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CHAPTER 4

Monilophytes and lycophytes of Malaysia: Diversity, threats and conservation priorities

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Abstract: Malaysia harbours one of the richest monilophyte and lycophyte floras in Southeast Asia, with approximately 1,165 documented taxa occupying habitats ranging from coastal and lowland forests to limestone karsts and montane cloud forests. The last national assessment of this group was provided by Aziz Bidin in *The State of Nature Conservation in Malaysia* (1991), which recognised approximately 650 species and highlighted habitat loss, limestone quarrying and development as major conservation concerns. Over the past three decades, substantial advances in floristic exploration, taxonomy and systematics have transformed understanding of Malaysia's pteridophyte diversity. Numerous surveys have expanded knowledge of species distributions and habitat associations, while molecular phylogenetic studies and modern classification systems have refined taxonomic concepts and evolutionary relationships. Continued fieldwork has also resulted in the discovery of species new to science, new national records and the rediscovery of rare, poorly-known taxa previously thought to be lost. This chapter synthesises current knowledge of Malaysia's ferns and lycophytes, examines diversity patterns across major habitats including lowland forests, limestone hills and montane ecosystems, and reviews emerging conservation challenges. While habitat conversion, forest fragmentation, and limestone quarrying remain significant threats, climate change is increasingly recognised as a major concern, particularly for moisture-dependent species restricted to montane environments. The chapter highlights the importance of continued taxonomic research, long-term monitoring, and habitat protection for safeguarding Malaysia's pteridophyte diversity. By revisiting and expanding upon Bidin's 1991 assessment, this review provides an updated national perspective and identifies priorities for research and conservation in the decades ahead.

INTRODUCTION

Revisiting Malaysia's ferns after 1991

Monilophyte and lycophytes (the "ferns and fern-allies" of older literature) are a vital part of Malaysia's natural heritage. They regulate forest moisture, stabilise soils, contribute to nutrient cycling, and act as sensitive indicators of environmental change (Lu *et al.* 2023). From coastal mangroves to the tops of the main range, fern communities are a conspicuous and dominant element of the Malaysian flora, yet they remain less documented and less protected than the flowering plants with which they share these forests.

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The last dedicated overview of this group at a national scale was written by Aziz Bidin for the Malaysian Nature Society's *State of Nature Conservation in Malaysia* (Bidin 1991). That chapter recognised about 650 species of ferns and fern-allies, described their distribution from the lowlands to the cloud forests, and flagged the most threatened settings of the day – island floras, limestone hills, and lower montane forests under pressure from logging and land development. It provided a strong foundation and reflected the taxonomic and ecological understanding available at the time.

Over the past 34 years, both Malaysia's forests and the science describing them have changed substantially. Land-use change, climate variability and habitat fragmentation have continued to reshape forest ecosystems (NRECC 2022). At the same time, sustained survey efforts, new records and rediscoveries in Malaysia—including *Diplazium velutinum* (Aliah *et al*. 2026), *Diplazium procumbens* (Maideen *et al.* 2019) and *Cornopteris* (Maideen *et al.* 2021)—and a community-derived phylogenetic classification (PPG I 2016) have considerably expanded and refined our understanding of fern diversity. Subsequent compilations and floristic studies have increased the documented Malaysian pteridophyte flora to approximately 1,165 taxa (Parris and Latiff 1997). This chapter provides an updated conservation reassessment of Malaysia's ferns since Bidin (1991), where we attempt to summarise the ferns that occur across the major forest zones in Malaysia, update the assessment of the threats they face (while illustrating these patterns with a case insight from Sabah) and recommend conservation priorities. The reassessment is organised around a simple question: What has changed in our understanding of Malaysian ferns since Bidin's 1991 account? While many of the habitats and conservation concerns identified three decades ago remain relevant today, substantial advances in taxonomy, floristic exploration and conservation science now provide a much clearer picture of the country's fern flora. Understanding these developments is essential for setting conservation priorities for the decades ahead.

Advances in knowledge since 1991

The most significant change since 1991 is not the fern flora itself, but the amount of information available about it. New surveys, taxonomic revisions, and modern analytical tools have expanded our understanding of species diversity, distribution, and conservation status across Malaysia. As a result, the picture available today is far more comprehensive than that described three decades ago. Three developments have transformed our knowledge of Malaysian ferns since Bidin wrote. First, documentation has deepened. Systematic surveys of individual forest reserves, many leading led from the cryptogamic herbarium at Universiti Kebangsaan Malaysia (UKMB), have produced published checklists for sites spanning a the full elevational range, from lowland reserves such as Kenong and Endau -Rompin (Maideen *et al*. 2004; Jaman and Latiff 2007) to montane settings such as Mount Tebu and the Cameron Highlands mossy forest (Maideen *et al.* 2012, 2025). Where Bidin could only draw on a handful of well-botanised localities, today's picture rests on a far broader base of well-recorded documentation.

Second, the taxonomy has been modernised. The classification used in 1991 has been superseded by the community-derived framework of the Pteridophyte Phylogeny Group (PPG I 2016), and molecular tools such as DNA barcoding and phylogenetics now complement classical morphology. These approaches have resolved long-standing uncertainties and made it possible to recognise taxa that earlier surveys could not separate. In parallel, comprehensive taxonomic revisions have clarified species boundaries in several groups occurring in Malaysia. For example, a revision of the Asian genus *Oleandra* reduced numerous previously recognised taxa and provided a clearer circumscription of species distributed in Peninsular Malaysia and Borneo (Hovenkamp and Ho 2012). In addition, integrative systematic studies combining molecular and anatomical evidence have improved understanding of relationships within Malaysian fern groups. A phylogenetic study of Athyriaceae in Peninsular Malaysia confirmed the monophyly of the family and clarified

relationships among *Diplazium*, *Athyrium*, *Cornopteris* and *Deparia* (Aliah *et al.* 2024). Together, these studies illustrate how modern systematic approaches continue to refine our understanding of Malaysia's fern flora.

Third, continued fieldwork and taxonomic research have yielded numerous new discoveries, rediscoveries and nomenclatural updates. Recent examples include the rediscovery and lectotypification of *Diplazium velutinum*, a rare endemic fern from Peninsular Malaysia (Aliah *et al*. 2026), the first record of the genus *Cornopteris* (Athyriaceae) for Peninsular Malaysia (Maideen *et al.* 2021), and the rediscovery of *Diplazium procumbens* after more than 70 years (Maideen *et al.* 2019). Taxonomic studies have also revealed previously unrecognised diversity, such as the description of two new species of *Phlegmariurus* (Lycopodiaceae) and a new combination from Peninsular Malaysia (Kiew and Kamin 2018). Together, these findings demonstrate that Malaysia's fern and lycophyte flora remains incompletely documented and that continued exploration, particularly in under-surveyed regions and specialised habitats, is likely to reveal additional taxa and distribution records. The net effect is a far clearer – though still incomplete – understanding of Malaysia's pteridophyte diversity than was available in 1991.

MALAYSIA'S FERNS ACROSS THE MAJOR HABITATS

Lowland forests

Lowland dipterocarp forests remain the principal centre of fern diversity in Malaysia. Their extensive environmental heterogeneity, including shaded forest floors, riparian corridors, treefall gaps and humid understories, provides a wide variety of ecological niches for terrestrial, epiphytic and climbing species. Common genera include *Stenochlaena*, *Blechnum*, *Nephrolepis*, *Lygodium*, *Asplenium* and *Pyrrosia*. Despite their importance, lowland forests continue to experience the greatest pressure from land-use change and habitat conversion, making them a priority for conservation.

Limestone hills

Limestone hills support a specialised fern flora adapted to the unique environmental conditions associated with karst landscapes. Although occupying only a small proportion of Malaysia's land area, these habitats contribute disproportionately to national biodiversity and contain numerous restricted-range species. As noted by Bidin (1991), limestone ecosystems remain among the most vulnerable habitats due to quarrying, mining and habitat fragmentation.

Many limestone-associated ferns exhibit strong habitat specialisation. *Antrophyum parvulum* Blume, for example, is closely associated with limestone substrates throughout Peninsular Malaysia and is capable of withstanding prolonged drought periods typical of exposed karst environments (Holttum 1968; Piggott 1988). Field observations from Mount Baling, Kedah, and Mount Senyum, Pahang, showed that populations occur on limestone rock surfaces ranging from shaded, moss-covered habitats to exposed cliff faces, illustrating adaptation to the diverse microhabitats found within limestone ecosystems (Kiew *et al.* 2011). Likewise, *Calciphilopteris alleniae* (R.M.Tryon) Yesilyurt & H.Schneid. is a limestone specialist typically confined to shaded crevices and moss-covered limestone outcrops and is considered conservation-dependent because of its restricted distribution and the ongoing impacts of quarrying and forest clearing on limestone habitats (Kiew *et al.* 2017).

Recent botanical exploration has further demonstrated the conservation significance of limestone habitats. The discovery of *Asplenium merapohense* Jaman & K.Imin, a limestone endemic described from karst hills in Pahang and Kelantan, highlights the continued potential for new discoveries in these habitats (Jaman *et al.* 2017). This species is currently assessed as Critically Endangered because it is known from only two localities, occupies a

highly restricted area, and faces continuing threats from quarrying and agricultural encroachment (Jaman *et al*. 2017). Restricted to steep limestone cliffs and crevices, *A. merapohense* exemplifies the vulnerability of narrowly endemic fern species dependent on intact karst ecosystems. Limestone habitats also support high levels of pteridophyte diversity. In Sarawak, surveys of the Bau Limestone area documented approximately 120 species of ferns and lycophytes representing 55 genera and 26 families, accounting for approximately 20% of Sarawak's known pteridophyte flora despite the relatively limited extent of limestone habitat (Kalu 2004). The concentration of both species richness and habitat specialists within isolated karst systems underscores the importance of limestone hills as centres of pteridophyte diversity and conservation priority in Malaysia.

Montane forests

Montane forests support distinct fern assemblages adapted to cooler temperatures, frequent cloud cover and consistently high humidity. Filmy ferns (Hymenophyllaceae), grammitid ferns and species associated with moss-covered substrates are characteristic components of these communities. Studies from Kinabalu Park have shown that montane habitats between 1,500 and 2,200 m elevation support high fern diversity, particularly within Hymenophyllaceae and Polypodiaceae, with genera such as *Hymenophyllum* and *Oreogrammitis* being especially well represented (Anthony *et al.* 2024). These taxa are closely associated with humid cloud -forest environments where persistent moisture and reduced evapotranspiration create favourable conditions for epiphytic and moisture-dependent species. Furthermore, Kinabalu Park remains one of the most important centres of fern diversity in Southeast Asia, supporting approximately 645 species of ferns and numerous endemic taxa (Parris and Latiff 1997; Anthony *et al*. 2024).

Montane forests also contribute significantly to the evolutionary diversity of Malaysia's fern flora and continue to yield important botanical discoveries. Recent studies from Borneo have documented several species new to science, including *Pteris borneensis* from the Trus Madi Forest Reserve in Sabah (Chao *et al.* 2017), and *Antrophyum hovenkampii* and *Pteris hovenkampii* from Mount Mulu National Park, Sarawak (Chen *et al.* 2021). Similar discoveries have been made in Peninsular Malaysia, where *Cornopteris opaca* was recorded for the first time from Mount Berinchang, Cameron Highlands, extending the known distribution of the genus beyond Mount Kinabalu in Sabah (Maideen *et al.* 2021). More recently, *Diplazium velutinum*, a rare endemic species originally described from Cameron Highlands, was rediscovered after more than three decades without confirmed collections, underscoring the continued value of floristic surveys in Malaysia's montane forests (Aliah *et al.* 2026). The rediscovery of *D. velutinum* also highlighted the importance of protecting upper montane habitats, where the species appears restricted to cool, humid forests above 1,400 m elevation.

Although montane forests generally contain fewer species than lowland forests, they contribute unique ecological and evolutionary elements to Malaysia's fern flora and provide important refugia for moisture-dependent taxa. Their significance is further reflected in protected areas such as Kinabalu Park and Mount Mulu National Park, both internationally recognised for their exceptional biodiversity and high levels of plant endemism (Jermy *et al.* 1984; UNESCO 2000). Mount Mulu alone supports at least 442 recorded species of pteridophytes across a wide range of montane and limestone habitats (Jermy *et al*. 1984), making it one of the richest fern localities in Borneo. Together, these findings demonstrate that Malaysia's montane forests are not only reservoirs of fern diversity but also centres of endemism, ecological specialisation and ongoing evolutionary diversification. Because many montane fern species depend on consistently cool, humid conditions and persistent cloud cover, these ecosystems may be particularly vulnerable to climate-driven changes in temperature, rainfall and cloud formation. Protecting Malaysia's montane forests, including those of the Cameron Highlands, Crocker Range (Majuakim and Anthony 2016), Mount Kinabalu and Mount Mulu, is therefore essential for safeguarding some of the country's most specialised and range-restricted fern species.

THREATS AND PRESSURES: AN UPDATED PICTURE

Many of the conservation concerns identified by Bidin (1991) remain highly relevant today. More than three decades ago, Bidin highlighted the vulnerability of lowland forests, limestone hills and island ecosystems to logging, land conversion and development. While substantial progress has been made in expanding protected areas and improving knowledge of Malaysia's fern flora, habitat loss and degradation continue to threaten many fern-rich ecosystems. Lowland dipterocarp forests remain under the greatest pressure because they coincide with areas most suitable for agriculture, infrastructure development and human settlement. As these forests support the highest fern diversity in the country, continued habitat loss poses a significant risk to many species. Limestone hills remain particularly vulnerable because their specialised fern communities are confined to isolated outcrops and cannot easily disperse when habitats are destroyed. Similarly, island floras continue to face pressures associated with tourism development and habitat modification.

The most significant new challenge since 1991 is climate change. Unlike habitat loss, which primarily affects specific locations, climate change has the potential to alter environmental conditions across entire landscapes. Montane and cloud forests are especially vulnerable because many of their fern species depend on persistently cool and humid conditions. Rising temperatures, changing rainfall patterns and shifts in cloud formation may reduce the extent of suitable habitat available to these specialised species, many of which occur in restricted high-elevation environments. Several broader challenges further complicate fern conservation in Malaysia. Habitat fragmentation reduces connectivity between forest habitats and may limit the movement and long-term persistence of some species. At the same time, large areas of Malaysia, particularly in Sabah and Sarawak, remain incompletely surveyed, making it difficult to determine the true conservation status of many taxa. Although hundreds of fern species are known from Malaysia, only a small proportion have undergone formal conservation assessment.

CONSERVATION MEASURES AND OPPORTUNITIES

Many of the conservation measures proposed by Bidin (1991) remain highly relevant today. His recommendations included the establishment of fern conservatories, the collection and storage of spores, the protection of fern-rich habitats through gazettement, and the cultivation of rare species in botanic gardens. More than three decades later, these measures continue to provide a strong foundation for fern conservation in Malaysia. However, advances in scientific knowledge and the emergence of new environmental pressures require these efforts to be expanded and updated.

Protect whole elevational gradients, not isolated patches

As each zone holds a largely distinct community and the transitions between them matter, conservation should aim to keep lowland, hill and montane habitats connected rather than protecting fragments in isolation. Particular attention should be given to lowland forests and limestone ecosystems, where biodiversity value remains high but conservation pressures continue to intensify.

Strengthen ex situ conservation

Living collections and spore banks remain essential insurance against habitat loss. There is a notable continuity here: the fern garden Bidin illustrated at Universiti Kebangsaan Malaysia in 1991 (Bidin 1991) (Figure 4; Taman Paku-pakis) has since developed into an established fernarium that supports conservation, research and education—a concrete example of the kind of ex situ facility he envisioned, now realised and expandable.

Apply modern tools to set priorities
Modern scientific tools provide new opportunities to strengthen fern conservation. DNA barcoding, phylogenetic analyses, species distribution modelling and climate-vulnerability assessments can help identify species and habitats most at risk. When combined with renewed field surveys and herbarium-based research, these approaches can improve conservation planning and support the formal assessment of Malaysian fern species, many of which remain unevaluated.

Use ferns to engage the public
Ferns are charismatic, easily recognised and present in every forest type, which makes them an accessible entry point for public awareness and education. Because they are sensitive to changes in moisture and forest structure, making them useful ecological indicators of forest condition. Advances in ecological monitoring and molecular tools now provide opportunities to strengthen their application in biodiversity assessment and conservation.

CONCLUSION: THE WAY FORWARD

More than three decades after the *State of Nature Conservation in Malaysia* 1991 assessment of Malaysia's ferns and lycophytes, our understanding of this important component of biodiversity has expanded substantially. Continued floristic surveys, taxonomic revision, herbarium research and molecular phylogenetic studies have revealed a richer and more complex flora than was previously recognised. New species, new national records and the rediscovery of rare taxa demonstrate that Malaysia's pteridophyte diversity remains incompletely documented and that further exploration continues to yield significant findings. Despite these advances, many of the conservation concerns identified in 1991 remain relevant today. Lowland forests, limestone hills and island ecosystems continue to face pressures from habitat loss, fragmentation and development, while climate change has emerged as an additional threat, particularly for moisture-dependent species confined to montane environments. Significant knowledge gaps also persist, especially in under-surveyed regions of Sabah and Sarawak, and many species have yet to undergo formal conservation assessment. The priorities for the coming decades are therefore clear: (1) strengthening habitat protection across Malaysia's diverse forest ecosystems, (2) expanding long-term inventories and monitoring programmes, (3) enhancing *ex situ* conservation initiatives, and (4) integrating modern tools such as DNA barcoding, phylogenomics and species distribution modelling into conservation planning. Greater collaboration among researchers, conservation agencies, protected-area managers and local communities will also be essential to ensure that scientific knowledge is translated into effective conservation action. By building on the foundation laid by Bidin (1991), Malaysia is well positioned to advance both the study and conservation of its fern and lycophyte flora. Conserving these ancient plant lineages is not only a matter of protecting species diversity, but also of safeguarding the ecological integrity, evolutionary heritage and resilience of Malaysia's forests for future generations.

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