State of Nature Conservation in Malaysia 2025, 123–130
doi: 10.62613/sonc2025.v1flc11

CHAPTER 11

Nepenthes (Nepenthaceae) of Peninsular Malaysia: Taxonomy and conservation

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Abstract: Peninsular Malaysia represents a critical centre of diversity for *Nepenthes* (Nepenthaceae), commonly known as pitcher plants. These carnivorous plants are ecologically significant, thriving in nutrient-poor soils by supplementing nutrition through insect catch. At least 18 species are currently recognised in the Peninsula, ranging from widespread lowland species such as *N. mirabilis*, *N. gracilis* and *N. ampullaria* to montane endemics including *N. macfarlanei*, *N. ramispina* and *N. alba*. Taxonomic research has revealed considerable morphological variation and frequent natural hybridisation, complicating species delimitation. Molecular phylogenetic studies support the existence of distinct lowland and highland clades, reflecting adaptive radiation along ecological gradients. Despite their ecological and cultural importance, many *Nepenthes* species face significant threats from deforestation, habitat fragmentation, illegal collection for horticultural trade, and climate change impacts on montane ecosystems. Conservation measures include the establishment of protected areas, *ex situ* cultivation, and public awareness initiatives, yet enforcement and long-term monitoring remain limited. This review synthesises current taxonomic and phylogenetic knowledge, evaluates conservation status, and highlights future directions for research and management. Integrated strategies combining taxonomy, molecular ecology, habitat protection, and community engagement are essential to ensure the persistence of Nepenthes diversity in Peninsular Malaysia.

INTRODUCTION

Nepenthes (Nepenthaceae), commonly known as pitcher plants, are among the most iconic representatives of Southeast Asia's flora (Cheek 2001). These plants are characterised by their modified leaf structures forming pitfall traps, which enable them to supplement nutrient intake in nutrient-poor habitats through insect digestion. To date, *Nepenthes* comprises over 120 described species distributed across Southeast Asia, Madagascar, and northern Australia, with the highest diversity concentrated in the Sundaland region (Borneo, Sumatera, Jawa, and Peninsular Malaysia) (MacPherson 2009).

Peninsular Malaysia harbours a significant assemblage of *Nepenthes* species. Early botanical records documented 11 species, including *N. alba*, *N. albomarginata*, *N. gracillima*, *N. ampullaria*, *N. benstonei*, *N. gracilis*, *N. macfarlanei*, *N. rafflesiana*, *N. mirabilis*, *N. ramispina* and *N. sanguinea*. However, recent field surveys and taxonomic studies have expanded this number to at least 18 species, with discoveries between 2019 and 2022 adding new taxa and natural variations such as *N. domei*, *N. latiffiana*, *N. malayensis*, *N. ridzaiana*, *N. rafflesiana* var. *zabawiana*, *N.* × *langkawiensis*, and hybrids (Tamizi *et al.* 2021; Ghazalli *et al.* 2022). These findings underscore the dynamic nature of *Nepenthes* taxonomy in the region, where hybridisation and morphological plasticity complicate species delimitation.

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The ecological significance of *Nepenthes* extends beyond their carnivory. Their pitchers serve as microhabitats for specialised infauna, including mosquito larvae, mites, and symbiotic ants, contributing to broader ecosystem processes such as nutrient cycling. Locally, *Nepenthes* are known as *periuk kera* (monkey cups), reflecting their cultural presence in Malay folklore and traditional practices. Despite their ecological and cultural importance, *Nepenthes* species in Peninsular Malaysia face increasing threats. Habitat loss due to deforestation, agricultural expansion, and urbanisation has reduced suitable habitats, particularly for montane endemics. Illegal collection for horticultural trade further exacerbates population declines, while climate change poses long-term risks to montane ecosystems. Conservation efforts, including protected area designation, *ex situ* cultivation, and public education, have been initiated, but enforcement and monitoring remain limited.

This review aims to synthesise current knowledge on the taxonomy, phylogenetic relationships, and conservation status of *Nepenthes* in Peninsular Malaysia. By integrating recent discoveries, molecular insights, and conservation frameworks, we highlight both the richness and fragility of these carnivorous plants and propose strategies for their long-term preservation.

TAXONOMIC HISTORY AND SYSTEMATICS

The taxonomic history of *Nepenthes* in Peninsular Malaysia reflects more than a century of botanical exploration, beginning with early colonial records in the late nineteenth and early twentieth centuries. Botanists such as Ridley (1901, 1923); Holttum (1940); Kiew (1990); Clarke (1997, 2001, 2002); Rohana (1988); Shivas (1989); Turner (1995); Adam *et al.* (2005); Adam *et al*. (2007); and Latiff *et al.* (2011, 2016) documented various *Nepenthes* species and hybrids in lowland forests and montane areas, relying primarily on morphological descriptions of pitcher shape, coloration, and lid structure. These early works provided the foundation for subsequent studies but were often limited by the high degree of morphological variation within populations and the frequent occurrence of natural hybrids, which blurred species boundaries.

By the mid-twentieth century, herbarium collections and field surveys expanded knowledge of montane taxa, leading to the recognition of species such as *N. macfarlanei* and *N. ramispina*. However, taxonomic confusion persisted, with overlapping traits resulting in misidentifications. For example, *N. gracillima* was long considered a distinct montane species until later revisions clarified its affinities with *N. alba*. These challenges highlighted the need for more rigorous approaches to species delimitation.

Clarke's monograph (2001) consolidated knowledge of 11 Peninsular Malaysian taxa through extensive fieldwork and herbarium studies. Clarke's work provided detailed species accounts, ecological notes, and illustrations, and also validated the description of *N. benstonei* as a distinct endemic species (Clarke 1999). Subsequent revisions continued to refine the taxonomy with some proposed species such as *N. sharifah-hapsahii*, later reclassified as natural hybrids rather than valid taxa. Recent years have seen a surge in discoveries, with recent surveys documenting six additional taxa, bringing the total to at least 18 species. Among these, *N. malayensis* was described from montane forests in Terengganu, distinguished from *N. sanguinea* by both molecular and morphological traits (Tamizi *et al.* 2020). Systematics has advanced significantly with the integration of molecular phylogenetics. Studies using chloroplast (trnL intron) and nuclear (ITS) markers have revealed two major clades: a lowland group comprising species such as *N. ampullaria*, *N. mirabilis*, *N. gracilis*, and *N. rafflesiana*, and a highland group including *N. macfarlanei*, *N. ramispina*, *N. alba*, and *N. sanguinea* (Bunawan *et al*. 2017). These clades reflect ecological

adaptation along altitudinal gradients and support hypotheses of adaptive radiation within Peninsular Malaysia. Modern systematics now integrates morphology, molecular data, and ecological distribution, providing a more robust framework for species delimitation and highlighting the evolutionary processes shaping *Nepenthes* diversity.



Figure 1. *Nepenthes* of Peninsular Malaysia. **A.** *Nepenthes alba*, **B.** *N. albomarginata*, **C.** *N. ampullaria*, **D.** *N. benstonei*, **E.** *N. gracilis*, **F.** *N. ramispina*, **G.** *N. macfarlanei*, **H.** *N. mirabilis*, **I.** *N. sanguinea*, **J.** *N. rafflesiana*. (Photos: Mohd. Norfaizal Ghazalli).



Figure 2. *Nepenthes latiffiana* is endemic to Terengganu, Peninsular Malaysia. It thrives in high-altitude, understorey, typically growing as a terrestrial climber on shaded, rocky hill slopes.

THE PENINSULAR MALAYSIAN TAXA

A summary of Peninsular Malaysian taxa with their known distribution and IUCN conservation categories are given in Table 1.

Table 1. *Nepenthes* species in Peninsular Malaysia.

Species	Distribution	IUCN Conservation Category
Nepenthes gracilis	Lowlands, Peninsular Malaysia, Singapore, Sulawesi, Sumatera and Borneo	Least Concern (LC)
N. mirabilis	Lowlands, Peninsular Malaysia, Indochina, Thailand, Borneo, Southern China, the Philippines and New Guinea	Least Concern (LC)
N. ampullaria	Lowlands, Peninsular Malaysia, Singapore, Thailand, Borneo, New Guinea and Sumatera	Least Concern (LC)
N. albomarginata	Hills, Peninsular Malaysia, Borneo and Sumatera	Least Concern (LC)
N. macfarlanei	Highlands, Peninsular Malaysia, endemic	Vulnerable (VU)
N. rafflesiana	Lowlands and hills, Peninsular Malaysia, Sumatera and Borneo	Least Concern (LC)
N. rafflesiana var. *zabawiana*	Lowlands and hills, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. ramispinosa	Highlands, Peninsular Malaysia, endemic	Least Concern (LC)
N. alba	Highlands, Peninsular Malaysia, endemic	Vulnerable (VU)
N. gracillima	Highlands, Peninsular Malaysia, endemic	Least Concern (LC)
N. sanguinea	Highlands, Peninsular Malaysia, endemic	Least Concern (LC)
N. benstonei	Highlands, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. domei	Lowlands, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. malayensis	Highlands, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. latiffiana	Highlands, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. limiana	Highlands, Peninsular Malaysia, endemic	Not Evaluated (NE)
N. ridzaina	Highlands, Peninsular Malaysia, endemic	Not Evaluated (NE)

CONSERVATION STATUS AND THREATS

The conservation of *Nepenthes* in Peninsular Malaysia has become a major concern as these carnivorous plants face increasing pressures from human activities and environmental changes. While widespread species such as *N. mirabilis* and *N. ampullaria* are currently assessed as Least Concern (LC) due to their broad distribution and tolerance of disturbed habitats, many montane and limestone-associated species are far more vulnerable. Endemic species including *N. macfarlanei*, *N. ramispina*, and *N. alba* are restricted to narrow ecological niches within the Banjaran Titiwangsa and other highland forests, making them particularly susceptible to habitat loss and climate fluctuations. Their limited distribution and specialized habitat requirements mean that even small-scale disturbances can have disproportionate impacts on population viability (Clarke 2001; Bunawan *et al*. 2017).

Habitat loss and fragmentation remain the most significant threats to *Nepenthes* populations. Lowland dipterocarp forests, once extensive across Peninsular Malaysia, have been reduced to isolated fragments due to logging, agricultural expansion, and urban development

Species such as *N. rafflesiana* and *N. gracilis*, which thrive in lowland habitats, have experienced notable declines in population density as a result of this fragmentation. Montane habitats, although less disturbed historically, are increasingly affected by infrastructure development, including road construction and tourism facilities. Fragmentation not only reduces available habitat but also limits genetic exchange between populations, increasing the risk of inbreeding and local extinctions.

Illegal collection for horticultural trade represents another major conservation challenge. Large, colourful species such as *N. rafflesiana* and rare endemics like *N. macfarlanei* are particularly targeted by collectors. Despite regulations under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), enforcement remains inconsistent, and wild populations continue to be depleted by unsustainable harvesting practices (McPherson 2009). The popularity of Nepenthes in international horticulture has created strong economic incentives for illegal trade, further exacerbating conservation difficulties.

Climate change adds a long-term dimension to conservation threats. Montane species such as *N. sanguinea* and *N. alba* are adapted to cooler, humid conditions, and even slight increases in temperature or shifts in rainfall patterns can disrupt their ecological balance. Rising temperatures are expected to reduce suitable habitat ranges for highland taxa, forcing populations into increasingly restricted conservation areas. Conservation measures have been initiated at both national and local levels. Malaysia's Central Forest Spine initiative and the establishment of national parks such as Taman Negara and Cameron Highlands Forest Reserves provide legal protection for key habitats. *Ex situ* conservation efforts, including tissue culture propagation and cultivation in botanical gardens, have created alternative sources for horticultural demand, thereby reducing pressure on wild populations. Public awareness campaigns, such as the publication *Trappers in Nature: The Nepenthes of Peninsular Malaysia* (Ghazalli *et al.* 2023), have also played an important role in promoting appreciation of these plants.

Despite these efforts, significant challenges remain. Enforcement of conservation laws is often limited, and monitoring programs are insufficient to track population trends across fragmented landscapes. Many limestone and montane habitats remain underexplored, leaving gaps in knowledge about species distributions and conservation needs. Furthermore, community engagement in conservation is still developing, with local stewardship programmes requiring greater support and integration into national biodiversity strategies. Addressing these challenges will require a combination of scientific research, stronger policy enforcement, and inclusive conservation approaches that involve local communities as active stakeholders in protecting *Nepenthes* diversity.

RESEARCH PRIORITIES

Critical priority lies in refining species delimitation through integrative taxonomy. Morphological plasticity and frequent natural hybridisation complicate traditional classification, underscoring the need for molecular approaches. Phylogenetic studies using chloroplast and nuclear markers have already revealed distinct lowland and highland clades, but broader genomic analyses could provide deeper insights into evolutionary relationships, hybridisation dynamics, and adaptive radiation. Linking molecular data with ecological traits would strengthen systematics and improve conservation planning. Ecological research also requires expansion, particularly in understanding the role of *Nepenthes* within broader forest ecosystems. Their pitchers host diverse infaunal communities, including insects, mites, and symbiotic organisms, yet the ecological interactions and nutrient cycling processes remain under-investigated. Studies on mutualistic relationships, such as ant-plant interactions, could reveal important ecosystem functions and resilience mechanisms.

From a conservation perspective, research should prioritise long-term population monitoring under climate change scenarios. Montane species such as *N. macfarlanei* and *N. alba* are highly sensitive to temperature and humidity shifts, and predictive models could identify future refugia and guide conservation strategies. Socio-economic studies on the horticultural trade and community perceptions of *Nepenthes* would also inform policy interventions, ensuring that conservation measures are both scientifically sound and socially sustainable.

Finally, *ex situ* conservation research, including tissue culture propagation and genetic banking, should be expanded to safeguard genetic diversity. Developing standardised protocols for cultivation and reintroduction could provide insurance against wild population declines. Collaborative research involving local universities, conservation agencies, and international partners will be vital to address these priorities and secure the long-term survival of Nepenthes in Peninsular Malaysia.

IN SITU CONSERVATION

Ayer Hitam Utara Forest Reserve, Johor, represents an important in situ conservation site for the *Nepenthes* species and other peat swamp flora. As the largest remaining peat swamp forest in Johor, the reserve provides critical habitat for pitcher plants and supports the maintenance of natural ecological and evolutionary processes. An on-going biodiversity assessment and habitat protection efforts have strengthened the conservation value of the area, although further research is needed to comprehensively document *Nepenthes* diversity and population status within the reserve. Ayer Hitam Utara Forest Reserve is known to provide suitable ecological conditions for several lowland *Nepenthes* species. The species that occur in the Ayer Hitam Forest Reserve include *N. ampullaria*, *N. gracilis*, *N. mirabilis*, and *N. rafflesiana*, and their hybrids. These species are commonly associated with acidic soils, peat swamp forests, heath (*kerangas*) forests, and other lowland habitats throughout Peninsular Malaysia. The presence of these habitats highlights the importance of Ayer Hitam Utara as a potential refuge for lowland *Nepenthes* diversity and underscores its value for *in situ* conservation.

EX SITU CONSERVATION

Bukit Bendera, Pulau Pinang

There is a private nursery and conservatory at Bukit Bendera, Pulau Pinang, which cultivated and conserved both the lowland and highland species for public awareness and education. A total of six species, namely *N. albomarginata*, *N. rafflesiana*, *N. macfarlanei*, *N. ampullaria*, *N. gracilis* and *N. mirabilis* and their hybrids especially *N.* × *hookeriana* are propagated and conserved there.

Nepenthes Conservatory, Kledang Saiong, Ipoh, Perak

The Department of Forestry Perak established a *Nepenthes* Conservatory in 2021 at Kledang Saiong Forest Reserve. Both the Malaysian and non-Malaysian species are introduced and cultivated in the conservatory for public education and awareness. The non-Malaysian species introduced are from northern Australia, Indonesia, the Philippines, Thailand, India and Madagascar. We assumed they were imported from those countries.

Sungai Menyala Forest Reserve, Port Dickson, Negeri Sembilan

The Department of Forestry Negeri Sembilan also established an *ex situ* conservation garden at PDForest, Sungai Menyala in 2024. Only the lowland species namely, *N. rafflesiana*, *N. ampullaria*, *N. gracilis* and *N. mirabilis* are introduced in this garden.

Private nursery
A notable private-sector initiative is Four Z E Plant Nursery in Ampang, Selangor, which is operated by Mr. Mohd. Fauzi Abu Bakar. The nursery maintains an extensive living collection of *Nepenthes* species and horticultural hybrids, serving both commercial and conservation purposes. Through propagation, hybridisation, and public engagement, the nursery contributes to the *ex situ* conservation and sustainable utilisation of *Nepenthes* genetic resources in Malaysia.

Dome Nikong Plant Conservatory
There is a private conservatory of plants established by Mr. Dome Nikong at Sungai Tong, Setiu, Terengganu which contains several lowland (*N. gracilis*, *N. mirabilis*, *N. rafflesiana*, *N. ampullaria*) and highland (*N. domei*, *N. latiffiana*, *N. sanguinea*, *N. ramispina*, *N. malayensis*) species and their hybrids.

CONCLUSION

The *Nepenthes* of Peninsular Malaysia embody both extraordinary biodiversity and pressing conservation challenges. Taxonomic research over the past century has revealed a rich assemblage of species, ranging from widespread lowland taxa such as *N. mirabilis* and *N. ampullaria* to highly localised montane endemics like *N. macfarlanei* and *N. alba*. Advances in molecular systematics have clarified evolutionary relationships, highlighting distinct lowland and highland clades and underscoring the adaptive radiation of these plants across ecological gradients. Yet, despite these scientific achievements, the persistence of Nepenthes populations is increasingly threatened by deforestation, habitat fragmentation, illegal collection, and the looming impacts of climate change.

Conservation initiatives, including protected area designation, *ex situ* cultivation, and public awareness programs, have provided important safeguards, but enforcement and long-term monitoring remain limited. The survival of these species will depend on integrated strategies that combine rigorous taxonomy, ecological research, and conservation policy with active community engagement. Future research priorities must focus on documenting undescribed taxa, refining species delimitation through genomic approaches, and modeling habitat responses to climate change. Equally important is the need to strengthen socio-economic studies on horticultural trade and to expand ex-situ conservation protocols to preserve genetic diversity.

Ultimately, *Nepenthes* serve not only as botanical curiosities, but also as flagship species for biodiversity conservation in Peninsular Malaysia. Their unique ecological roles, cultural significance, and vulnerability make them powerful symbols of the broader challenges facing tropical ecosystems. Protecting these plants is therefore not only a matter of preserving taxonomic diversity but also of safeguarding ecological integrity and cultural heritage. A coordinated effort that bridges science, policy, and community stewardship will be essential to ensure that the remarkable pitcher plants of Peninsular Malaysia continue to thrive for generations to come.

Acknowledgements: The authors are grateful to the curator of the Forest Research Institute Malaysia (KEP), for permission to conduct *Nepenthes* herbarium specimen analysis for this study.

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