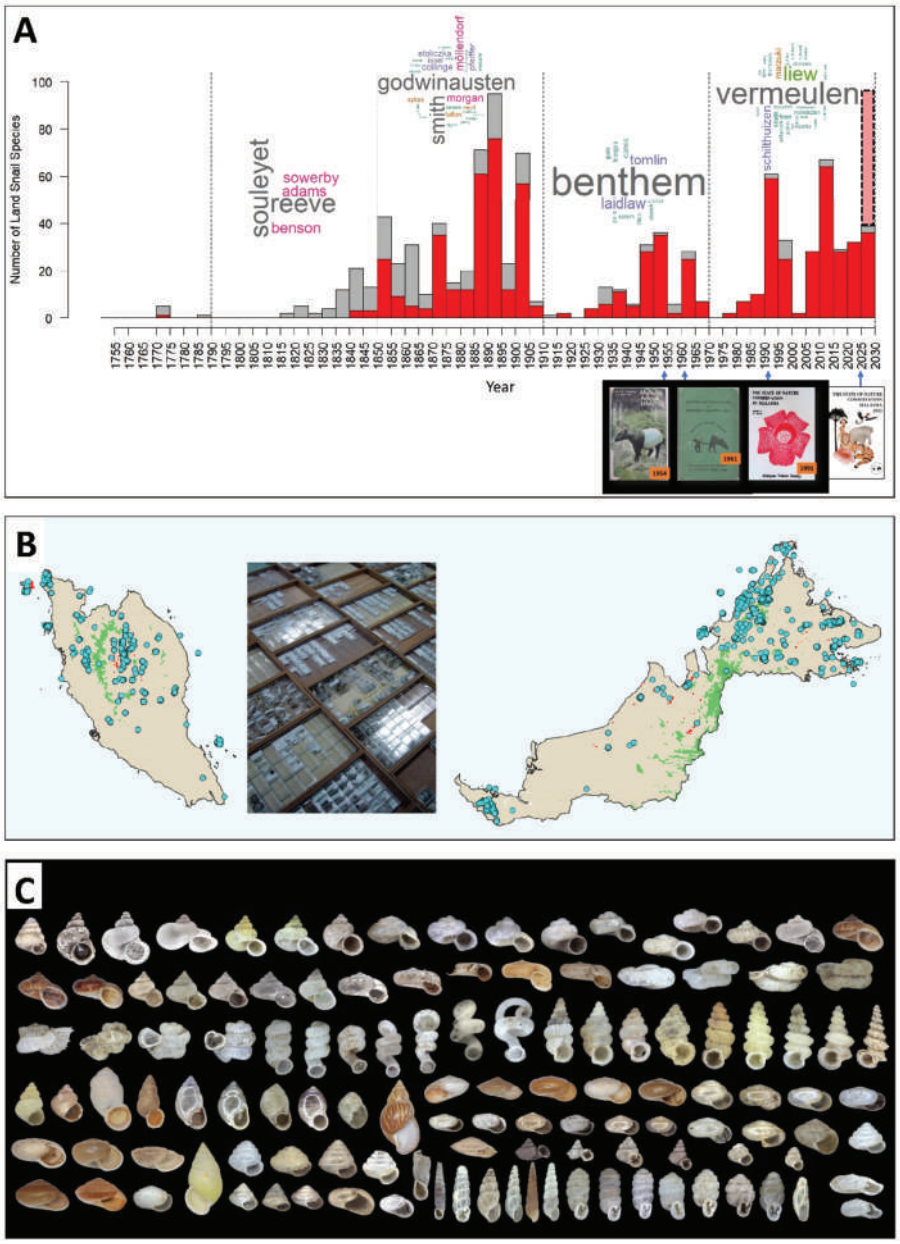

Figure 1. An overview of land snail discovery in Malaysia spanning over two centuries. **(A)** A temporal histogram showing the number of land snail species described (red) or recorded (grey) in Malaysia from 1755 to 2025, with projections to 2030 based on ongoing research (pink dashed bar). Word clouds highlight the main authors of each era and cover images of key SoNC reports (1961, 1991, 2025); **(B)** Distribution of specimen records across Peninsular Malaysia, Sabah, and Sarawak (blue dots) since the 2000s, curated by the BORNEENSIS collection (Universiti Malaysia Sabah) and illustrating the gaps in the land snail surveys; **(C)** Representative morphological diversity of 122 species collected from 12 limestone hills in the Kinta Valley, Perak (Foon *et al.* 2007).

TWO CENTURIES OF LAND SNAIL DISCOVERY AND RESEARCH

Land snail research in Malaysia has a long history, spanning over two centuries, which provides a valuable starting point for understanding their unique diversity and conservation (Figure 1A). Until 1960, there were already around 625 species of land snails recorded, though scattered in literature, in Malaysia (347 in Peninsular Malaysia and 313 species in Sabah and Sarawak, with 32 shared species). Two-thirds (414) of these species were originally described from Malaysia since the mid-19th century by the early explorers, collectors, and scientists. Although their works only covered a relatively tiny portion of Malaysia's landscape, the high species richness of land snails was noticed in isolated ecosystems such as limestone hills and highlands (Tweedie and Harrison 1954; Tweedie 1961). These observations of possibly very high endemism for land snails in limestone ecosystems were also noted in the Nature Conservation in Western Malaysia, 1961 report (Allen 1961; McClure 1961).

In the next three decades, an additional 54 species were added to the list of land snails in Malaysia, bringing the total to 679, with 51 of these originally described from Malaysia (Figure 1A). Although the description of the new species was not as intensive as in previous decades, our understanding of land snail distribution improved significantly. This improvement came when Davison (1990, 1991a) explored more limestone hills in Kelantan and Perak, confirming that the endemism of land snails was extremely high and that many hills possessed their own endemic species, many of which had yet to be discovered. In The State of Nature Conservation in Malaysia 1991 (SoNC 1991), Davison (1991b) stressed that the conservation of these endemic land snails, which are restricted to a single hill or a cluster of hills, cannot be detached from the conservation of the limestone hills themselves, particularly those threatened by quarrying. However, these localised observations were insufficient for the assessment of their conservation status based on IUCN Red List criteria.

Since 1991 to date, an additional 291 species have been discovered in Malaysia, bringing the land snail species total to 970 (Figure 1A). More than 90% of these were new species originally described from Malaysia (49 new species from Peninsular Malaysia and 225 from Sabah and Sarawak) (e.g. Foon *et al.* 2017; Phung *et al.* 2017; Marzuki *et al.* 2021; Vermeulen and Liew, 2022; Liew *et al.* unpublished). This drastic increase in species was a result of several factors, namely, (1) the establishment of specimen collections in the BORNEENSIS collection, Universiti Malaysia Sabah; (2) exploration into more localities of various ecosystems, particularly the isolated ones such as limestone hills, mountaintops, and islands; and (3) continuous taxonomic and faunistic research started by foreign malacologists (Jaap J. Vermeulen and Menno Schilthuizen) and subsequently continued by their locally trained researchers (Figures 1A and 1B). These developments in local land snail research have successfully filled the research and knowledge gaps highlighted by Davison (1991b), such as fragmented and outdated taxonomic research and a lack of systematic surveys to provide data for conservation assessment.

These 970 species of land snails and slugs (hereafter land snails) belong to around 170 genera across 40 families and display a wide variety of colours, shapes, and sizes (Figure 1C) (Liew and Foon 2024). Their size can range from <1 mm to 85 mm, with more than half of the species classified as micro snails (size of < 5 mm). Except for approximately 20 to 30 non-native land snails often found in human settlements, gardens, and plantations, all other species are restricted to natural forests. These forests span the entire elevation gradient, from lowland tropical rainforests up to subalpine forests above 4000 m a.s.l. at Mount Kinabalu (Liew *et al.* 2010). Land snails can also be found in forests across different hydrological and edaphic backgrounds, including heath forest, peat swamp forest, ultramafic forest and limestone forest. Recent studies confirm that the extraordinarily high species diversity and endemism of land snails are overwhelmingly concentrated in highland forests and limestone forests (Liew *et al.* 2014; Vermeulen *et al.* 2015; Foon and Liew, 2017; Khalik *et al.* 2018, 2019).

KEY HABITATS

Highland forest ecosystem

In Peninsular Malaysia, the highland forests above approximately 1000 m a.s.l. harbour land snails with limited distribution, often endemic to these montane habitats (Figure 2A). In contrast, lowland forests are usually occupied by more widespread land snails that can be divided into three distinct assemblages in Peninsular Malaysia: between the east and west sides of the Main Range and adjacent to the Kangar-Pattani line in the northern region, where species affinities are similar to those found in Indochina (Clements *et al.* 2008). In Sabah and Sarawak, particularly Sabah, where the distribution data are more comprehensive, the high-endemism zone begins above approximately 1500 m a.s.l.. Almost all species occurring above 2600 m are endemic to Mount Kinabalu, and lowland land snail assemblages differ between the east and west sides of the Crocker and Trusmadi Ranges. These highland snails are ecologically adapted to the cooler, high-moisture conditions of montane forests (Figure 2B). In Peninsular Malaysia, only 3.8% of the forest lies above 1000 m, with a few peaks exceeding 2000 m, while in Sabah and Sarawak, approximately 6.9% of the combined forest area is above 1000 m, and almost all of the 0.07% of the forest above 2000 m is concentrated in Sabah.

Although no systematic conservation status assessment has been conducted for all highland land snails, many of these highland endemic species are currently under threat. For example, the largest native land snail in Peninsular Malaysia, *Platymma tweediei* Tomlin, 1938, faces risks from increasing habitat degradation and wildlife trade (Figure 2B) (Foon 2014). This species and the other highland endemics are suffering habitat degradation due to logging, agricultural, road and urban development, which is reducing the once continuous forest along the mountain ranges into fragmented and isolated forest islands on the mountain tops (Peh *et al.* 2011). These high-altitude habitats are intrinsically more sensitive to climate change, where the effect of rising temperature is typically more pronounced at higher elevations (Anthony *et al*. 2025). Furthermore, ongoing global warming is causing the upslope shifts of montane cloud forests towards the mountain tops, constricting the available habitat for the land snails adapted to these cool, high-moisture conditions. The subalpine land snails on Mount Kinabalu (above 2600 m) are particularly vulnerable; they are almost entirely endemic to the mountain, likely representing relict lineages that have persisted in these high-elevation refugia through past climate cycles (Liew *et al*. 2020).

Limestone ecosystems

Similar to highland forests, limestone forests, which are almost all lowland forests, harbour remarkably high land snail population density, species richness and endemism compared to the non-limestone lowland forest (Schilthuizen *et al*. 2003; Liew *et al*. 2008). This remarkable density is largely due to the high availability of calcium carbonate (resulting in low acidic soil) in limestone environments, an essential resource for shell growth. These limestone forests on the fragmented and isolated outcrops, known for their distinctive geomorphological features called “fenglin”, function as “islands” (Waltham 2008) (Figures 2A and 2C). The surrounding non-calcareous, highly acidic soils act as barriers to dispersal for many small, slow-moving land snails (Figure 2A). Hence, close to 30% of all known land snail species in Malaysia can only be found on limestone hills. Over tens of millions of years of allopatric speciation, many genera such as *Plectostoma*, *Opisthostoma*, *Georissa*, *Arinia*, and *Diplommatina*, have become exceptionally diverse and hyper-endemic on these limestone hills, with many species restricted to a single hill (Vermeulen 1991, 1993, 1994, 1996; Liew *et al*. 2014; Khalik *et al*. 2018, 2019).

An increasing number of these hills are being developed into tourism sites for their scenic and aesthetic values. However, approximately 10% of limestone hills in Malaysia are currently being quarried or have been completely quarried away (Liew *et al.* 2021) (Figure 3).

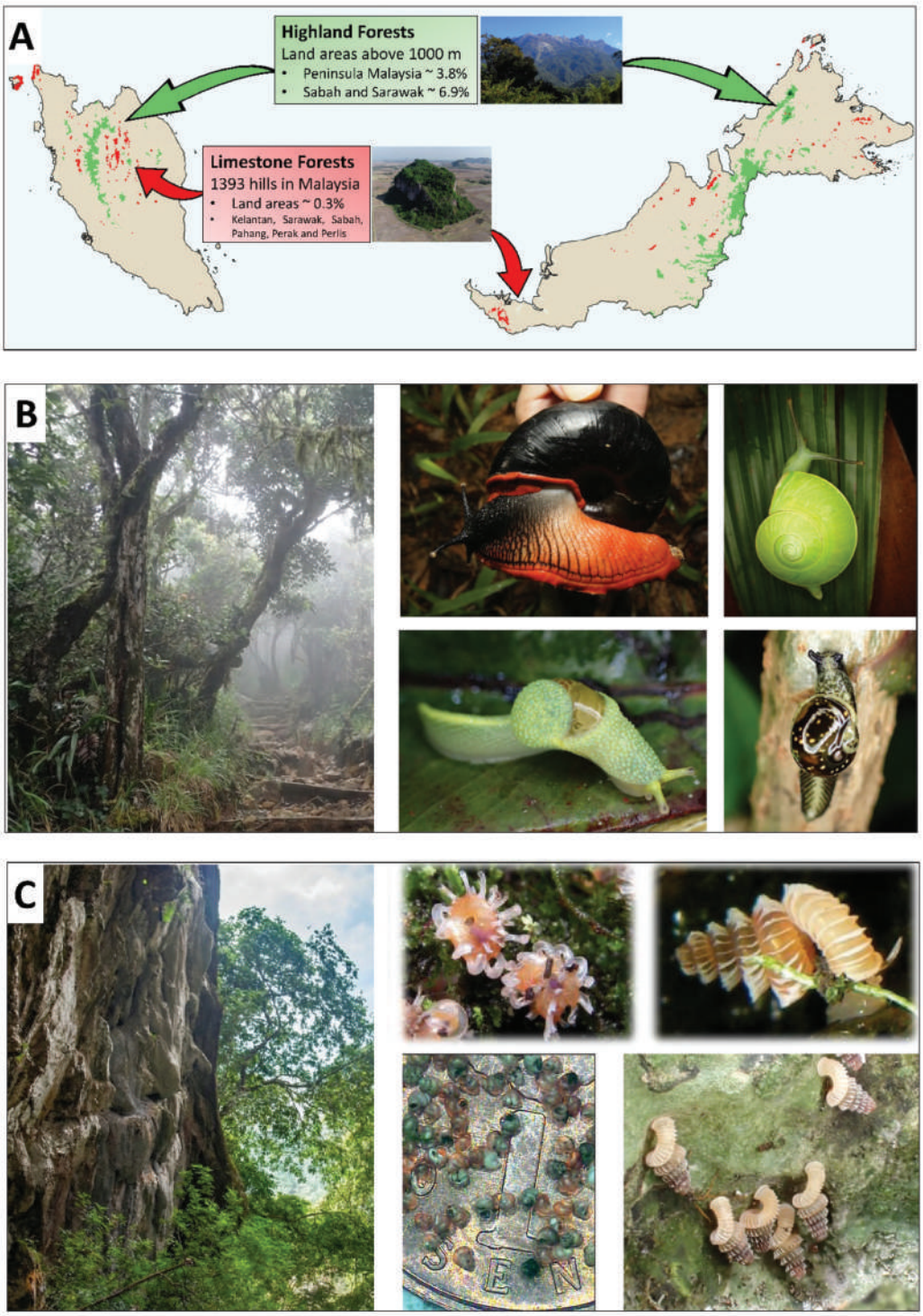

Figure 2. Critical habitats for Malaysia's endemic land snails. **(A)** Distribution map of highland (> 1000 m a.s.l.) forests (green) and limestone forests (red). Highland forests cover only 3.8% of Peninsular Malaysia and 6.9% of Sabah and Sarawak, while limestone hills cover a mere 0.3% of the total land area; **(B)** Highland forest environment and its unique land snails: (top centre) the large, colourful *Platymma tweediei*; (clockwise) *Rhinocochlis chlorosoma*, *Sabalimax pantherina*, and *Ibycus rachelae*; **(C)** Limestone karst ecosystems, which serve as biological islands for rock-dwelling micro snails: (top centre) *Plectostoma grandispinosum*; (clockwise) *Plectostoma siphonostoma*, and *Georissa bangueyensis* (shown against a 1-cent coin for scale).

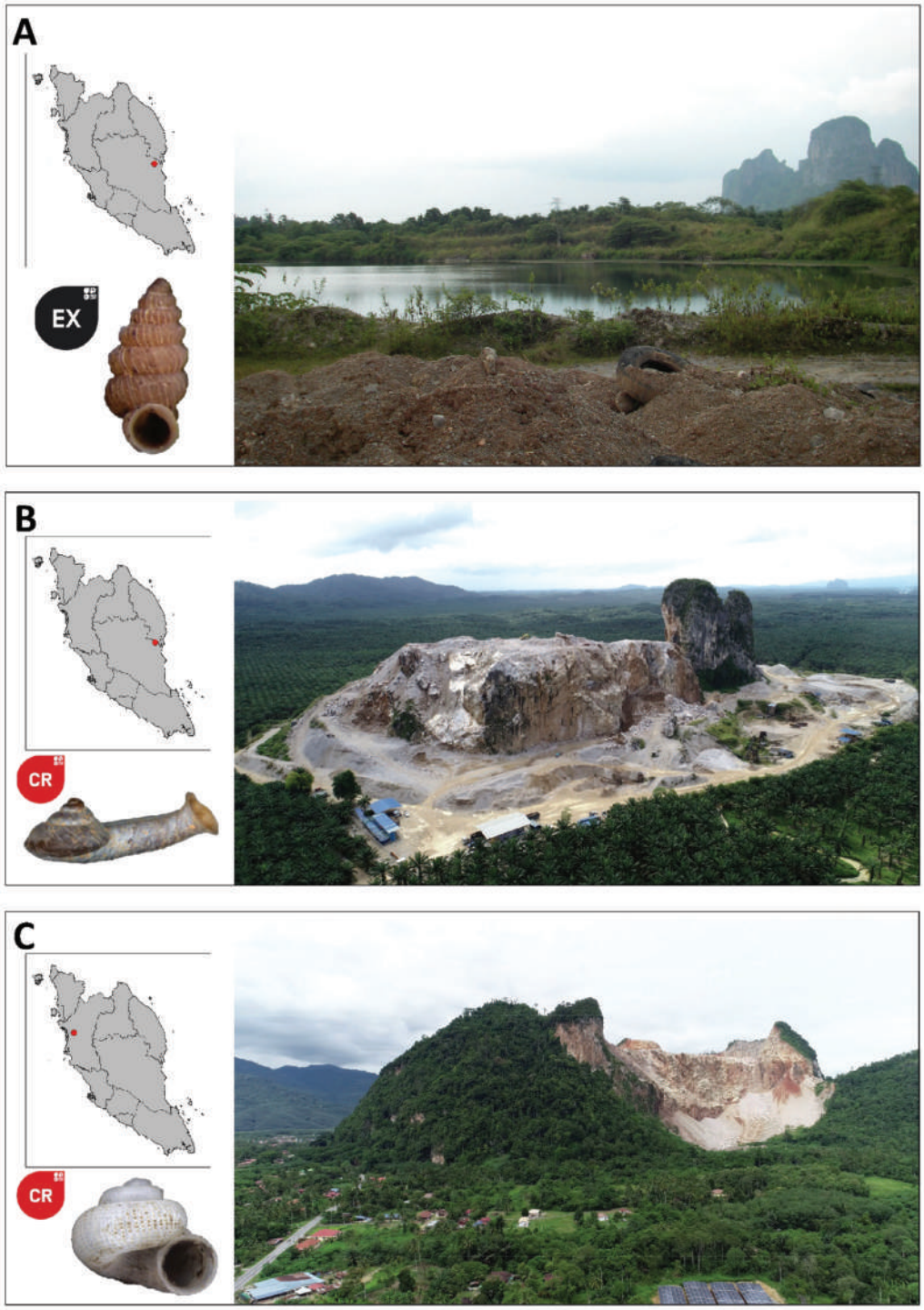

Figure 3. Endangered land snail species endemic to limestone hills in Malaysia (habitat images captured 2018 – 2019). **(A)** The site of Bukit Panching (Phg 72), Kuantan in Pahang, where complete quarrying led to the global extinction (EX) of *Plectostoma sciaphilum*; the photograph shows the abandoned pond remaining after the limestone substrate removal; **(B)** *Hypselostoma elephas* of Bukit Tenggek (Phg 75), Kuantan in Pahang (red dot), is listed as Critically Endangered (CR) due to limestone extraction that has destroyed nearly its entire habitat; the species is projected to go extinct soon; **(C)** *Dicharax microconus* of Gunung Pondok (Prk 55), Perak (red dot), is listed as Critically Endangered (CR) because a large section of the hill has been quarried, highlighting the urgent need for in-situ or ex-situ conservation interventions.

Beyond being a main raw material for the construction sector, lime is also required for the metals industry, environmental protection, agriculture, and the chemical industry (Conway 2003). The extraction of limestone results in irreplaceable habitat destruction. This threat is far more critical than timber extraction from other forest types because the removal of the underlying substrate—the limestone—extirpates the entire ecosystem. Since many endemic plants and animals have evolved specific adaptations to these hills over tens of millions of years, it is unlikely the forest can be restored without the underlying limestone. Therefore, the destruction leads directly to the extinction of endemic plants and animals that have evolved uniquely on those hills.

Limestone hills in a few locations were mentioned in the Nature Conservation in Western Malaysia, 1961 report, such as Kuala Lumpur (Hilton 1961; McClure 1961), Ipoh (Allen 1961) and National Park, Pahang (Hislop 1961). The uniqueness and importance of limestone ecosystems have received increasing attention in the subsequent SoNC 1991 report, where various chapters outlined the threats to limestone flora (Bidin 1991; Kiew 1991a,1991b; Kiew and Pearce 1991; Lamb 1991) and land snails (Davison 1991). However, the importance of these ecosystems extends beyond these groups. Besides land snails, limestone forests are also the sole habitats for many endemic species of herpetofauna (Quah *et al.* 2021) and cave arthropods (e.g. Deharveng *et al.* 2018; Schwendinger 2017; Schwendinger *et al.* 2019; Promdam *et al.* 2022). The conservation challenges facing flora in the limestone ecosystem are presented in another chapter in this SoNC 2025, *Limestone flora of Malaysia: Their threats and conservation* (Rafidah *et al*. 2026).

LAND SNAILS ARE MALAYSIA'S MOST THREATENED TERRESTRIAL ANIMALS

The availability of distribution data for land snails have facilitated the first ever conservation status assessment in 2004. Since then, a total of 40 Malaysian land snails have been placed in the threatened categories (IUCN 2025), comprising 28 Critically Endangered, six Endangered, and six Vulnerable species (Table 1). The 28 critically endangered land snail species are nearly equal to the combined total (29) of critically endangered bird, reptile and mammal species in Malaysia. In 2015, the extinction of two species was officially declared by the IUCN, one of which was the Malaysian land snail species, *Plectostoma sciaphilum*, endemic to the single limestone hill of Bukit Panching, in Pahang (Liew 2015). This extinction represents the only Malaysian terrestrial animal species that is Globally Extinct (Figure 3A). The fact that land snails account for the nation's only Globally Extinct terrestrial species, and hold a staggering 28 Critically Endangered species, demonstrates that they are the most severely threatened terrestrial animal group in Malaysia.

All 40 Malaysian land snail species listed in the IUCN Red List Threatened categories are endemic to limestone hills that are currently facing forest loss and quarrying (Table 1). This vulnerability is directly linked to their high degree of endemism, with many species being restricted to a single limestone hill and sensitive to habitat degradation (Schilthuizen *et al.* 2005; Clements *et al.* 2006). The fate of these limestone hills is clearly illustrated by Bukit Panching, the only known habitat for the extinct land snail *P. sciaphilum* (van Benthem Jutting 1952). The hill has been completely quarried away, leaving behind an abandoned pond where the recovery of the forest and land snail is impossible (Figure 3A). The species was first collected in 1947 and described as a new species in 1952, but was listed as Critically Endangered in 2009 and confirmed extinct in 2015 (van Benthem Jutting 1952; Clements 2009; Liew 2015). This tragic loss was featured in the book, *Lost Wonders: 10 Tales of Extinction from the 21st Century* (Lathan 2024). Another land snail, *Plectostoma tenggekense* (Liew *et al.* 2014), described only in 2014 based on specimens collected in 1997, was immediately listed as Critically Endangered (Liew and Seddon, 2020) and is likely

facing imminent extinction, together with other land snail species, such as *Hypselostoma elephas*, due to ongoing quarrying (Figure 3B). This situation is similar to other Critically Endangered land snails, which face the same threats. Furthermore, many undescribed species may have already become extinct without our knowledge.

Table 1. The conservation status of 55 land snail species in Malaysia is listed in the IUCN Red List (IUCN 2025). The species are categorised by their current IUCN status and taxonomic family.

Conservation Status	No.	Species
EXTINCT	1.	**Diplommatinidae**
		Plectostoma sciaphilum
CRITICALLY ENDANGERED	2.	**Alycaeidae**
	3.	*Chamalycaeus microconus*
	4.	*Chamalycaeus mixtus*
		Stomacosmethis balingensis
	5.	**Charopidae**
		Gleniskos lafargei
	6.	**Diplommatinidae**
	7.	*Arinia boreoborneensis*
	8.	*Arinia dentifera*
	9.	*Arinia oviformis*
	10.	*Arinia simplex*
	11.	*Diplommatina cacuminulus*
	12.	*Diplommatina madaiensis*
	13.	*Opisthostoma thersites*
	14.	*Opisthostoma trapezium*
	15.	*Plectostoma decrespignyi*
	16.	*Plectostoma fraternum*
	17.	*Plectostoma inornatum*
	18.	*Plectostoma jucundum*
	19.	*Plectostoma mirabile*
	20.	*Plectostoma otostoma*
	21.	*Plectostoma perspectivum*
	22.	*Plectostoma charasense*
	23.	*Plectostoma dindingense*
	24.	*Plectostoma retrovertens*
	25.	*Plectostoma tenggekense*
	26.	*Plectostoma turriforme*
		Plectostoma umbilicatum
	27.	**Hypselostomatidae**
	28.	*Hypselostoma elephas*
		Hypselostoma serpa
	29.	**Pupillidae**
		Hypselostoma luctans
ENDANGERED	30.	**Diplommatinidae**
	31.	*Arinia biplicata*
	32.	*Arinia streptaxiformis*
	33.	*Plectostoma dormani*
	34.	*Plectostoma kubuense*
	35.	*Plectostoma palinhelix*
		Plectostoma simplex

VULNERABLE		**Diplommatinidae**
	36.	*Opisthostoma michaelis*
	37.	*Plectostoma bihamulatum*
	38.	*Plectostoma laidlawi*
	39.	*Plectostoma senex*
		Hypselostomatidae
	40.	*Hypselostoma megaphonum*
	41.	*Hypselostoma perigyra*
NEAR THREAENED		**Diplommatinidae**
	42.	*Plectostoma christae*
	43.	*Plectostoma kakiense*
	44.	*Plectostoma mengaburense*
	45.	*Plectostoma tohchinyawi*
LEAST CONCERN		**Diplommatinidae**
	46.	*Plectostoma crassipupa*
	47.	*Plectostoma davisoni*
	48.	*Plectostoma ikanense*
	49.	*Plectostoma kayiani*
	50.	*Plectostoma laemodes*
	51.	*Plectostoma praeco*
	52.	*Plectostoma relauense*
	53.	*Plectostoma salpidomon*
	54.	*Plectostoma siphonostomum*
	55.	*Plectostoma whitteni*

ONGOING ACTIONS AND FUTURE DIRECTIONS FOR LAND SNAIL CONSERVATION

The conservation story of Malaysia's land snails is both compelling and urgent, making them a vital example for many more relatively unknown invertebrates in Malaysia that are now facing extinction. In fact, the urgency of the situation was recognised in the first report, where Allen (1961) stated that conservation action for the limestone ecosystem "*must be done NOW*" and that "*There is still time, but only just time, to prevent this [extinction] occurring to the unique flora and fauna of the limestone hills of Ipoh.*" In the same report, Corner (1961) further noted that proposals had been put to UNESCO to undertake a scientific survey of the limestone hills of Southeast Asia. In the SoNC 1991 report, Kiew (1991) reported that there were no specific statutory and legally restrictive regulations for limestone hills, except for those hills in Taman Negara in Pahang, Gunung Mulu and Niah in Sarawak, as National Parks, and a few hills in recreational forests or forest reserves in Malaysia. She also stressed that at least 200 m of forest around limestone hills needed to be included to maintain the ecological integrity of the hills by providing a buffer zone that prevents direct anthropogenic disturbance immediately adjacent to limestone habitat.

Despite these warnings, legal protection remains limited. Between 2017 and 2025, more limestone hills were included in the National Geoparks of Kinta Valley, Lenggong, Lipis, Langkawi, Labuan, Kenyir, Sarawak Delta, Stong, Gombak-Hulu Langat and Perlis, though these Geoparks do not have the same protection levels as National or State Parks. Furthermore, Niah, Gunung Mulu, Lenggong and Langkawi are later recognised as UNESCO World Heritage and /or Global Geopark sites. Given that existing statutory

protection is inadequate, a proactive and multifaceted approach is required. Therefore, current conservation efforts focus on systematic data generation, legal and ecosystem status assessments, and immediate species survival measures.

Responding to this historical and ongoing crisis, one of the primary conservation efforts is currently focused on generating systematic data on species and their ecosystems to enable the future implementation of high-level policy changes to secure the future of these threatened ecosystems. Crucially, for limestone hills, only around 20% of the hills currently have at least one published biodiversity record, leaving the vast majority of these unique ecosystems scientifically unassessed (Liew *et al.* 2021). This aims not only to identify conservation important species but also to determine which limestone hills are more unique than others, aiding decision-making in conservation prioritisation. This is critical because balancing conservation must account for the extraction of limestone for development; limestone is the second most extracted resource by humans after water, and currently has no substitute, unlike fossil fuels (Conway 2023).

To transform these data into actionable policy, the Forest Research Institute Malaysia (FRIM) has identified limestone and highland ecosystems as key targets for conservation status assessment using the IUCN Red List of Ecosystems framework (Hamidah *et al.* 2024). The establishment of this conservation framework is crucial, as it will enable conservationists, policymakers, industries, and communities to collaboratively plan the future of Malaysia's limestone ecosystems (Liew *et al.* 2021, 2023). Furthermore, this framework serves as a guide for vital future actions, specifically: (i) periodic monitoring of limestone hills, such as the full assessment conducted in 2018 – 2019 (Liew *et al.* 2021), to be repeated every five to ten years; and (ii) conservation status assessment of endemic species, particularly those in highland ecosystems, alongside updating the status of currently IUCN-listed land snail species.

In addition to these data collection and policy initiatives, if avenues for conserving a species' habitat are impractical, immediate action is needed to prevent species extinction, such as emergency collecting for ex-situ conservation and translocation, particularly for the land snail species that are already listed as Critically Endangered (Vermeulen and Whitten 1999; Liew *et al*. 2021) (Figure 3A). Recent in-situ conservation work has also commenced, including the trial of translocation of land snail populations from severely degraded sites to nearby, more protected sites, which has demonstrated promising results (Liew *et al.* 2023).

CONCLUSION

The conservation narrative of land snails presented here serves as a critical case study for the broader invertebrate fauna, which remains largely overlooked. While land snails currently stand as the most threatened terrestrial animal group in Malaysia, this status is likely shared by many other hyper-diverse invertebrate groups that lack comparable taxonomic attention. The trajectory of land snail conservation issues has evolved from initial observations in Nature Conservation in Western Malaysia, 1961 to the arising concerns in SoNC 1991, and finally the critical urgency presented here in SoNC 2025. This development towards urgency is supported by decades of taxonomic research and documentation. To uncover the true state of Malaysia's biodiversity and ensure this diversity does not face silent extinction before discovery, we must acknowledge that many lesser-known invertebrates require equal, if not greater, attention and investment than charismatic vertebrates to develop the taxonomic capacity and conservation actions needed to describe and protect this hidden biodiversity.

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CHAPTER 23

Conservation status of corals in Malaysia

JULIAN HYDE, ALVIN JEYANATHAN CHELLIAH
and SUE YEE CHEN*

Abstract: Malaysia, located within the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security Implementation Area, is home to 1,687 km^2 of coral reefs that support 501 species of hard corals. These coral reefs host high biodiversity that plays a vital role in supporting fisheries, tourism, and coastal protection. Currently, the health of Malaysia's coral reefs is rated as fair, with an average live coral cover of 44.65%. However, recent data from Reef Check Malaysia's 2025 monitoring program show that coral reef health is in decline nationally, with average live coral cover dropping for the third consecutive year. This trend highlights that current coral reef conservation efforts are not sufficient to address ongoing threats. Key challenges include fragmented management, weak governance, limited stakeholder involvement, insufficient funding, poor waste management, and sporadic research. To protect and restore these coral reefs, Malaysia needs a coordinated national approach that unites State and Federal government agencies, scientists, local communities, and other stakeholders. Correspondingly, improving land-sea management integration is a crucial step toward securing the future of Malaysia's coral reefs.

INTRODUCTION

Malaysia is located in the South China Sea and sits within the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security Implementation Area (Figure 1). The country has a coastline of 4,675 km and an Exclusive Economic Zone (EEZ) area of 334,671 km^2, which includes 1,687 km^2 of coral reefs (Coral Triangle Atlas 2025; Leong 2025). These reefs are home to an incredible variety of life, including 1,428 species of coral reef fish and 386 taxa of seaweed and algae (Phang *et al.* 2007; Chong *et al*. 2010). Coral reefs are not only rich in biodiversity, but they are also vital to the economy and the well-being of millions of Malaysians. They help support tourism and provide income for coastal communities (Academy of Sciences Malaysia 2022). With a population of about 34.2 million people (Department of Statistics Malaysia 2025), nearly all Malaysians live within 100 km of the coast (Asian Development Bank 2014), showing Malaysians are deeply connected to the sea.

Malaysia's coral reefs are under threat from various sources. Rising sea temperatures, coastal development, overfishing, pollution, and irresponsible tourism are damaging these fragile ecosystems. This leads to the loss of marine life, reduced income for local communities, and reduced food security, as well as making it harder for these coral reefs to recover from future environmental changes (Asian Development Bank 2014; Yu and Wee 2023; Reef Check Malaysia 2025). To help protect these coral reefs, Malaysia has established 51 marine protected areas, covering about 3,856 km^2 of its marine areas (Coral Triangle Atlas 2025).

Present status

Malaysia's coral reefs contain 501 species of hard corals (Scleractinia) recorded across the country. Out of the 501 species, only 56 species have been found in the Malacca Strait region, while 398 species have been found in the Sunda Shelf region, and 382 species in the North Borneo region (Figure 2). Although it might seem surprising that the Sunda Shelf has

Reef Check Malaysia, Lot 5.19-5, Wisma Central, 22, Jalan Ampang, Wilayah Persekutuan, 50450 Kuala Lumpur, Federal Territory of Kuala Lumpur, Malaysia.
***Corresponding author: sue@reefcheck.org.my**

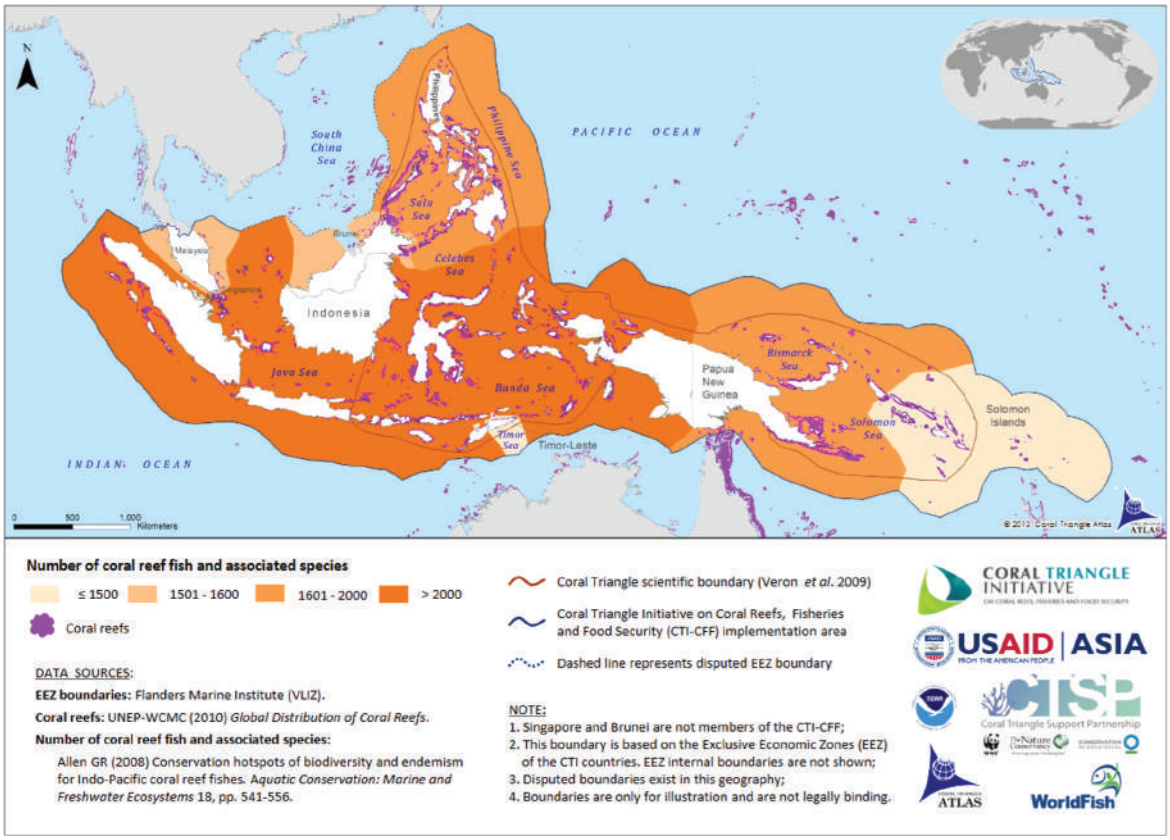

Figure 1. Map showing Malaysia situated within the Coral Triangle Initiative on Coral Reefs, Fisheries, and Food Security Implementation Area (Coral Triangle Atlas 2025).

more reef coral species than North Borneo, this may be due to limited research and data from the North Borneo region (Waheed 2016). In general, coral diversity decreases with increasing distance from the centre of the Coral Triangle (Carpenter *et al.* 2011). One of Malaysia's most important coral reef areas is Semporna, located in eastern Sabah. Semporna sits just inside the boundaries of the Coral Triangle and has the highest concentration of coral reefs in the country. It also boasts the richest variety of mushroom corals (Fungiidae), even more than some other areas within the Coral Triangle (Waheed and Hoeksema 2013).

In 2024, Reef Check Malaysia conducted its annual coral reef monitoring surveys at a total of 41 coral reef locations, covering 315 individual sites: 22 locations (157 sites) in the Sunda Shelf, five locations (22 sites) in the Malacca Strait, and 14 locations (136 sites) in North Borneo. These surveys covered both marine protected areas and non-protected areas, mostly around islands. Based on Reef Check Malaysia's 2024 coral reef monitoring surveys data and the classification system developed by Chou *et al*. (1994), Malaysia's coral reefs are currently in fair condition with an average of 44.65% live coral cover. When looking at different regions, Sunda Shelf reefs are in good condition with an average of 50.21% live coral cover, Malacca Strait reefs are in fair condition with 36.36% live coral cover, and North Borneo reefs are also in fair condition with 39.56% live coral cover. Across these locations, 39.02% were in good condition, 51.22% were in fair condition, and 9.76% were in poor condition. None were found to be in excellent condition. A breakdown by region shows over half (54.55%) of the coral reef locations surveyed in Sunda Shelf were in good condition and the rest in fair, 80% in Malacca Strait were in fair condition and 20% in good, and 50% in North Borneo were in fair condition, 28.57% in poor, and the remaining in good (Reef Check Malaysia 2025).

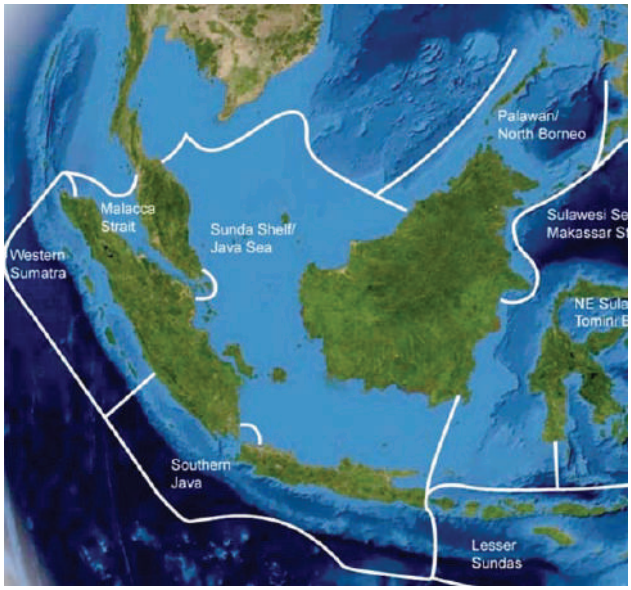

Figure 2. Map showing the Malacca Strait, Sunda Shelf and North Borneo marine ecoregions as defined in the Marine Ecoregions of the World (MEOW) classification scheme (Huffard *et al*. 2012).

Malaysia's coral reefs are facing threats from both human activities and environmental stress (Figure 3). According to Reef Check Malaysia's 2024 coral reef monitoring, about 83% of coral reef locations surveyed were heavily affected by discarded fishing nets and marine trash and 56% showed damage from boat anchors. In Sabah, a worrying 64% showed signs of dynamite fishing, an illegal practice that causes extensive reef destruction. High levels of disturbance indicators such as recently killed coral, rubble, and silt were found across all regions. Some of the worst affected coral reef locations include Tunku Abdul Rahman Park (over 50% disturbance indicators) and Pulau Redang (over 40%). Pulau Pangkor, Malacca, Port Dickson, Pulau Mantanani, Pulau Mataking, Pulau Penyu, Pulau Sipadan, and Tun Sakaran Marine Park recorded between 20% to 30% disturbance indicators. High pollution indicator levels were mainly found in the Malacca Strait and Sunda Shelf regions. Locations with notable pollution issues (over 10%) include Pulau Sembilan, Port Dickson, Lang Tengah, Aur and Dayang, Besar, Pemanggil, Sibu and Larapan.

While crown-of-thorns starfish, which feed on coral, are generally not a widespread issue in Malaysia, they are causing local problems in Pulau Tioman, Pulau Bidong and Yu, Pulau Pemanggil and Lahad Datu. Malaysia's coral reefs were also affected by the 4th Global Coral Bleaching Event in 2024, which impacted coral reefs around the world. Bleaching was reported at nearly 90% of all coral reef locations surveyed in Malaysia (Reef Check Malaysia 2025). A separate study by Szereday *et al.* (2025) found that the average coral mortality in Malaysia from the 4th Global Coral Bleaching Event was 34.1%. The Terengganu archipelago was the hardest hit, with an average mortality rate of 44.2%.

Preliminary findings from Reef Check Malaysia's 2025 coral reef monitoring show a continued decline in Malaysia's coral reef health, with live coral cover dropping for the third year in a row. This steady downward trend highlights a worrying reality: current reef conservation efforts are not enough or not effective to protect Malaysia's coral reefs. Without stronger action, these coral reefs and the communities that depend on them face increasing risks.

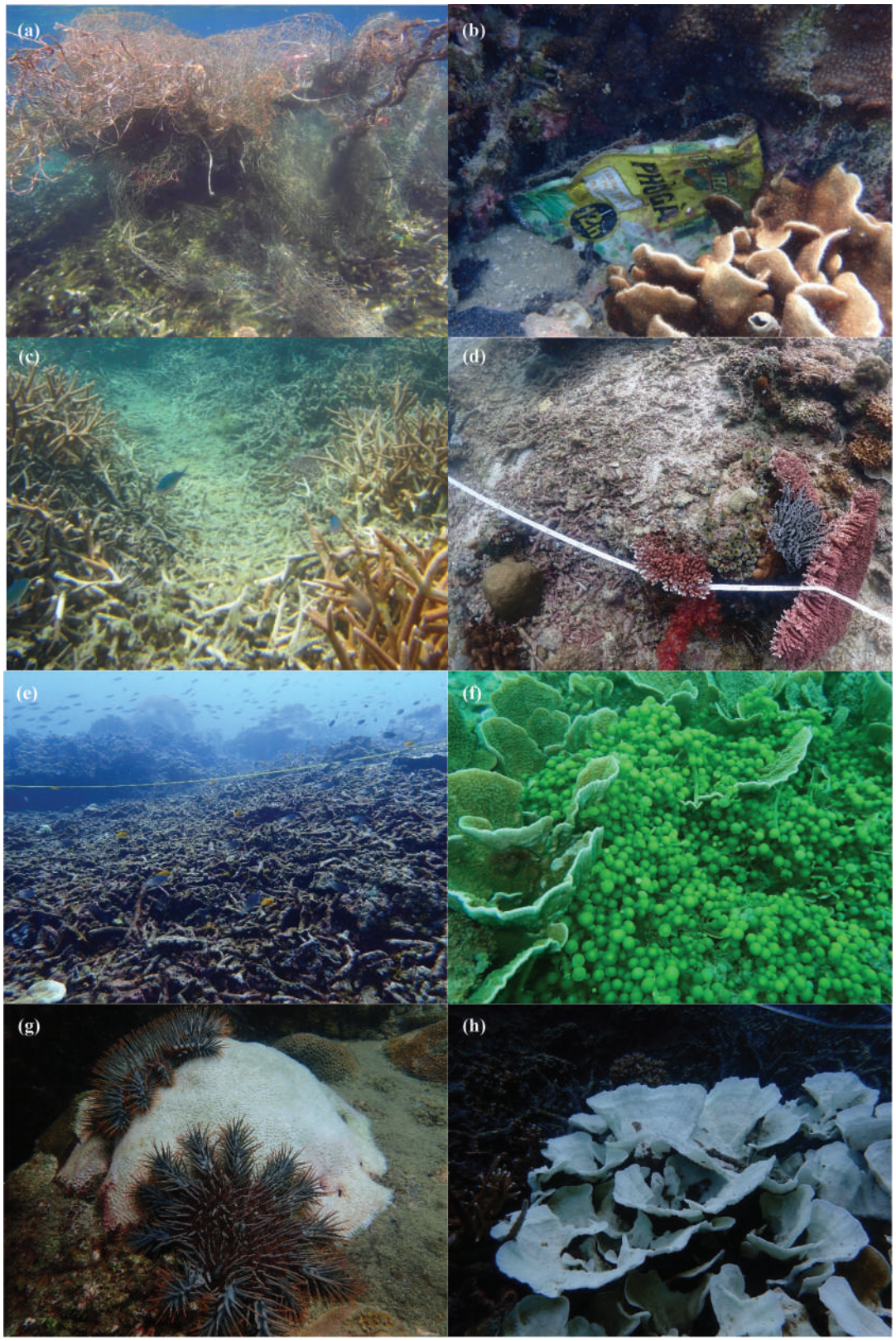

Figure 3. Threats to Malaysia's coral reefs – a) discarded fishing nets, b) marine trash, c) boat anchor damage, d) dynamite fishing, e) high level of disturbance indicators, f) high level of pollution indicators, g) crown-of-thorns starfish predation and h) coral bleaching.

CHALLENGES

Based on 18 years of data from coral reef surveys, as well as 10 years' experience working with local communities, Reef Check Malaysia has identified several key reasons why Malaysia is struggling to protect its coral reefs effectively. These problems include:

No central body to oversee and enforce marine protection efforts
Malaysia has made commitments to protecting the nation's coral reefs. The country is part of major global agreements such as the Convention on Biological Diversity and the United Nations Sustainable Development Goals. It is also a key partner in the Coral Triangle Initiative and has aligned its national policies with the Kunming-Montreal Global Biodiversity Framework through the National Policy on Biological Diversity (2022–2030). Malaysia has even pledged support for the UN Ocean Decade (2021–2030). However, despite these commitments, there is currently no single agency or national committee responsible for making sure marine policies are fully enforced and implemented across the country. This means that many good policies are not fully implemented, progress is not tracked, and no one is held accountable.

Governance issues
The lack of coordination between government agencies and other stakeholders stems from the country's institutional structure, as outlined in the Malaysian Constitution. According to Schedule 9 of the Constitution, power to make laws is divided between the Federal and State Governments. However, responsibility for environmental and biodiversity management is not clearly defined, which has led to confusion and overlapping responsibilities. The Federal Government manages Malaysia's Exclusive Economic Zone, which stretches up to 200 nm (nautical miles) from the coastline. The State Governments control land-based matters, including the seabed up to 3 nm from the low-water mark. In Peninsular Malaysia and Labuan, marine protected areas are managed by the Department of Fisheries Malaysia. In Sabah, they are overseen by Sabah Parks. In Sarawak, they fall under the Sarawak Forestry Corporation. While this governance structure allows for localised decision-making, it also makes it difficult to enforce consistent national standards. Without a cohesive and well-coordinated framework, management efforts often become fragmented, with agencies working in isolation, and missing opportunities for unified action.

Inadequate enforcement
In many marine protected areas, there are not enough resources or staff to properly enforce rules and regulations that protect marine life.

Limited involvement of local communities and stakeholders
Often, local communities and stakeholders are only given information, rather than being actively involved in making decisions. This means programmes are usually created based on assumptions about what communities need, instead of working together with them to understand their real needs. Because of this, local people often don't feel a sense of ownership or pride in these efforts, which makes it harder for management efforts to succeed in the long run. Also, the participation of local communities and stakeholders in management efforts is still limited. Coral reef management is mostly controlled from the top down by federal agencies, with little input from the people who rely on the coral reefs for their food security and livelihoods. This makes it difficult to develop management efforts that truly fit local needs and that can adapt over time.

Lack of reliable funding
There is a lack of well-planned or coordinated mechanisms to secure ongoing funding for coral reef protection, with little sign of efforts to create lasting financial support systems to keep coral reef management efforts going.

Uncoordinated research and development
Malaysia does not have a clear, coordinated plan for marine research and development. Many research groups and government agencies work separately and rarely share information or work together, which limits our understanding of the need for greater protection of coral reefs.

Lack of proper waste management systems
Many islands do not have proper systems to manage trash and sewage. In some places, these systems are completely missing, which means waste is often dumped directly or indirectly into the sea, harming coral reefs and marine life.

RECOMMENDATIONS

Coral reef conservation in Malaysia would be strengthened by the existence of a dedicated body or central coordinator whose role is to make sure policies are not only created but followed through. In Indonesia, the Ministry of Marine Affairs and Fisheries (MMAF) is the government body responsible for overseeing, formulating, and implementing marine and fisheries policies. It serves as a comprehensive institutional model that may be emulated by Malaysia in developing an effective framework for marine and fisheries governance. Malaysia government is also encouraged to take a more complete and connected approach to protecting coral reefs. This means understanding how land and sea environments are linked and managing them together. A key part of this approach should be to ensure that everyone who has a stake is engaged and able to contribute and work together. To make this happen, there should be one integrated management body with a clear role to oversee both the islands and the surrounding waters. This body would work together to make decisions in an open, fair, and coordinated way. Each member of this management body would represent a specific group or community, making sure their views are included in decision making. By giving certain responsibilities to these members, government agencies can work more closely with local communities and share everyday management tasks. This collaboration would free up government agencies to focus more on big-picture goals, like identifying and protecting new areas. Having different stakeholders involved encourages sustainable use of marine resources across the many industries on the islands. Working together, these groups can take a unified approach to managing both terrestrial and marine ecosystems. By forming strong partnerships, coral reef management can be better included in the State's overall plans for economic growth and environmental protection, ensuring efforts strike a balance between generating economic benefits and safeguarding coral reefs.

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