

The Ecology and Conservation of Orchids in Ultramafic Habitats of Kinabalu Park, Sabah, Malaysia

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ABSTRACT

Kinabalu Park in Sabah, Malaysia, is renowned for its exceptional biodiversity, particularly its diverse orchid (Orchidaceae) flora, many of which grow in ultramafic soils. These soils are known to contain high levels of nickel and magnesium, low levels of calcium, few essential nutrients, and low water retention, hence bringing serious ecological problems to the survival of plants. This paper summarises existing information on the ecology and conservation of orchids in the ultramafic zone of Kinabalu Park, with emphasis on how the species adapt and why conservation efforts are necessary. This work is completely grounded on secondary data and is based on an in-depth evaluation of scientific literature (articles, books, journals, and online herbarium records) to evaluate the orchid diversity and ecological significance in the park. It has been found that there are up to 340 orchid species in the ultramafic sections of the Kinabalu Park, the highest density of which is Marai Parai (136 species), home to the locally endemic *Dendrobium maraiparense* Wood and Chan, described first at this location. Significant dangers such as excessive collection, illegal commerce, poaching, and climate change demonstrate the necessity of a more powerful conservation and rescue policy. The use of in-situ and ex-situ methods of conservation, increasing community education, and legal enforcement of the control of orchid species are required to protect the orchid species and preserve the ecological health of Kinabalu Park.

Keywords: Endemic, Mount Kinabalu, Marai Parai, UNESCO global geopark

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INTRODUCTION

Ultramafic outcrops are known to host exceptionally high levels of endemism in the flora, including, though not limited to, species with specialised adaptations such as hyperaccumulation of nickel or manganese. The ultramafic rocks are found in Malaysia, the Philippines and Indonesia in tropical

countries of Southeast Asia (Figure 1). Nevertheless, the ecological features are under-researched despite the great value of the species group in conservation. Such rocks are composed of the upper mantle of the Earth and usually contain magnesium and iron and have low silicates (Estrada, 2021; Jakub Kierczak et al., 2020). The soils that are created on the basis of such bedrock have comparatively high trace metals such as nickel (Ni), chromium (Cr), and cobalt (Co) and have severe cation imbalances with excess magnesium (Mg) and low calcium (Ca) (van der Ent et al., 2019). A distinct type of vegetation with high endemism and short stature has evolved as a result of this unusual soil chemistry. The primary soil-edaphic factors frequently identified as influencing ultramafic ecology include nutrient deficiencies caused by low Ca (and high Mg), extremely low potassium (K) and phosphorus (P), and the potential phytotoxicity associated with elevated Ni and, in some cases, Co and Cr (van der Ent et al., 2018; van der Ent et al., 2019).

In Southeast Asia, a high level of geological and environmental heterogeneity is shown in Malaysia, Indonesia, and the Philippines (Figure 2). Ultramafic soils in South and Southeast Asia have a very diverse vegetation, from short graminoid communities in the upper montane and subalpine zones to tall lowland forests with tree heights exceeding 50 meters. At the landscape scale, the level of endemism is consistently high. For example, a 250 m² montane forest plot on Mount Tambuyukon in Sabah recorded 132 species, placing it among the most biodiverse plant communities globally (Garnica-Díaz et al., 2022; van der Ent et al., 2016).

The Malaysian state of Sabah is recognised as one of the most environmentally diverse regions in the world, with an estimated 8,000 species of vascular plant (van der Ent et al., 2015a). While 4,252 plant species from 207 families and 1,047 genera

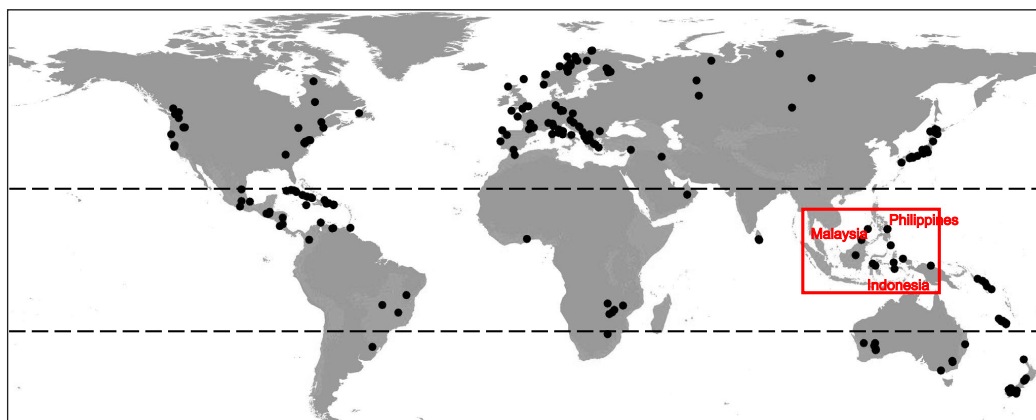


Figure 1. The distribution of ultramafic rocks worldwide. Black dotted - ultramafic formations are found on every continent; Red box - Southeast Asian countries where ultramafic rocks are distributed; Dashed lines - the Tropic of Cancer and Capricorn

*Source: Modified from Hulshof & Spasojevic (2020)

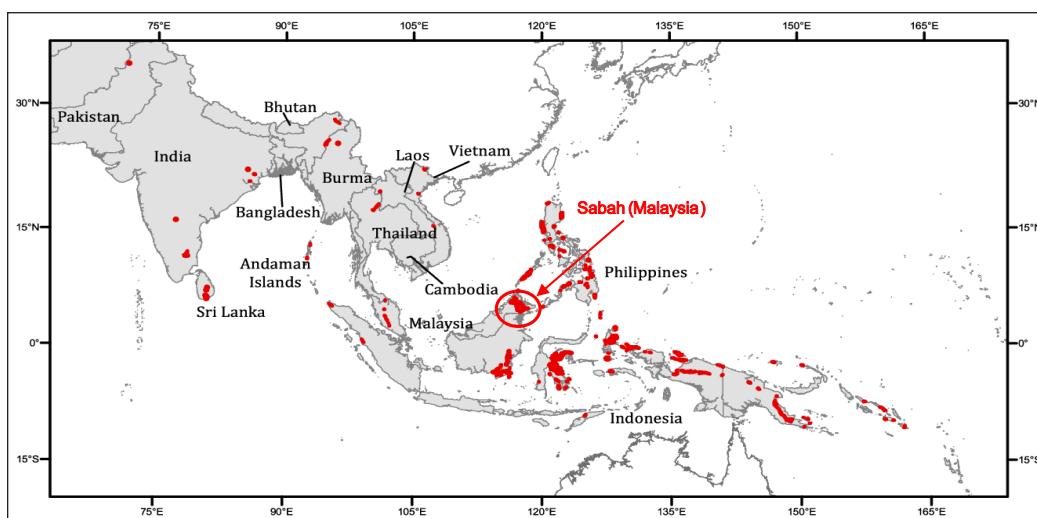


Figure 2. A close-up map of South and Southeast Asia displays the ultramafic outcrop spread throughout the area. Red circle - ultramafic outcrop spread throughout Sabah, Malaysia

*Source: Modified from Galey et al. (2017)

(including vascular plants and ferns) were documented on ultramafic soils (Hulshof & Spasojevic, 2020; van der Ent et al., 2015a). Kinabalu Park, with an area of approximately 754 km², supports more than 5,000 plant species representing 200 families and 1,000 genera (Sabah Park, 2025). The park is one of the most biodiverse locations on Earth, as it has more than 2,542 species found in ultramafic outcrops. Most of these species are endemic to Kinabalu Park or Borneo Island, highlighting the uniqueness and extraordinary conservation importance of the flora.

Many of the most diverse plant groups in Kinabalu Park--including a stunning diversity of orchid species are found on serpentine-derived soils. Ultramafic substrates with unique chemical characteristics, namely serpentine, support highly specialised ecological communities. As an example, the high-magnesium and high-nickel toleration of some orchid species is exceptional (e.g. *Paphiopedilum rothschildianum* (Rchb.f.) Stein, *Crepidium metallicum* (Rchb.f.) Szlach, and *Dendrobium maraiparense* J.J. Wood & C.L. Chan), traits rarely observed in orchids from non-ultramafic environments. The majority of these species have slow growth rates, which could be one of the reasons why they become confined to edaphic habitats in which their fast-growing competitors effectively fringe them out.

This paper is the inaugural synthesis of ecological adaptation that incorporates diversity along with conservation concerns in the ultramafic community of Kinabalu Park, Sabah, Malaysia. Although the existing literature has recorded the floristic richness of the park, the little literature that has been conducted has not examined how the edificial factors that include soils, heavy-metal tolerance and orchid-mycorrhiza association all interact to

determine orchid distribution patterns. This paper can contribute to the study of diversity in orchids by providing a new view on the role of ultramafic habitat as an area of endemism and specialisation.

This work is grounded on the review of published scientific literature, herbarium records, and other secondary sources. There was no new fieldwork; rather, it is aimed to synthesise the available information to deepen the knowledge of species diversity, ecological adaptations, and species conservation concerns specific to orchids in ultramafic settings. Finally, the current review will guide conservation efforts in one of the most distinctive areas of Borneo on the botanical scale. It can also establish the basis of future studies by revealing important species of interest and pointing out existing gaps in knowledge.

ECOLOGICAL ASPECT OF ULTRAMAFIC IN SABAH

The ultramafic landscape is preserved and extensive in Sabah, Malaysia, which is one of the most significant areas in the globe to gain an insight into ultramafic studies. This region is full of endemism; soils are hostile with the extreme levels, and environmental stress is setting in. Kinabalu Park is home to one of the largest ultramafic ecosystems in Southeast Asia, where the ultramafic rock formations occupy up to 16% of the total vegetation cover (Sabah Park, 2025). The areas possess peculiar geological and ecological features.

The extremely harsh conditions are common to ultramafic soils that have a high degree of metal toxicity, low water-retention capacity, and nutrient deficiencies that have stimulated the development of highly specialised plant species (Galey et al., 2017). Many species can be found endemically in Sabah: orchids, pitcher plants (*Nepenthes*), and metal hyperaccumulator species like *Rinorea bengalensis*, which is found nowhere in Sabah or Borneo (van der Ent et al., 2015b). This situation can be studied to determine how plants have evolved to survive in extreme environments, and these areas include the variety of nutrient-acquisition methods, metal tolerance, and symbiotic relationships between plant roots and fungi.

The detailed ecological theories are also used to explain the distributions of orchid endemism and variation of the ultramafic habitat of the Kinabalu Park. Isolated ultramafic outcrops act as "edaphic islands" in the context of island biogeography, where limited soil conditions encourage high levels of endemism but limit species dispersal (Madsen et al., 2025). Orchid persistence on these substrates also reflects niche conservatism, with generations maintaining strong habitat fidelity and long-term adaptation to metal-bearing soils. Furthermore, because many orchid species exist in small, dispersed populations at risk of local extinction but are maintained by infrequent colonisation events, their distribution across the isolated ultramafic landscapes is consistent with metapopulation theory. Together, orchid diversity is shaped by the framework of soil specialisation, population dynamics and spatial isolation interacting in the ultramafic habitats of Kinabalu Park.

Plant Endemism

Soil edaphism greatly influences endemism in Sabah, making it an important global centre of plant endemism, particularly in its ultramafic ecosystems. Levels of endemism vary regionally among species inhabiting ultramafic substrates. Strong climatic and edaphic stressors, coupled with geographic isolation of many ultramafic outcrops, have likely facilitated speciation. However, most plant species in Sabah occur facultatively on ultramafic soils, and only a limited number are considered obligate ultramafic specialists. High endemism is usually in geographically or altitudinal remote areas. While some species exhibit broad ecological tolerances and occur across multiple substrates, others show a strong affinity to ultramafic soils and may be more abundant or entirely restricted to particular sites.

Neo-endemics are species that evolved *in-situ* from closely related taxa and often indicate recent speciation on ultramafic substrates. For example, *Dendrobium maraiparense* J.J. Wood & C.L. Chan, described from Marai Parai, is a neo-endemic confined to the ultramafic habitats of Kinabalu Park. In contrast, paleo-endemics are relict species now restricted to ultramafic soils due to competitive exclusion elsewhere; for instance, *Paphiopedilum rothschildianum* (Rchb. f.) Stein is a paleo-endemic frequently associated with ultramafic habitats. In this review, the term "ultramafic-associated" refers to species that have been consistently recorded on ultramafic soils based on floristic survey, herbarium data, and literature reports, rather than species with experimentally confirmed edaphic tolerance.

Orchids constitute an ecologically significant and highly diverse plant family in Sabah (Zhang et al, 2018), with substantial levels of endemism in ultramafic regions, especially within Kinabalu Park. Ultramafic obligate endemic orchids include both terrestrial and lithophytic slipper orchids: *Paphiopedilum rothschildianum* (Rchb. f.) Stein and *P. dayanum* (Rchb. f.) Pfitzer (Kinabalu Park), *P. hookerae* var. *volonteanum* (Sander ex Rolfe) Braem (Meliau Range, Kinabalu Park), the terrestrial *Calanthe otuhanica* C.L.Chan & T.J.Barkman (restricted to landslide zones in Kinabalu Park), *Platanthera kinabaluensis* Kraenzl. ex Rolfe and *Coelogyne rupicola* Carr (high-altitude ultramafic scrub), and the epiphytes *Paraphalaenopsis labukensis* Shim, A.Lamb & C.L.Chan, *Arachnis longisepala* (J.J. Wood) Shim & A.Lamb, and *Porpax borneensis* J.J.Wood & A.Lamb (limited accessibility in lowland ultramafic forests).

The endemism in orchids is a factor that is affected by both intrinsic and extrinsic factors in this environment. Examples of intrinsic factors are biological attributes affecting orchid reproduction and survival, like the use of mycorrhizal fungi to germinate seeds, reproductive isolation through being highly inbreeding-depressive, or reproductive isolation through limitation of pollination (Yang et al., 2021). Orchids are very sensitive to all environmental factors that have a direct impact on the population dynamics and reproductive success. Extrinsic factors are mainly manmade and commonly occur in combination with natural

environmental stressors. Habitat degradation and climate change influence the orchid distribution and ecological interaction, and biological pressures (pollinator decline, invasive species competition, etc.) contribute to the aggravation of conservation issues (Morales et al., 2017).

Mycorrhizal Associations

The microbial and fungal relationships are vital in the adaptation of plants to the ultramafic soils. Orchid plants are also mycorrhizal symbionts that can live in habitat characterised by severe soil conditions. These networks increase the resilience of ultramafic flora and are involved in the increased ecological role of these landscapes.

Mycorrhizal fungi, especially *Rhizoctonia* or *Tulasnella* genera, are needed by orchids specialised to ultramafic habitats (Arriagada et al., 2015). Mycorrhizal fungi have been associated with the acquisition of nutrients, particularly those of nitrogen and phosphorus and during early development of orchids, they are of great significance. They control the germination of seed and affect growth, which will determine survival, abundance, and spatial distribution (Yeh et al., 2019). Orchids have no endosperm in their orchid seeds, hence are entirely reliant on external sources of nutrients to germinate. When intoxicated into the orchid tissues, the fungi form platoons, and an exchange of nutrients takes place. The interaction is called mycoheterotrophy and enables orchids to acquire nutrients via fungal mediation and is at least partially mutualistic, because the fungi also obtain organic carbon through the orchid (Read et al., 2024).

This symbiosis is critical to endemic orchids like *Paphiopedilum rothschildianum* because the plants are only found in ultramafic soils of high altitude and are rich in metals within the Kinabalu Park. Without the help of fungi, orchids would fail to grow and to live in the inhospitable environment.

GLOBAL COMPARISON OF ULTRAMAFIC ORCHID DIVERSITY

Ultramafic habitats all around the globe are marked by ecological specialisation, great endemism, and adaptation of plants to soils rich in heavy metals. Having a high percentage of endemic species that are limited by edaphic factors and altitude, Kinabalu Park in Borneo is one of the richest centres of orchid diversity in the world, which is tied to ultramafic substrates. Other ultramafic parts of the Earth present a number of similarities and differences when compared to this region.

In New Caledonia, ultramafic soils cover roughly one-third of the island and support exceptional plant diversity. More than 3,309 species of ultramafic flora (2,492 of which are endemic) are highly specialised and endemic (Isnard et al., 2016). Even though orchid diversity is not as high as in Borneo, a number of genera can grow on nickel-containing materials, which suggests high adaptability to serpentine soils.

In Cuba, orchids form an important component of serpentine outcrops' floras, which function as hotspots of plant diversity and endemism. Habitat-driven distribution patterns and narrow-range endemism are comparable to Southeast Asia, although orchid richness there is lower. In California, the diversity of orchids in serpentine habitats is also lower than in tropical ultramafic regions, but orchids are suitable as valuable examples of chemically challenging soils. Despite differences in overall richness, the presence of edaphic-specific features in some temperate species suggests that orchids across climatic zones may have evolved similar ecological strategies.

Table 1 summarises selected South and Southeast Asian countries with ultramafic floras and the number of ultramafic endemics. This global comparison highlights the uniqueness of the ultramafic environment of Kinabalu Park as a potential tropical centre for orchid diversity. Kinabalu Park contains hundreds of species, many of which are endemic, compared to California, which supports only a few orchid taxa. Kinabalu orchids exhibit a unique combination of strong land specialisation, high species richness, and significant conservation importance compared to regions such as New Caledonia and Cuba. This highlights the global importance of Kinabalu Park as an orchid biodiversity hotspot and reinforces its status as a conservation priority.

ORCHIDS IN ULTRAMAFIC HABITATS OF SABAH

Sabah is known for its extensive ultramafic landscape. Ultramafic rocks underlie approximately 3,500 km² of the state, representing about ~4.6% of its total land area.

Table 1
Comparison of orchid diversity and endemism across selected ultramafic landscapes worldwide

Region	Ultramafic Coverage (km ²)	Total Number of Vascular Plant Species in the Flora	Number of Ultramafic-associated Species	Number of Ultramafic Endemic Species (% Ultramafic Endemism)	Orchid Richness	References
Kinabalu Park (Borneo)	754 square km	5000	-	2542 (50.8%)	High (hundreds of spp.)	Sabah Park, 2025
New Caledonia	1/3 of the island	3309	2492	1178 (47.3%)	Moderate	Isnard et al., 2016
Cuba	7% of the land area	6375	-	920 (14.4%)	Moderate	Reeves et al., 1999
California (USA)	~6,360 km ² (<1.5% of 423,970 km ²)	Not specified precisely; >1315 endemic species	255 taxa (strict + broad endemics)	14.7% of endemic species	Low	Safford & Miller, 2020

As shown in Figure 3, the largest ultramafic outcrops extend from Mount Tawai, Meliau Range, and the Bidu-bidu Hills through Mount Silam to Mount Kinabalu. Specific plant species found in Sabah's ultramafic soils have adapted to environments with high concentrations of heavy metals and low nutrient availability (Meindl et al., 2021). Consequently, these ultramafic areas are of exceptional ecological and botanical significance. The distribution of these rocks spans a broad elevational range, from low-lying islands in Darvel Bay to nearly 2,900 m above sea level on Mount Kinabalu.

The Sabah ultramafic flora is remarkably species-rich in contrast to other better-known ultramafic areas, e.g., New Caledonia, California (USA), Queensland (Australia), and Zimbabwe. The soil sustains very diverse vegetation, and the orchid is especially endemic. The number of orchid species is approximately 1,300 in Sabah, with approximately 250 species being endemic. This diversity is brought about mostly by the fact that they exist at Mount Kinabalu, the tallest mountain on the Malay Archipelago. Its varied ecosystem, comprising lowland rainforests to alpine meadows offer habitats where different assemblages of orchids thrive (Md.-Isa et al., 2024). Orchids can acclimatise to high levels of heavy metals by a symbiotic mutualism with fungi and specialised root systems.

Supplementary 1 shows that 563 orchid species have been recorded in Mount Kinabalu and other ultramafic outcrops in the state of Sabah. These data were assembled by looking at books, journals, articles, and herbarium database, but screened so as to obtain only those records in which the locality is known exactly; records which were simply labelled Sabah or those in cultivated plantations were ignored. Amongst the notable species, there are *Campanulorchis leiophylla* (Lindl.) Y.P.Ng & P.J.Cribb, a highly localised and

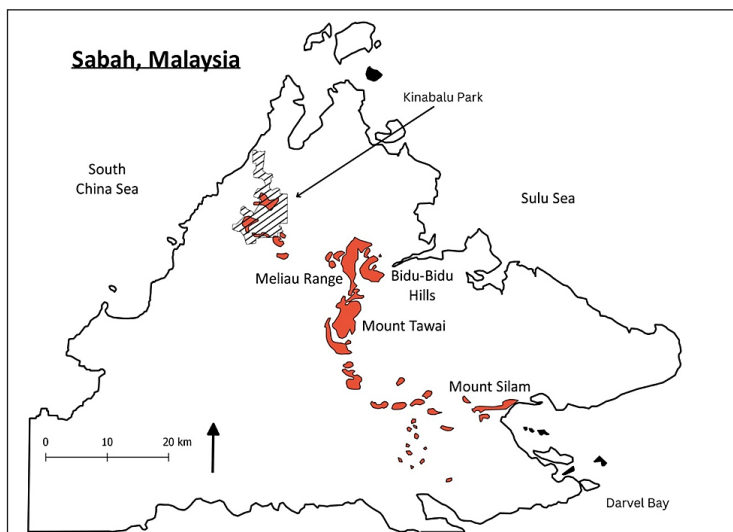


Figure 3. Igneous Rocks of Sabah, Malaysia. The line pattern fill - Kinabalu Park is situated

*Source: Modified from van der Ent et al. (2011)

taxonomically unique orchid; *Bulbophyllum longhutense* J.J.Sm., endemic to Borneo and restricted to montane forests; and *Ascidieria longifolia* (Hook.f.) Seidenf., a monopodial orchid with a unique taxonomy; all three demonstrate the importance of Mount Kinabalu as a biodiversity hotspot. The survival of the species shows that the ecological processes, such as specialist pollination, are preserved. Orchids are extremely sensitive to changes in their environment, and the fact that they are found in abundant numbers on Mount Kinabalu is a testimony to the relatively undisturbed and well-preserved habitats.

In the ultramafic areas around the range of Mount Kinabalu, there is also less orchid species diversity: it has 31 species on Mount Tawai, 13 on the Meliau Range, seven on Mount Silam and just five species on the Bidu-bidu Hills, the least orchid diversity that is ever reported within the ultramafic sites of Sabah. Species such as *Ascidieria grandis* (Ridl.) J.J.Wood and *Bulbophyllum chanii* J.J.Verm. & A.Lamb occur in the Meliau Range, which are reflections of ecological niches that enable the adaptation to ultramafic soils. Epiphytic orchid *B. chanii* is reliant on dense forest cover and is highly humid throughout to maintain its climate conditions, conditions preserved through the Meliau Range and also crucial to orchid species that adapt to shady habitats to microclimatic change.

There are a lot of species that are confined to localities. As an example, the number of species documented in Bidu-bidu Hills is only four species, with few trees and/or hydration causing low humidity and limited populations of mycorrhizal fungi that may have been encountered. Species richness can also be underestimated due to limited botanical surveys. This orchid faces threats of loss of its habitat, climate change and other human-driven forces. Therefore, immediate conservation action is required to take care of these delicate ecosystems and their rare orchid biodiversity.

STATUS OF ORCHID IN ULTRAMAFIC AREA OF KINABALU PARK, SABAH

There are a few key locations in the largest ultramafic outcrops of the Kinabalu Park: i. Mount Nambuyukon, ii. Mount Tambuyukon, iii. Wuluh River, iv. Nalumad, v. Panataran valley, vi. Marai Parai, vii. Layang-layang, viii. Mesilau, and ix. Bukit Babi (van der Ent & Wood, 2013). Outside the park, the most extensive serpentinite outcrops are found in the Hampuan Hill Forest Reserve, Kulung Hill, and the Lohan Valley on the southern slopes of Mount Kinabalu, with smaller occurrences reported from Bambang. Such ecosystems are usually characterised by bodies of serpentinite that are abraded by rivers to form small valleys that have steep sides. These sceneries usually contain a lot of landslides having different successional stages which slowly progress into a closed-canopy forest.

In Kinabalu Park, the ultramafic soils occur in 13 places that are mainly or wholly underlying (Figure 4). These locations demonstrate the importance of soils in diversifying plants and the phenomenal concentration of plant species in the ultramafic environments. The park is surrounded by ultramafic rock formations that occupy an area of about 151 km²

around the granite massif of Mount Kinabalu (van der Ent et al., 2016). This form features Mount Tambuyukon, which is contained within the whole composition of ultramafic rocks. The largest outcrops are found at Mount Tambuyukon (90 km²) and Panataran Valley (30 km²) (van der Ent et al., 2013).

Kinabalu Park, characterised by rocky, nutrient-poor soils, support orchids that have evolved distinct adaptations across different localities. The abundance of both terrestrial and epiphytic orchids likely reflects the open forest structure typical of serpentinite soils. High endemism among terrestrial orchids may be linked to the physiological adaptations to adverse soil chemistry, while epiphytic orchids exhibit parallel adaptations to ultramafic conditions.

Because records of orchid species are incomplete or unavailable records in some areas, only the green-shaded regions in Figure 4 were included in this study. These regions represent sites with detailed species-level records documented in publications and herbarium collections, allowing a more accurate assessment of diversity. An estimated 340 orchid species have been recorded across ten ultramafic outcrops in Kinabalu Park: Mount Tambuyukon, Panataran Valley, Marai Parai, Bukit Babi, Bambang, Nalumad, Mesilau, Layang-layang, Hampuan Hill, and Lohan Valley (Table 2). Records were included only when precise locality information was available; generic records lacking detailed site descriptions were excluded from the analysis.

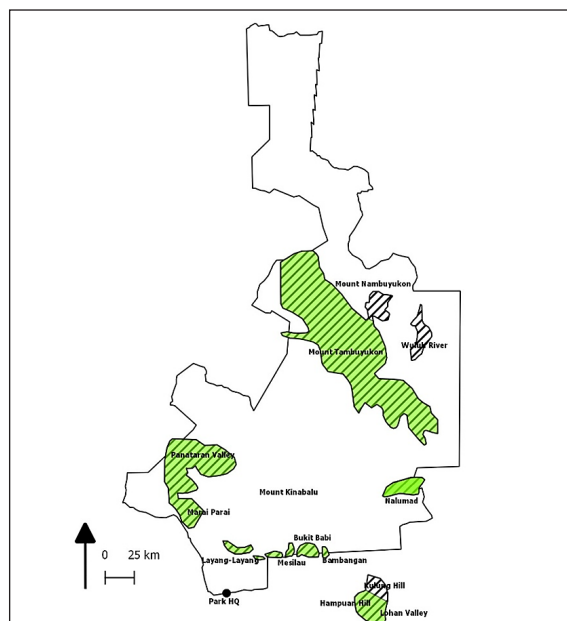


Figure 4. An overview of the major ultramafic outcrops in Kinabalu Park. The line pattern fill - regions indicate areas with ultramafic soils. These green-shaded areas represent locations where detailed records of orchid species have been found

**Source:* Modified from: van der Ent et al. (2015a)

Table 2

List of orchids species recorded in the ultramafic area of Kinabalu Park

Species	Ultramafic Areas in Kinabalu Park									
	Mount Tambuyukon ^{3,6,7,10,11}	Panataran Valley ^{3,7,8,11}	Marai Parai ^{3,4,7,8,9,10,11,12,13,14,15,18}	Bukit Babi ³	Bambangan ^{3,8,11}	Nalunad ^{7,8,10,11}	Mesilau ^{3,4,11,12,13,14}	Layang-Layang ^{3,11,14}	Hampuan Hill ^{3,4,7,11,13}	Lohan Valley ^{3,4,7,8,11,15}
<i>Appendicula congesta</i> Ridl.	✓		✓							
<i>Appendicula linearifolia</i> Ames & C.Schweinf.			✓							
<i>Appendicula longirostrata</i> Ames & C.Schweinf.			✓							
<i>Appendicula magnibracteata</i> Ames & C.Schwein.			✓							
<i>Appendicula fractiflexa</i> J.J.Wood						✓				
<i>Appendicula foliosa</i> Ridl. & Schltr.						✓				
<i>Appendicula lucida</i> Ridl.										✓
<i>Appendicula divaricata</i> Ames & C.Schweinf.									✓	✓
<i>Appendicula floribunda</i> (Schltr.) Schltr.										✓
<i>Appendicula pendula</i> Blume		✓	✓		✓					
<i>Appendicula reflexa</i> Blume									✓	
<i>Appendicula torta</i> Blume					✓				✓	
<i>Appendicula undulata</i> Blume						✓				
<i>Arachnis breviscapa</i> (J.J.Sm.) J.J.Sm.										✓
<i>Arachnis flos-aeris</i> (L.) Rchb.f.						✓				
<i>Arachnis longisepala</i> (J.J.Wood) Shim & A.Lamb	✓								✓	✓
<i>Arachnis calcarata</i> Holttum			✓							✓
<i>Arundina graminifolia</i> (D.Don) Hochr.			✓			✓			✓	
<i>Appendicula tembuyukenensis</i> J.J.Wood	✓									
<i>Appendicula anceps</i> Blume			✓							
<i>Ascidieria grandis</i> (Ridl.) J.J.Wood						✓	✓			
<i>Ascidieria cymbidiifolia</i> (Ridl.) W.Suarez & Cootes			✓				✓			
<i>Ascidieria maculiflora</i> J.J.Wood	✓									
<i>Ascidieria cymbidiifolia</i> var. <i>pandanifolia</i> (J.J.Wood) J.J.Wood	✓									
<i>Ascidieria longifolia</i> (Hook.f.) Seidenf.	✓									
<i>Anoectochilus geniculatus</i> Ridl.	✓									
<i>Agrostophyllum globigerum</i> Ames & C.Schweinf.			✓							
<i>Agrostophyllum majus</i> Hook.f.			✓							
<i>Apostasia nuda</i> R.Br.			✓							
<i>Apostasia wallichii</i> R.Br.	✓									✓

Table 2 (continued)

<i>Aeridostachya robusta</i> (Blume) F.G.Brieger	✓	✓		
<i>Adenoncos parviflora</i> Ridl.				✓
<i>Adenoncos borneensis</i> Schltr.				✓
<i>Bromheadia longifolia</i> Kruiz. & de Vogel		✓		
<i>Bromheadia lohaniensis</i> Kruiz. & de Vogel				✓
<i>Bromheadia divaricata</i> Ames & C.Schweinf.		✓		
<i>Bulbophyllum apheles</i> J.J.Verm.			✓	
<i>Bulbophyllum gibbsiae</i> Rolfe		✓		
<i>Bulbophyllum mandibulare</i> Rehb. f.				✓
<i>Bulbophyllum gamosepalum</i> (Griff.) J.J.Sm.			✓	
<i>Bulbophyllum gibbosum</i> (Blume) Lindl.			✓	
<i>Bulbophyllum microglossum</i> Ridley			✓	
<i>Bulbophyllum apodum</i> Hook.f.		✓	✓	
<i>Bulbophyllum biflorum</i> Teijsm. & Binn.				✓
<i>Bulbophyllum breviflorum</i> Ridl.			✓	
<i>Bulbophyllum chanii</i> J.J.Verm. & A.Lamb			✓	
<i>Bulbophyllum coriaceum</i> Ridl.		✓		✓
<i>Bulbophyllum dracunculus</i> J.J.Verm.		✓		
<i>Bulbophyllum dryas</i> Ridl.	✓			
<i>Bulbophyllum lambii</i> J.J.Verm.			✓	
<i>Bulbophyllum praetervisum</i> J.J.Verm.				✓
<i>Bulbophyllum sigmoideum</i> Ames & C.Schweinf.			✓	
<i>Bulbophyllum tortuosum</i> (Blume) Lindl.				✓
<i>Bulbophyllum trifolium</i> Ridl.				✓
<i>Bulbophyllum vaginatum</i> (Lindl.) Rehb.f.			✓	
<i>Bulbophyllum planibulbe</i> Ridl.				✓ ✓
<i>Bulbophyllum depressum</i> King & Pantl.			✓	✓
<i>Bulbophyllum flavescens</i> (Blume) Lindl.		✓	✓	✓
<i>Bulbophyllum vinaceum</i> Ames & C.Schweinf.		✓		
<i>Bulbophyllum anguliferum</i> Ames & C.Schweinf.			✓	
<i>Bulbophyllum aeolium</i> Ridl.			✓	
<i>Bulbophyllum caudatisepalum</i> Ames & C.Schweinf.			✓	✓
<i>Bulbophyllum flammuliferum</i> Ridl.				✓
<i>Bulbophyllum lobbii</i> subsp. <i>lobbii</i>			✓	✓ ✓
<i>Bulbophyllum lobbii</i> subsp. <i>boreoborneense</i> Mangal, F.Velazquez & J.J.Verm.			✓	
<i>Bulbophyllum nubinatum</i> J.J.Verm.	✓	✓		
<i>Bulbophyllum coniferum</i> Ridl.	✓		✓	
<i>Bulbophyllum disjunctum</i> Ames & C.Schweinf.	✓	✓		✓

Table 2 (continued)

<i>Bulbophyllum deltoideum</i> Ames & C.Schweinf.	✓		✓	
<i>Bulbophyllum latisepalum</i> Ridl. & C.Schweinf.			✓	
<i>Bulbophyllum turgidum</i> J.J.Verm.			✓	
<i>Bulbophyllum retrorsum</i> J.J.Verm. & A.Lamb			✓	
<i>Bulbophyllum membranifolium</i> Hook.f.	✓			
<i>Bulbophyllum montense</i> Ridl.	✓		✓	
<i>Dendrochilum exasperatum</i> Ridl.	✓			
<i>Dendrochilum lancilabium</i> Ridl.	✓			
<i>Dendrochilum alatum</i> Ridl.	✓			
<i>Dendrochilum haslamii</i> Ridl.			✓	
<i>Dendrochilum joclemensii</i> Ridl.	✓			
<i>Bulbophyllum hyalosemoides</i> J.J.Verm. & P.O'Byrne	✓		✓	
<i>Bulbophyllum obtusum</i> (Blume) Lindl.			✓	
<i>Bulbophyllum unguiculatum</i> Rchb.f.	✓		✓	
<i>Bulbophyllum mutabile</i> (Blume) Lindl.	✓			
<i>Bulbophyllum pocillum</i> J.J.Verm.	✓			
<i>Coelogyne latiloba</i> de Vogel	✓			
<i>Coelogyne chanii</i> Gravend. & de Vogel			✓	
<i>Coelogyne craticulilabris</i> Carr		✓		
<i>Coelogyne pandurata</i> Lindl.				✓ ✓
<i>Coelogyne planiscapa</i> var. <i>planiscapa</i>	✓	✓		
<i>Coelogyne septemcostata</i> J.J.Sm.	✓			
<i>Cleisocentron abasii</i> Cavestro	✓			
<i>Calanthe lyroglossa</i> Rchb.f.	✓			
<i>Calanthe woodii</i> P.J.Cribb				✓
<i>Calanthe otuhanica</i> C.L.Chan & T.J.Barkman	✓			
<i>Calanthe musa-amani</i> J.J.Wood	✓			
<i>Calanthe kinabaluensis</i> Rolfe		✓		
<i>Calanthe triplicata</i> (Willemet) Ames		✓ ✓ ✓		
<i>Calanthe vestita</i> Wall. ex Lindl.				✓
<i>Calanthe lambii</i> P.J.Cribb	✓		✓	
<i>Callostylis pulchella</i> (Lindl.) S.C.Chen & Z.H.Tsi			✓	
<i>Campanulorchis leiophylla</i> (Lindl.) Y.P.Ng & P.J.Cribb	✓			
<i>Ceratostylis longisegmenta</i> Ames & C.Schweinf.			✓	
<i>Ceratostylis pendula</i> Hook.f.				✓
<i>Ceratostylis ampullacea</i> Kraenzl.	✓			
<i>Cleisocentron merrillianum</i> (Ridl.) Christenson	✓	✓		
<i>Ceratostylis crassilingua</i> Ames & C.Schweinf.	✓			

Table 2 (continued)

<i>Chelonistele amplissima</i> (Ames & C.Schweinf.) Carr				✓	✓
<i>Chelonistele kinabaluensis</i> (Rolfe) de Vogel				✓	
<i>Chamaeanthus brachystachys</i> Schltr.	✓				✓
<i>Chroniochilus minimus</i> (Blume) J.J.Sm.	✓				✓
<i>Coelogyne radioferens</i> Ames & C.Schweinf.			✓	✓	✓
<i>Coelogyne genuflexa</i> Ames & C.Schweinf.		✓			
<i>Coelogyne clemensii</i> Ames & C.Schweinf.		✓		✓	
<i>Coelogyne compressicaulis</i> Ames & C.Schweinf.		✓			
<i>Coelogyne kinabaluensis</i> Ames & C.Schweinf.		✓	✓		✓
<i>Coelogyne tenompokensis</i> Carr				✓	
<i>Coelogyne monilirachis</i> Carr				✓	
<i>Coelogyne swaniana</i> Rolfe				✓	✓
<i>Coelogyne exalata</i> Ridl.				✓	
<i>Coelogyne cuprea</i> H.Wendl. & Kraenzl. var. <i>cuprea</i>	✓			✓	
<i>Coelogyne cuprea</i> var. <i>planiscapa</i> J.J.Wood & C.L.Chan	✓				
<i>Coelogyne papillosa</i> Ridl.	✓	✓		✓	
<i>Coelogyne plicatissima</i> Ames & C.Schweinf.	✓	✓	✓		✓
<i>Coelogyne hirtella</i> J.J.Sm.		✓	✓	✓	
<i>Coelogyne rupicola</i> Carr		✓		✓	
<i>Chroniochilus virescens</i> (Ridl.) Holttum	✓				
<i>Cystorchis aphylla</i> Ridl.			✓		✓
<i>Cymbidium angustifolium</i> Ames & C.Schweinf.			✓		
<i>Cymbidium elongatum</i> J.J.Wood, Du Puy & Shim	✓	✓	✓		
<i>Cymbidium ensifolium</i> (L.) Sw.				✓	✓
<i>Cymbidium sigmoideum</i> J.J.Sm.	✓				
<i>Cryptostylis acutata</i> J.J.Sm.	✓	✓			✓
<i>Corybas pictus</i> (Blume) Rchb.f.	✓	✓			
<i>Cylindrolobus linearifolius</i> (Merr.) J.J.Wood				✓	✓
<i>Cylindrolobus nutans</i> (Lindl.) J.J.Wood		✓			
<i>Cylindrolobus jensenianus</i> (J.J.Sm.) Rauschert	✓				
<i>Cleisocentron merrillianum</i> (Ames) Christenson			✓		
<i>Cleisostoma discolor</i> Lindl.					✓
<i>Cleisostoma striatum</i> (Rchb.f.) N.E.Br.				✓	✓
<i>Cleisostoma koeteiense</i> (Schltr.) Garay					✓
<i>Cleisocentron abasii</i> Cavestro	✓	✓			
<i>Crepidium metallicum</i> (Rchb.f.) Szlach.	✓				✓
<i>Crepidium lowii</i> (E.Morren) Szlach.					✓
<i>Crepidium mieczyslawii</i> Marg. & Szlach.		✓			✓

Table 2 (continued)

<i>Crepidium kinabaluense</i> (Rolfe) Szlach.		✓		✓		
<i>Dimorphorchis lowii</i> (Lindl.) Rolfe	✓					
<i>Dimorphorchis rossii</i> Fowlie						✓
<i>Dendrobium aloifolium</i> (Blume) Rchb.f.						✓
<i>Dendrobium longirepens</i> Ames & C. Schweinfurth		✓				
<i>Dendrochilum alatum</i> Ames		✓				
<i>Dendrobium anosmum</i> Lindl.						✓
<i>Dendrobium beamanianum</i> J.J.Wood & A.Lamb		✓				
<i>Dendrobium compressum</i> Lindl.				✓		✓
<i>Dendrobium gracile</i> (Blume) Lindl.		✓		✓		
<i>Dendrobium leonis</i> (Lindl.) Rchb.f.						✓ ✓
<i>Dendrobium macrophyllum</i> A.Rich.						✓
<i>Dendrobium pachyphyllum</i> (Kuntze) Bakh.f.						✓ ✓
<i>Dendrobium panduriferum</i> Hook.f.						✓
<i>Dendrobium xanthoacron</i> Schltr.				✓		
<i>Dendrobium acuiferum</i> Ormerod						✓
<i>Dipodium pictum</i> (Lindl.) Rchb.f.			✓			
<i>Dendrobium tetrachromum</i> Rchb.f.		✓				
<i>Dendrobium lambii</i> J.J.Wood		✓				
<i>Dendrobium daimandau</i> J.J.Wood				✓		
<i>Dendrobium hirsutifolium</i> J.J.Wood						✓
<i>Dendrobium serena-alexianum</i> J.J.Wood & A.Lamb	✓					
<i>Dendrobium angustipetalum</i> J.J.Sm.		✓				
<i>Dendrobium alabense</i> J.J.Wood		✓		✓		
<i>Dendrobium prostratum</i> Ridl.						✓ ✓
<i>Dendrobium hirsutifolium</i> J.J.Wood						✓
<i>Dendrobium kiauense</i> Ames & C.Schweinf.						✓
<i>Dendrobium patentilobum</i> Ames & C.Schweinf.	✓	✓				✓
<i>Dendrobium parthenium</i> Rchb.f.		✓				✓ ✓
<i>Dendrobium olivaceum</i> J.J.Sm.	✓					
<i>Dendrobium cymbulipes</i> J.J.Sm.	✓	✓	✓	✓		
<i>Dendrobium minimum</i> Ames & C.Schweinf.		✓				
<i>Dendrobium spectatissimum</i> Rchb.f.	✓					
<i>Dendrobium kinabaluense</i> Ridl.	✓					
<i>Dendrobium tridentatum</i> Ames & C.Schweinf.	✓	✓			✓	
<i>Dendrochilum kinabaluense</i> Rolfe		✓				
<i>Dendrochilum simplex</i> J.J.Sm.		✓				
<i>Dendrochilum longifolium</i> Rchb.f.		✓				✓
<i>Dendrochilum anomalum</i> Carr						✓

Table 2 (continued)

<i>Dendrochilum dewindtianum</i> W.W.Sm.		✓		✓
<i>Dendrochilum imbricatum</i> Ames			✓	
<i>Dendrochilum longirachis</i> Ames		✓		
<i>Dendrochilum planiscapum</i> Carr		✓		
<i>Dendrochilum pterogyne</i> Carr		✓		✓
<i>Dendrochilum fimbriatum</i> Ridl.		✓		
<i>Dendrochilum angustifolium</i> Ridl.	✓	✓		
<i>Dendrochilum crassilabium</i> J.J.Wood	✓			
<i>Dendrochilum corrugatum</i> (Ridl.) J.J.Sm.		✓		
<i>Dendrochilum cruciforme</i> J.J.Wood var. <i>cruciforme</i>	✓			
<i>Dendrochilum gibbsiae</i> Rolfe	✓	✓		
<i>Dendrochilum grandiflorum</i> (Ridl.) J.J.Sm.	✓	✓		
<i>Dendrochilum pallide-flavens</i> Blume var. <i>pallidiflavens</i>		✓		
<i>Dendrochilum kamborangense</i> Ridl.	✓			✓
<i>Dendrochilum stachyodes</i> (Ridl.) J.J.Sm.		✓		✓
<i>Dendrobium maraiparense</i> J.J.Wood & C.L.Chan		✓		
<i>Dendrochilum transversum</i> Carr		✓		
<i>Dendrobium piranha</i> C.L.Chan & P.J.Cribb	✓	✓		
<i>Dendrobium lancilabium</i> J.J.Sm.	✓			
<i>Dendrobium lohanense</i> J.J.Wood				✓
<i>Dendrobium spurium</i> (Blume) J.J.Sm.				✓ ✓
<i>Dendrobium rosellum</i> Ridl.				✓
<i>Dilochia parviflora</i> J.J.Sm.		✓		
<i>Dilochia cantleyi</i> (Hook.f.) Ridl.	✓	✓		✓
<i>Dilochia wallichii</i> Lindl.				✓
<i>Dilochia beamanii</i> Ormerod				✓
<i>Dilochia gracilis</i> (Ames & C.Schweinf.) Carr		✓		
<i>Dendrobium bifarium</i> Lindl. Ex Hook.f.				✓
<i>Neuwiedia borneensis</i> de Vogel	✓			✓
<i>Bromheadia brevifolia</i> Ridl.				✓
<i>Bromheadia acerate</i> Ames & C.Schweinf.	✓	✓		
<i>Eria major</i> Stapf		✓		
<i>Eria villosissima</i> Rolfe		✓		
<i>Entomophobia kinabaluensis</i> (Ridl.) de Vogel		✓		
<i>Epigeneium tricallosum</i> (Ames & C.Schweinf.) J.J.Wood				✓
<i>Epigeneium longirepens</i> (Ames & C.Schweinf.) Seidenf.		✓		
<i>Epigeneium kinabaluense</i> (Ridl.) Summerh.	✓	✓	✓	

Table 2 (continued)

<i>Epigeneium suberectum</i> (Ridl.) Summerh.		✓		
<i>Epidendrum longirepens</i> (C.Schweinf.) C.Schweinf.	✓			
<i>Eria javanica</i> (Sw.) Blume		✓		
<i>Eria linearifolia</i> Ridl.				✓
<i>Eria robusta</i> (Blume) Lindl.			✓	✓
<i>Eria oblitterata</i> (Blume) Rchb.f.			✓	
<i>Eria acerate</i> Ames & C.Schweinf.			✓	
<i>Eria aceratedes</i> (Blume) Lindl.			✓	
<i>Eria major</i> Ridl. Ex Stapf			✓	
<i>Eulophia graminea</i> Lindl.				✓
<i>Flickingeria scopa</i> (Lindl.) Brieger				✓
<i>Flickingeria fimbriata</i> (Blume) A.D.Hawkes			✓	✓
<i>Flickingeria xantholeuca</i> (Rchb.f.) A.D.Hawkes			✓	
<i>Gastrodia javanica</i> (Blume) Lindl.			✓	
<i>Geodorum densiflorum</i> (Lam.) Schltr.				✓
<i>Goodyera bifida</i> (Blume) Blume			✓	
<i>Goodyera condensata</i> Ormerod & J.J.Wood			✓	
<i>Goodyera rubicunda</i> (Blume) Lindl.			✓	
<i>Goodyera rostellata</i> Ames & C.Schweinf.		✓		✓
<i>Habenaria muricata</i> (Schauer) Rchb.f.			✓	
<i>Hetaeria anomala</i> Lindl.			✓	
<i>Liparis kinabaluensis</i> J.J.Wood				✓
<i>Liparis viridicallus</i> Holttum		✓		✓
<i>Liparis nervosa</i> (Thunb.) Lindl.		✓		
<i>Liparis elegans</i> Lindl.				✓
<i>Liparis pandurata</i> Ridl.			✓	
<i>Liparis kamborangensis</i> Ames & C.Schweinf.	✓	✓		
<i>Liparis atosanguinea</i> Ridl.		✓		
<i>Lepidogyne longifolia</i> (Blume) Blume		✓		
<i>Malleola punctata</i> J.J.Wood & A.Lamb				✓ ✓
<i>Micropera callosa</i> (Blume) Garay				✓
<i>Micropera fuscolutea</i> (Lindl.) Garay				✓
<i>Mycaranthes latifolia</i> Blume				✓
<i>Mycaranthes magnicallosa</i> (Ames & C.Schweinf.) J.J.Wood			✓	
<i>Mycaranthes major</i> (Stapf) J.J.Wood	✓	✓		
<i>Neuwiedia borneensis</i> de Vogel				✓
<i>Neuwiedia veratrifolia</i> Blume				✓
<i>Neuwiedia zolingeri</i> Rchb.f.				✓

Table 2 (continued)

<i>Nephelaphyllum flabellatum</i> Ames & C.Schweinf.	✓		✓
<i>Nephelaphyllum pulchrum</i> Blume			✓
<i>Nabaluia clemensii</i> Ridl.			✓
<i>Nabaluia angustifolia</i> de Vogel			✓
<i>Neuwiedia borneensis</i> de Vogel	✓		
<i>Neuwiedia zolingeri</i> var. <i>javanica</i> (J.J.Sm.) de Vogel	✓		
<i>Paphiopedilum lowii</i> (Lindl.) Stein			✓
<i>Paphiopedilum rothschildianum</i> (Rchb.f.) Stein	✓		
<i>Phalaenopsis modesta</i> J.J.Sm.			✓
<i>Paraphalaenopsis labukensis</i> Shim, A.Lamb & C.L.Chan	✓		
<i>Phaius subtrilobus</i> Ames & C.Schweinf.			✓
<i>Phaius pauciflorus</i> subsp. <i>Sabahensis</i> J.J.Wood & A.Lamb	✓		
<i>Renanthera bella</i> J.J.Wood	✓		✓
<i>Calanthe speciosa</i> (Blume) Lindl.			✓
<i>Calanthe otuhanica</i> C.L.Chan & T.J.Barkman	✓		
<i>Platanthera kinabaluensis</i> Kraenzl. Ex Rolfe	✓	✓	
<i>Thrixspermum kocyanii</i> J.J.Wood & A.Lamb	✓		
<i>Hetaeria hylophiloides</i> (Carr) Ormerod & J.J.Wood	✓		
<i>Liparis viridiflora</i> (Blume) Lindl.		✓	
<i>Liparis lacerata</i> Ridl.	✓		
<i>Liparis tricallosa</i> Rchb.f.	✓	✓	
<i>Malaxis punctata</i> J.J.Wood		✓	
<i>Malaxis subtiliscapa</i> (J.J.Sm.) J.J.Wood		✓	
<i>Malaxis graciliscapa</i> Ames & C.Schweinf.		✓	
<i>Malaxis ophrydis</i> (J.König) Ormerod			✓
<i>Nervilia plicata</i> (Andrews) Schltr.			✓
<i>Nervilia borneensis</i> (J.J.Sm.) Schltr.			✓
<i>Kuhlhasseltia kinabaluensis</i> Ames & C.Schweinf.	✓		
<i>Kuhlhasseltia javanica</i> J.J.Sm.	✓		
<i>Oberonia patentifolia</i> Ames & C.Schweinf.			✓
<i>Oberonia microphylla</i> (Blume) Lindl.	✓		
<i>Paphiopedilum dayanum</i> (Robert Stone ex J.Dix) Stein	✓		
<i>Paphiopedilum javanicum</i> var. <i>virens</i> (Rchb.f.) Stein			✓
<i>Paphiopedilum hookerae</i> var. <i>volonteanum</i> (Sander ex Rolfe) Braem	✓	✓	
<i>Paphiopedilum sugiyamanum</i> Cavestro			✓
<i>Pomatocalpa kunstleri</i> (Hook.f.) J.J.Sm.			✓

Table 2 (continued)

<i>Peristylus gracilis</i> Blume		✓			
<i>Pholidota kinabaluensis</i> Ames		✓			
<i>Pholidota pectinata</i> Ridl.		✓			
<i>Pholidota clemensii</i> Ridl.		✓		✓	
<i>Pholidota sigmatochilus</i> (Rolfe) J.J.Sm.	✓				
<i>Phreatia densiflora</i> Lindl.				✓	
<i>Phreatia listrophora</i> Ridl.		✓			
<i>Plocoglottis lowii</i> Rchb.f.		✓			
<i>Platanthera Stapfii</i> Kraenzl. Ex Rolfe	✓	✓			
<i>Podochilus sciuroides</i> Rchb.f.					✓
<i>Podochilus tenuis</i> Lindl.				✓	
<i>Podochilus microphyllus</i> Lindl.		✓			
<i>Pteroceras teres</i> (Blume) Holttum					✓
<i>Peristylus hallieri</i> J.J.Sm.		✓			
<i>Poaephyllum podochiloides</i> (Schltr.) Ridl.					✓
<i>Robiquetia merrilliana</i> (Ames) Lückel, M. Wolff & J.J.Wood		✓			
<i>Spiranthes sinensis</i> (Pers.) Ames		✓			
<i>Schoenorchis buddleiflora</i> (Schltr. & J.J.Sm.) J.J.Sm.		✓			
<i>Schoenorchis paniculata</i> Blume				✓	✓
<i>Stichorkis lobongensis</i> (Ames) J.J.Wood			✓		✓
<i>Stichorkis mucronata</i> (Blume) J.J.Wood					✓
<i>Stichorkis pandurata</i> (Ames) J.J.Wood			✓	✓	
<i>Spathoglottis affinis</i> de Vriese					✓
<i>Spathoglottis gracilis</i> Rolfe ex Hook.f.	✓	✓	✓		✓
<i>Spathoglottis microchilina</i> Kraenzl.		✓			
<i>Spathoglottis kimballiana</i> Hook.f.		✓			
<i>Spathoglottis kimballiana</i> var. <i>kimballiana</i>		✓			
<i>Taeniophyllum rubrum</i> Ridl.					✓
<i>Thelasis carnosa</i> Ames & C.Schweinf.				✓	
<i>Tainia purpureifolia</i> Carr	✓				
<i>Tainia speciosa</i> Blume	✓				
<i>Thrixspermum pensile</i> Schltr.					✓
<i>Thrixspermum kocyanii</i> J.J.Wood & A.Lamb	✓				
<i>Thrixspermum triangulare</i> Ames & C.Schweinf.	✓	✓			
<i>Trichotosia brevipedunculata</i> Ames & C.Schweinf.		✓		✓	
<i>Trichotosia aurea</i> (Ridl.) Carr	✓	✓			
<i>Trichotosia ferox</i> Blume		✓			
<i>Trichoglottis smithii</i> Carr					✓ ✓

Table 2 (continued)

<i>Trichoglottis maculata</i> (J.J.Sm.) J.J.Sm.										✓	
<i>Tropidia pedunculata</i> Blume										✓	
<i>Vanilla kinabaluensis</i> Carr							✓				
<i>Trichostia microphylla</i> Blume		✓									
<i>Vanilla pilifera</i> Holttum									✓		
<i>Vanilla havilandii</i> Rolfe							✓				
<i>Zeuxine gracilis</i> (Breda) Blume										✓	
<i>Stigmatodactylus maraiparaiensis</i> S.F.Md-Isa & A.S.Rob.		✓									
	340	74	8	136	4	23	23	77	9	49	62

*Sources: (Naturalis Bioportal, 2024)³; (Wood & Cribb, 1994)⁴; (Wood & van der Ent, 2012)⁶; (Wood et al., 2011a)⁷; (GBIF.org, 2017)⁸; (Md.-Isa et al., 2024)⁹; (van der Ent et al., 2014)¹⁰; (Wood et al., 2011b)¹¹; (Natural History Museum, 2025)¹²; (Harvard University Herbaria & Libraries, 2025)¹³; (Royal Botanic Gardens, Kew, 2025)¹⁴; (JACQ - Virtual Herbaria, 2020)¹⁵; (Md.-Isa et al., 2025)¹⁸

Differences in species richness among ultramafic sites in Kinabalu Park may reflect unequal survey efforts rather than true biological variation. According to Table 2, Marai Parai hosts the highest orchid diversity among these sites, with 136 species recorded. A new species, *Stigmatodactylus maraiparaiensis* S.F.Md-Isa & A.S.Rob., has been formally described from Marai Parai, highlighting the site's importance for ongoing taxonomic discoveries and orchid diversity (Md.-Isa et al., 2025). Marai Parai is a protected area where minimal disturbance and intensive botanical surveys likely contribute to the high number of recorded species.

Orchid richness at other ultramafic sites is as follows: Mesilau (77), Mount Tambuyukon (74), Lohan Valley (62), Hampuan Hill (49), Bambang (23), Nalumad (23), Layang-layang (9), Panataran Valley (8), and Bukit Babi (4). The low diversity documented at Bukit Babi likely reflects limited botanical survey efforts relative to other areas. However, *Coelogyne radioferens* Ames & C.Schweinf., is remarkably effective at Bukit Babi, where numerous orchids cannot perform well, and where it seems especially successful because instead of bending upright like typical inflorescent orchids, it grows in an arch, with its flowers well-spaced and having a remarkable lip, all features that increase the appeal of pollinating insects.

There are also species which are broadly adapted in several ultramafic locations. An example is *Bulbophyllum disjunctum* Ames & C.Schweinf., which has been reported in Mount Tambuyukon, Marai Parai and Mesilau. Other horticulturally viable plants are *Coelogyne hirtella* J.J.Sm. (Marai Parai, Bambang, Mesilau), *Dilochia cantleyi* (Hook.f.) Ridl. (Mount Tambuyukon, Marai Parai, Mesilau), and *Epigeneium kinabaluense* (Ridl.) Summerh. (Mount Tambuyukon, Marai Parai, Bukit Babi).

Despite the lack of an international assessment of the threat to extinction of most of these species, the existence of the endangered *Paphiopedilum dayanum* (Robert Stone ex J.Dix) Stein indicates that these habitats are conservation-urgent (Md.-Isa et al., 2024). To balance the ecosystem and ensure biodiversity conservation, there is a need to conserve the under-researched and species-poor sites like Panataran Valley, Bukit Babi, Bambang, and Nalumad.

When contrasting the Mount Kinabalu and ultramafic sections of the Kinabalu Park, some interesting trends are visible. Mount Kinabalu alone sustains 564 species of orchids, including endemic taxa such as *Paphiopedilum rothschildianum* (Rchb.f.) Stein, while Kinabalu Park's ultramafic areas host 340 recorded species, highlighting their complementary roles in orchid conservation. The orchids in the two locations also have a different microhabitat: epiphytic orchids such as *Bulbophyllum salaccense* Rchb.f., *Schoenorchis juncifolia* Reinw. ex-Blume and *Pholidota carnea* (Blume) Lindl. need to have a particular host tree, such as *Schima wallichii* and *Lyonia ovalifolia* (Ai et al., 2023; Fardhani et al., 2019), whereas terrestrial orchids, such as *Apostasia wallichii* R.Br. and *Paphiopedilum dayanum* (Robert Stone ex J.Dix) Stein, depend on shaded, moist forests floors (van der Ent & Wood, 2013). The large gradient of elevation of Mount Kinabalu creates diverse microhabitats, which are home to orchid communities, which are not similar to those in the ultramafic soils of the park.

Mount Kinabalu has been extensively researched, and many botanical surveys have been carried out by research institutions. Conversely, the ultramafic regions in Kinabalu Park have a lesser amount of records on orchid-specific investigations, possibly because of the focus on the ecological observation and protection by the status of the UNESCO World Heritage site. Table 3 presents the total number of orchid species, their endemism status, and associated threats across different ultramafic habitats to facilitate comparison. As a result of unequal past sampling and inadequate data, the available values on species richness and endemism patterns of the species should not be taken as final ones. The categories of threats are based on published literature in the conservation and regional reports, as opposed to site-specific assessment.

THREATS TO ORCHIDS IN KINABALU PARK

Over time, concerns about the decline of orchid populations across Malaysia have become increasing (Sudin & Md.-Isa, 2024). Kinabalu Park harbours numerous endemic orchid species within its unique montane and ultramafic habitats. Orchids are also among the most endangered due to their complex life cycles, despite being one of the most diverse plant families. Their dependence on mycorrhizal fungi, specialised pollinators, and host trees makes conservation particularly challenging (Fay, 2018). Orchids are highly vulnerable to pressures such as over-collection, illegal trade, poaching, and climate change (Fay, 2018; Wraith et al., 2020). These threats could drive rare and endemic species to extinction if left unchecked, further disrupting the ecological balance of Kinabalu Park.

Table 3

Summary of orchid diversity, endemism, and threats in ultramafic areas of Kinabalu Park

Site (Ultramafic Area)	Total Orchid Species	Endemic Species (Sabah/Kinabalu)	Non-endemic Species	% Endemic	Notes/Threats
Mount Tambuyukon	74	22	52	29.7%	Human activities (trekking or research expeditions)
Panataran Valley	8	0	8	0	Illegal collection and climate change
Marai Parai	136	41	94	30.4%	Construction of a new route to Mount Kinabalu, unregulated hiking activities, and illegal poaching and collection
Bukit Babi	4	1	3	25%	Poaching and illegal collection for trade, human activities (hiking), climate change
Bambangan	23	1	22	4.3%	Limited monitoring, illegal collection, climate change
Nalumad	23	5	18	21.7%	Illegal harvesting and poaching for trade, and climate change
Mesilau	77	19	58	24.7%	Illegal harvesting and poaching for trade, and climate change
Layang-Layang	9	4	5	44.4%	Limited monitoring, illegal harvesting and poaching for trade, and climate change
Hampuan Hill	49	3	46	6.1%	Forest fires, illegal hunting for wild orchids, and agricultural activities
Lohan Valley	62	5	57	8.1%	Illegal harvesting and poaching for trade, and climate change

Over-collection

Over-collection has become a significant menace to the orchids in the Kinabalu Park. Orchids tend to over-harvest wild (orchid enthusiasts, commercial collectors and even researchers regularly over-harvest them) (Hului, 2015), controlled by market pressures, pleasing scents, morphological variation and horticultural interest (Go et al, 2020). The collection of orchids in sealed gardens or in green-houses are especially sought after by collectors, because they are looking to discover species that are inimitable or have particular forms and structures. Nevertheless, its slow rates of growth and ecologically extreme specialisation can lead to massive catastrophic losses of orchid populations

since small-scale, yet frequent gathering can be conducted. Various species are sold at exorbitant prices in the local night markets and at the roadsides because of their charisma. Common genera are *Dendrobium*, *Coelogyne*, *Paphiopedilum* (lady's slipper orchids), *Gramatophyllum* (tiger orchids), *Phalaenopsis*, and some species of *Vanda* (Chadburn & Saputra, 2021; Chacko, 2025). Illegal harvesting still poses a threat to the endangered species regardless of the current laws, and it affects not only the genetic diversity but also the wildness population.

Illegal Trade and Poaching

Another great threat is the illegal trade. Endemic, rare orchids- especially *Paphiopedilum* and *Phalaenopsis* species are very expensive in the international market and fetch high prices. In the 2024 IUCN Red List assessment, 99% out of the 85 species of *Paphiopedilum* assessed are threatened with extinction and overexploitation and the horticultural trade was found to be the main factor (IUCN, 2024). One such example is *Paphiopedilum rothschildianum*, which has been reported to be being illegally collected in the wild by commercial traders (CITES, 2026; Rankou, 2015). All orchids are listed under CITES, and over 70% of CITES-listed plant species are orchids (Fay, 2018). Most Orchidaceae are classified under Appendix II, which allows international trade under permits and Non-Detriment Findings (NDFs), while some genera, such as *Paphiopedilum*, are in Appendix I, prohibiting commercial trade entirely. Nonetheless, orchids continue to be harvested and traded internationally for ornamental, medicinal, and culinary purposes, often without the necessary permits. Market surveys in Southeast Asia document cross-border trade of hundreds of wild-collected orchid species, particularly high-value *Paphiopedilum*, with illegal sales increasingly facilitated through e-commerce and social-media platforms despite regulatory (Phelps & Webb, 2015).

Even with legal protections, orchids are poached for international markets, including Taiwan, China, and Europe (Fay, 2015). Local, national, and international markets collectively trade thousands of orchid species, both legally and illegally, with impacts ranging from sustainable to destructive (Hinsley et al., 2018). Due to the absence of their fungal symbionts, most illegally harvested orchids fail to survive in cultivation (Makwela, 2021). Enforcement has become more difficult due to the rapid growth of online business platforms, which facilitate illegal sales. However, systematic monitoring studies of the online orchid trade in Sabah still remain limited.

Climate Change

Many orchid species, particularly those restricted to small elevational ranges, are directly threatened by climate change (Liu et al, 2024; Md.-Isa et al, 2018). These species are threatened by habitat loss, changes in rainfall patterns, desiccation, and disruption of

temperature-humidity regimes, even in protected areas. High-elevation orchids in Kinabalu Park depend on cool, humid conditions, and rising temperatures are forcing species upslope, gradually reducing their available habitat. Helmet orchids (*Corybas* species), which inhabit mossy high-mountain zones, are especially vulnerable due to their dependence on specific microclimatic conditions. Species that are unable to adapt or move higher up the slopes are at risk of local or total extinction.

Climate change also impacts the fungal community in the Borneo mountain system, which indirectly affects orchids by altering the distribution of their mycorrhizal partners (Geml et al., 2017; Kolanowska, 2023). This symbiosis is critical, particularly for endemic orchid species such as *Paphiopedilum rothschildianum*, which only occur exclusively on metal-rich soils at high elevations in Kinabalu Park (van der Ent et al., 2015c). As climate-induced changes reduce fungal growth or alter soil conditions, the recovery of orchids in their natural habitats will become increasingly difficult. In addition, climate change is exacerbating existing threats by reducing the availability of suitable habitat and increasing susceptibility to drought, fire, and invasive species.

STRATEGIES FOR SUSTAINABLE ORCHID CONSERVATION

Kinabalu Park has quite a vulnerable ultramafic flora, as it is highly endemic and specialised. The agencies of the government, such as Sabah Parks, Sabah Forestry Department (SFD), and Sabah Biodiversity Centre (SABC), are tasked with monitoring and protecting the wild orchids, but a lot of focus is paid to the regulation of the trade. They have worked towards the prevention of unlawful and unsustainable harvesting and controlling the legal trade of endemic orchids, including *Paphiopedilum*. Although conservation assessments use a variety of approaches to assess the risk of extinction, tools like Maximum Entropy (MaxEnt) modelling and IUCN Red List criteria are commonly used by researchers. The application of MaxEnt, environmental variable-based species distribution methods that utilise presence-only data have been used to conserve orchids in Sabah. As an example, Juiling et al. (2020) applied the MaxEnt to simulate potential distributions of 47 endemic orchid species to produce a species richness heatmap to support conservation priorities.

Associating orchid preservation with the UNESCO Global Geopark initiative may equally raise awareness of the ultramafic terrain of the Kinabalu Park internationally, and also other sustainable and responsible tourism. The main conservation priorities involve preventing over-collection, reducing human disturbance, and trying to control effects caused by climate change. A proper strategy involves both *in-situ* and *ex-situ* control, education of the communities and firm enforcement of the law with a view to protecting and restoring the wild populations, restoration of the habitats as well as engaging the local communities and policymakers.

***In-situ* and *Ex-situ* Conservation Strategies**

Multiple conservation strategies are needed in the conservation of orchids, both *in-situ* (within natural ecosystems like parks and reserves) and *ex-situ* environments (within orchidaria, botanical gardens, seed banks, nurseries, and laboratories). *In-situ* conservation focusses on conservation of the species in their natural environment, the ecological interactions between plants, animals, and the environment. The diversity of the orchids is the highest in Kinabalu Park (one of nine national parks in Sabah), with about ~711 reported species. Measures on conservation involve biodiversity vigilance, ecosystem preservation and limiting the possible adverse activities.

Simple and standardised survey designs that can be applied in remote ultramafic valleys should be used in long-term monitoring. This will include the drawing of permanent plots or transects at representative locations, which will be surveyed at intervals to monitor the presence of species, their state of habitat, and abundance. These methods draw a balance between scientific rigour and the logistical challenges of these difficult environments (Swarts & Dixon, 2017).

Threatened species need *ex-situ* plans. To conserve the germplasm, some of the techniques are tissue culture, micropropagation, and seed banking. Interest in plant success is gauged by survival and reproductive output as well as the retention of genetically representative material to the species. Research organisations including Universiti Malaysia Sabah, in collaboration with the Poring Orchid Conservation Centre in Kinabalu Park, propagate rare orchids to reintroduce them. As an example, an *in vitro* regeneration process of the Sabah endemic jewel orchid *Macodes limii* J.J.Wood & A.Lamb generated acclimatised plantlets that are later reintroduced to the Centre, demonstrating a successful reproduction and nursery handling (David et al., 2022).

Nevertheless, reintroductions pose a threat of genetic hazards such as outbreeding depression and the disappearance of local lineages. In an attempt to reduce this risk, the reintroduction programs employed local species that were specifically adapted to the target habitat and guaranteed genetic integrity, as well as reduced any potential adverse effects.

Education and Awareness through Communication

Community participation and education are important to the conservation of orchids. There is a cluster of local communities and organisations that give their contribution in the shape of labour, funding, and advocacy. Ignorance is a stimulating factor of black trade and excessive harvesting. Outreach programme—signage, ecotourism activities, as well as school learning—assists in minimising negative practices. Further opportunities to engage the public are offered by campaigns on social media, community science platforms, and documentaries. The conservation ambassadors work with the indigenous and local communities to establish sustainable sources of income, hence limiting the motivation to illegally harvest.

To illustrate, Sabah Parks has provided the Poring Hot Spring Orchid Adoption Programme, wherein the community is sensitised on the importance of protecting the endangered orchids and enabled them to participate in the conservation activities (Sabah Park, 2025). Increasing awareness through public campaigns can increase the long-term support of the forester community in the protection of orchids.

Strict Enforcement of Conservation Laws

It is necessary to implement stringent rules and police controls to protect orchids. Some of the challenges are the market demand and the inability to supervise the remote poaching locations. Enforcement of regulations governing the protected areas, under the Parks Enactment, state-level measures restricting the possession and transport of the protected plants, licensing access to the biological resources, and control of international trade by CITES are the policy instruments applicable to flatten the poaching of orchids in Sabah. These are measures which are in accordance with the requirements of the Convention on Biological Diversity, which advocates *in-situ* conservation and sustainable utilisation of wild species (Secretariat of the Convention on Biological Diversity, 2000).

Performing training on the identification and monitoring of the orchids and custom licenses of the forestry officers, park rangers, and other customs officials makes enforcement more effective. More financial resources are also required to enhance infrastructure and manpower. New technologies like online surveillance and reporting systems, as well as local communities, may reinforce the implementation of regulations and prevent crime.

The multi-agencies in Malaysia proves the efficacy of coordinated enforcement. In February 2025, law enforcement in Malaysia (General Operations Force) confiscated more than 4,000 orchids, valued at an estimated count of RM2 million (estimated at about \$450,000 USD). A 59-year-old man involved in the trade was detained (FMT Reporters, 2025). In November 2024, a 57-year-old man was caught smuggling ornamental orchids on board with an approximate value of over RM1 million of the plants without proper permission in Kelantan; the suspect and the orchids were rounded up to be reviewed according to Section 5 of the Plant Quarantine Act 1976 (Act 167) (Malay Mail, 2024).

CONCLUSION

Kinabalu Park's ultramafic habitat is a highly specialised ecosystem, supporting a remarkably diverse and well-adapted flora, particularly orchids that exhibit physiological and ecological adaptation enabling them to thrive in metal-rich and nutrient-poor soils. Despite its ecological importance and high degree of endemism, which have attracted international attention, the habitat remains under severe anthropogenic stress, including over-collection, illegal trade, poaching, and the increasing impacts of climate change. There is therefore an urgent need to develop robust and coordinated conservation efforts to prevent

further deterioration of these fragile environments. Priority measures include protecting habitats, strengthening both *in-situ* and *ex-situ* conservation management, enhancing public awareness and education, and reinforcing legal and institutional protection.

This paper highlights the ecological significance and richness of orchids within the ultramafic habitats in the Kinabalu Park; however, significant knowledge gaps remain. Priority research areas include understanding orchid-mycorrhizal fungal interactions, developing climate-based models to predict changes in dispersal, and establishing long-term monitoring programmes to track populations and habitat dynamics. Bridging these gaps will strengthen the scientific foundation needed to design effective restoration strategies for one of the world's most unique orchid floras.

Further research is essential to enhance our understanding of the ecological processes and specific adaptations that characterise this ecosystem. Integrating such scientific insights into conservation management will strengthen the resilience of ultramafic habitats within Kinabalu Park and support the persistence of endemic orchid species. Ultimately, conserving these ecosystems is crucial for preserving biodiversity, maintaining ecological balance, and safeguarding Sabah's natural heritage for future generations.

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SUPPLEMENTARY DATA

Table S1

List of orchid species recorded in the ultramafic area of Sabah, Malaysia

Species	Mount Kinabalu ^{1,3,4,7,8,11,12,13,14,15,16,17}	Ultramafic Areas in Sabah			
		Meliau Range ^{2,7,11}	Mount Tawai ^{3,4}	Bidu-bidu Hills ^{2,5,8}	Mount Silam ^{2,4}
<i>Aeridostachya macrophylla</i> (Ames & C.Schweinf.) J.J.Wood	✓				
<i>Ascidieria longifolia</i> (Hook.f.) Seidenf.	✓				
<i>Ascidieria grandis</i> (Ridl.) J.J.Wood	✓				
<i>Ascidieria cymbidiifolia</i> (Ridl.) W.Suarez & Cootes	✓				
<i>Arundina graminifolia</i> (D.Don) Hochr.	✓				
<i>Aphyllorchis montana</i> Rchb.f.	✓				
<i>Appendicula clemensiorum</i> J.J.Wood	✓				
<i>Appendicula calcarata</i> Ridl.	✓				
<i>Appendicula tubilabia</i> J.J.Wood	✓				
<i>Appendicula tembuyukenensis</i> J.J.Wood	✓				
<i>Acanthophippium lilacinum</i> J.J.Wood & C.L.Chan	✓				
<i>Arachnis calcarata</i> Holttum	✓				
<i>Bromheadia longifolia</i> Kruijz. & de Vogel	✓				
<i>Bulbophyllum lemniscatoides</i> Rolfe	✓				
<i>Bulbophyllum teres</i> Carr	✓				
<i>Bulbophyllum proculcastris</i> J.J.Verm.	✓				
<i>Bulbophyllum retrorsum</i> J.J.Verm. & A.Lamb	✓				
<i>Bulbophyllum microglossum</i> Ridl.	✓				
<i>Bulbophyllum chanii</i> J.J.Verm. & A.Lamb	✓				
<i>Bulbophyllum depressum</i> King & Pantl.	✓				
<i>Bulbophyllum longhutense</i> J.J.Sm.	✓				
<i>Bulbophyllum ionophyllum</i> J.J.Verm.	✓				
<i>Bulbophyllum calceolus</i> J.J.Verm.	✓				
<i>Bulbophyllum dearei</i> W.Watson	✓				
<i>Bulbophyllum pelicanopsis</i> J.J.Verm. & A.Lamb	✓				
<i>Bulbophyllum puntjakense</i> J.J.Sm.	✓				
<i>Bulbophyllum schefferi</i> (Kuntze) Schltr.	✓				
<i>Bulbophyllum undecifilum</i> J.J.Sm.	✓				
<i>Campanulorchis leiophylla</i> (Lindl.) Y.P.Ng & P.J.Cribb	✓				

Table S1 (continued)

<i>Campanulorchis pellipes</i> (Rchb.f. ex Hook.f.) Y.P.Ng & P.J.Cribb	✓
<i>Chroniochilus virescens</i> (Ridl.) Holttum	✓
<i>Chroniochilus minimus</i> (Blume) J.J.Sm.	✓
<i>Chamaeanthus brachystachys</i> Schltr.	✓
<i>Calanthe lambii</i> P.J.Cribb	✓
<i>Calanthe vestita</i> Wall. ex Lindl.	✓
<i>Calanthe woodii</i> P.J.Cribb	✓
<i>Calanthe musa-amani</i> J.J.Wood	✓
<i>Calanthe otuhanica</i> C.L.Chan & T.J.Barkman	✓
<i>Collabium ovalifolium</i> (Ames & C.Schweinf.) J.J.Wood	✓
<i>Collabium simplex</i> Rchb.f.	✓
<i>Corybas piliferus</i> J.Dransf.	✓
<i>Cleisocentron abasii</i> Cavestro	✓
<i>Cystorchis aphylla</i> Ridl.	✓
<i>Coelogyne latiloba</i> de Vogel	✓
<i>Coelogyne swaniana</i> Rolfe	✓
<i>Coelogyne dayana</i> Rchb.f.	✓
<i>Coelogyne pandurata</i> Lindl.	✓
<i>Coelogyne septemcostata</i> J.J.Sm.	✓
<i>Crepidium graciliscapum</i> (Ames & C.Schweinf.) Szlach.	✓
<i>Cymbidium borneense</i> J.J.Wood	✓
<i>Cymbidium tracyanum</i> L.Castle	✓
<i>Cymbidium lowianum</i> (Rchb.f.) Rchb.f.	✓
<i>Dilochia parviflora</i> J.J.Sm.	✓
<i>Dendrobium serena-alexianum</i> J.J.Wood & A.Lamb	✓
<i>Dendrobium cymboglossum</i> J.J.Wood & A.Lamb	✓
<i>Dendrobium hirsutifolium</i> J.J.Wood	✓
<i>Dendrobium beamanianum</i> J.J.Wood & A.Lamb	✓
<i>Dendrobium kentrophyllum</i> Hook.f.	✓
<i>Dendrobium kiauense</i> Ames & C.Schweinf.	✓
<i>Dendrobium indivisum</i> var. <i>pallidum</i> Seidenf.	✓
<i>Dendrochilum pseudoscriptum</i> T.J.Barkman & J.J.Wood	✓
<i>Dendrochilum cruciforme</i> var. <i>longicuspum</i> J.J.Wood	✓
<i>Dendrobium maraiparense</i> J.J.Wood & C.L.Chan	✓
<i>Dendrobium lohanense</i> J.J.Wood	✓
<i>Dendrobium grande</i> Hook.f.	✓
<i>Dendrobium linguella</i> Rchb.f.	✓
<i>Dendrobium jiewhoei</i> J.J.Wood & C.L.Chan	✓

Table S1 (continued)

<i>Dendrobium sanguinolentum</i> Lindl.	✓	
<i>Dendrobium cymbulipes</i> J.J.Sm.	✓	
<i>Grammatophyllum speciosum</i> Blume	✓	
<i>Habenaria koordersii</i> J.J.Sm.	✓	
<i>Habenaria setifolia</i> Carr	✓	
<i>Hetaeria hylophiloides</i> (Carr) Ormerod & J.J.Wood	✓	
<i>Hetaeria grandiflora</i> Ridl.	✓	
<i>Hetaeria rhombipetala</i> Ormerod & J.J.Wood	✓	
<i>Hetaeria elata</i> Hook.f.	✓	
<i>Hylophila lanceolata</i> (Blume) Miq.	✓	
<i>Jejewoodia jiewhoei</i> (J.J.Wood & Shim) Szlach.	✓	
<i>Lepidogyne longifolia</i> (Blume) Blume	✓	
<i>Liparis acaulis</i> Schltr.	✓	
<i>Lecanorchis multiflora</i> J.J.Sm.	✓	
<i>Nervilia borneensis</i> (J.J.Sm.) Schltr.	✓	
<i>Odontochilus hydrocephalus</i> (J.J.Sm.) J.J.Wood	✓	
<i>Gastrodia spatulata</i> (Carr) J.J.Wood	✓	
<i>Gastrodia javanica</i> (Blume) Lindl.	✓	
<i>Galeola nudifolia</i> Lour.	✓	
<i>Epigeneium treacherianum</i> (Rchb.f. ex Hook.f.) Summerh.		✓
<i>Epigeneium treacherianum</i> (Rchb.f. ex Hook.f.) Summerh.		✓
<i>Epipogium roseum</i> (D.Don) Lindl.	✓	
<i>Eulophia zollingeri</i> (Rchb.f.) J.J.Sm.	✓	
<i>Eulophia graminea</i> Lindl.	✓	
<i>Eria floribunda</i> Lindl.	✓	
<i>Eria augustifolia</i> Ridl.	✓	
<i>Eria borneensis</i> Rolfe	✓	
<i>Malaxis ophrydis</i> (J. König) Ormerod	✓	✓
<i>Malaxis crepidium</i> Bakh.f	✓	
<i>Malaxis damusica</i> (J.J.Sm.) Ames		✓
<i>Malaxis commelinifolia</i> (Zoll. & Moritzi) Kuntze		✓
<i>Chrysoglossum viridiflora</i> Hook.f.	✓	
<i>Chrysoglossum reticulatum</i> Carr	✓	
<i>Ceratostylis subulata</i> Blume	✓	
<i>Ceratostylis radiata</i> J.J.Sm.	✓	
<i>Liparis aurantiorbiculata</i> J.J.Wood & A.Lamb	✓	
<i>Stereosandra javanica</i> Blume	✓	
<i>Porrhachis galbina</i> (J.J.Sm.) Garay	✓	

Table S1 (continued)

<i>Pholidota sigmatochilus</i> J.J.Sm.	✓
<i>Pennilabium kidmancoxi</i> J.J.Wood	✓
<i>Paphiopedilum kolopakingii</i> Fowlie	✓
<i>Paphiopedilum sugiyamanum</i> Cavestro	✓
<i>Paphiopedilum lowii</i> (Lindl.) Stein	✓
<i>Peristylus candidus</i> J.J.Sm.	✓
<i>Pholidota carnea</i> (Blume) Lindl.	✓
<i>Pinalia latiuscula</i> (Ames & C.Schweinf.) J.J.Wood	✓
<i>Phaius tankervilleae</i> (Banks) Blume	✓
<i>Phaius reflexipetalus</i> J.J.Wood & Shim	✓
<i>Podochilus serpyllifolius</i> (Blume) Lindl.	✓
<i>Stichorkis lobongensis</i> (Ames) J.J.Wood	✓
<i>Stichorkis pandurata</i> (Ames) J.J.Wood	✓
<i>Spathoglottis microchilina</i> Kraenzl.	✓
<i>Trichotosia aurea</i> (Ridl.) Carr	✓
<i>Trichotosia brevipedunculata</i> (Ames & C.Schweinf.) J.J.Wood	✓
<i>Tainia malayana</i> J.J.Sm.	✓
<i>Tainia scapigera</i> (Hook.f.) J.J.Sm.	✓
<i>Thrixspermum acuminatissimum</i> (Blume) Rchb.f.	✓
<i>Tropidia saprophytica</i> J.J.Sm.	✓
<i>Trichoglottis sithasmahae</i> J.J.Wood & A.Lamb	✓
<i>Trichoglottis tenuis</i> Ames & C.Schweinf.	✓
<i>Dendrolirium ornatum</i> Blume	✓
<i>Dendrobium spectatissimum</i> Rchb.f.	✓
<i>Dendrobium sinsuronense</i> J.J.Wood	✓
<i>Dendrobium alabense</i> J.J.Wood	✓
<i>Dendrobium singulare</i> Ames & C.Schweinf.	✓
<i>Dendrobium oblongum</i> Ames & C.Schweinf.	✓
<i>Dendrobium tawaiense</i> J.J.Wood	✓
<i>Didymoplexiella kinabaluensis</i> (Carr) Seidenf.	✓
<i>Ania borneensis</i> (Rolfe) Senghas	✓
<i>Vanda helvola</i> Blume	✓
<i>Macropodanthus sabahensis</i> J.J.Wood & A.Lamb	
<i>Mycaranthes magnicallosa</i> (Ames & C.Schweinf.) J.J.Wood	✓
<i>Mycaranthes major</i> (Stapf) J.J.Wood	✓
<i>Neuwiedia borneensis</i> de Vogel	✓
<i>Oeceoclades pulchra</i> (Thouars) P.J.Cribb & M.A.Clem.	✓
<i>Paphiopedilum rothschildianum</i> (Rchb.f.) Stein	✓

Table S1 (continued)

<i>Phaius pauciflorus</i> subsp. <i>sabahensis</i> J.J.Wood & A.Lamb	✓		
<i>Porpax borneensis</i> J.J.Wood & A.Lamb	✓	✓	✓
<i>Platanthera saprophytica</i> J.J.Sm.	✓		
<i>Renanthera bella</i> J.J.Wood	✓		
<i>Crepidium metallicum</i> (Rchb.f.) Szlach.	✓		✓
<i>Dendrobium hamaticar</i> J.J.Wood & Dauncey	✓		
<i>Trichotosia mollicaulis</i> (Ames & C.Schweinf.) J.J.Wood	✓		
<i>Vanilla kinabaluensis</i> Carr	✓		
<i>Apostasia nuda</i> R.Br.	✓		✓
<i>Apostasia odorata</i> Blume	✓		
<i>Coelogyne cuprea</i> var. <i>planiscapa</i> J.J.Wood & C.L.Chan	✓		
<i>Coelogyne monilirachis</i> Carr	✓		
<i>Coelogyne moultonii</i> J.J.Sm.	✓		
<i>Coelogyne exalata</i> Ridl.	✓		
<i>Coelogyne incrassata</i> var. <i>valida</i> J.J.Sm.			✓
<i>Coelogyne verrucosa</i> S.E.C.Sierra			✓
<i>Phalaenopsis maculata</i> Rchb.f.			✓
<i>Paraphalaenopsis labukensis</i> Shim, A.Lamb & C.L.Chan	✓	✓	
<i>Platanthera crassinervia</i> (Ames & C.Schweinf.) J.J.Sm.	✓		
<i>Platanthera stapfii</i> Kraenzl. ex Rolfe	✓		
<i>Platanthera kinabaluensis</i> Kraenzl. ex Rolfe	✓		
<i>Dendrochilum planiscapum</i> Carr	✓		
<i>Dendrochilum angustilobum</i> Carr	✓		
<i>Dendrochilum stachyodes</i> (Ridl.) J.J.Sm.	✓		
<i>Thecopus secunda</i> (Ridl.) Seidenf.			✓
<i>Bulbophyllum placochilum</i> J.J.Verm.	✓		
<i>Bulbophyllum tenompokense</i> J.J.Sm.	✓		
<i>Bulbophyllum lambii</i> J.J.Verm.	✓		✓
<i>Microsaccus longicalcaratus</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum vinaceum</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum scabrum</i> J.J.Verm. & A.Lamb	✓		
<i>Bulbophyllum sigmoideum</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum lordoglossum</i> J.J.Verm. & A.Lamb	✓		
<i>Bulbophyllum dulitense</i> Carr	✓		
<i>Bulbophyllum koyanense</i> Carr	✓		
<i>Bulbophyllum gibbsae</i> Rolfe	✓		
<i>Bulbophyllum crassicaydatum</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum longimucronatum</i> Ames & C.Schweinf.	✓		

Table S1 (continued)

<i>Bulbophyllum minutiflorum</i> Ames & C.Schweinf.	✓				
<i>Bulbophyllum botryophorum</i> Ridl.				✓	
<i>Bulbophyllum flammuliferum</i> Ridl.		✓			
<i>Bulbophyllum limbatum</i> Lindl.				✓	
<i>Bulbophyllum sopoetanense</i> Schltr.	✓				
<i>Bulbophyllum lanceolatum</i> Ames & C.Schweinf.	✓				
<i>Bulbophyllum macrochilum</i> Rolfe		✓			
<i>Bulbophyllum deltoideum</i> Ames & C.Schweinf.	✓				
<i>Bulbophyllum reflexum</i> Ames & C.Schweinf.	✓				
<i>Bulbophyllum acuminatum</i> (Ridl.) Ridl.				✓	
<i>Bulbophyllum fascinator</i> (Rolfe) Rolfe	✓				
<i>Peristylus hallieri</i> J.J.Sm.	✓				
<i>Dendrobium pandaneti</i> Ridl.	✓				
<i>Corybas serpentinus</i> J.Dransf.				✓	✓
<i>Corybas crenulatus</i> J.J.Sm.	✓				
<i>Apostasia wallichii</i> R.Br.		✓	✓	✓	✓
<i>Liparis lingulata</i> Ames & C.Schweinf.	✓				
<i>Liparis anopheles</i> J.J.Wood	✓				
<i>Bulbophyllum flavescens</i> (Blume) Lindl.	✓			✓	
<i>Tainia purpureifolia</i> Carr	✓				
<i>Schoenorchis micrantha</i> Blume	✓				
<i>Coelogyne rigidiformis</i> Ames & C.Schweinf.	✓				
<i>Coelogyne genuflexa</i> Ames & C.Schweinf.	✓				
<i>Coelogyne clemensii</i> Ames & C.Schweinf.	✓				
<i>Coelogyne clemensii</i> var. <i>angustifolia</i> Carr	✓				
<i>Coelogyne clemensii</i> var. <i>longiscapa</i> Ames & C.Schweinf.	✓				
<i>Coelogyne tenompokensis</i> Carr	✓				
<i>Coelogyne obtusifolia</i> Carr	✓				
<i>Coelogyne craticulaelabris</i> Carr	✓				
<i>Coelogyne compressicaulis</i> Ames & C.Schweinf.	✓				
<i>Liparis elegans</i> Lindl.	✓			✓	
<i>Corymborkis veratrifolia</i> (Reinw.) Blume	✓				
<i>Pholidota clemensii</i> Ames	✓				
<i>Dendrochilum grandiflorum</i> J.J.Sm.	✓				
<i>Appendicula fractiflexa</i> J.J.Wood	✓				
<i>Appendicula pseudofractiflexa</i> J.J.Wood				✓	
<i>Appendicula torta</i> Blume	✓				
<i>Bulbophyllum marudiense</i> Carr				✓	
<i>Bulbophyllum coniferum</i> Ridl.	✓				

Table S1 (continued)

<i>Lecanorchis multiflora</i> J.J.Sm.	✓	
<i>Dendrobium roseobellum</i> J.J.Wood	✓	
<i>Bulbophyllum antenniferum</i> Rchb.f.	✓	
<i>Dendrochilum gibbsiae</i> Rolfe	✓	
<i>Cyrtosia javanica</i> Blume	✓	
<i>Coelogyne planiscapa</i> var. <i>grandis</i> Carr	✓	
<i>Coelogyne planiscapa</i> var. <i>plicatissima</i> Ames & C.Schweinf.	✓	
<i>Liparis parviflora</i> (Blume) Lindl.	✓	
<i>Anoectochilus integrilabris</i> Carr	✓	
<i>Coelogyne hirtella</i> J.J.Sm.	✓	
<i>Bulbophyllum coriaceum</i> Ridl. ex Stapf	✓	
<i>Coelogyne longibulbosa</i> Ames & C.Schweinf.	✓	
<i>Oberonia kinabaluensis</i> K.Y.Lang & D.S.Deng	✓	
<i>Cymbidium angustifolium</i> Ames & C.Schweinf.	✓	
<i>Cymbidium dayanum</i> Rchb.f.	✓	
<i>Cymbidium elongatum</i> J.J.Wood, Du Puy & Shim	✓	
<i>Dendrochilum sublobatum</i> Carr	✓	
<i>Cionisaccus procerus</i> (Ker Gawl.) M.A.Clem. & D.L.Jones	✓	
<i>Eria macrophylla</i> Ames & C.Schweinf.		
<i>Eria carnosissima</i> Ames & C.Schweinf.	✓	
<i>Eria magnicallosa</i> Ames & C.Schweinf.	✓	
<i>Eria villosissima</i> Rolfe	✓	
<i>Eria pseudoleiophylla</i> J.J.Wood	✓	
<i>Eria pseudocymbiformis</i> var. <i>hirsuta</i> J.J.Wood	✓	
<i>Dendrochilum scriptum</i> Carr	✓	
<i>Appendicula cornuta</i> Blume		✓
<i>Appendicula congesta</i> Ridl. ex Stapf	✓	
<i>Thrixspermum centipeda</i> Lour.	✓	
<i>Dilochia cantleyi</i> (Hook.f.) Ridl.	✓	
<i>Appendicula anceps</i> Blume	✓	
<i>Peristylus goodyeroides</i> (D.Don) Lindl.	✓	
<i>Liparis viridiflora</i> (Blume) Lindl.	✓	
<i>Trichotosia microphylla</i> Blume	✓	
<i>Chelonistele sulphurea</i> var. <i>sulphurea</i> (Blume) Pfitzer	✓	✓
<i>Neoclemensia spathulata</i> Carr	✓	
<i>Nephelaphyllum flabellatum</i> Ames & C.Schweinf.	✓	
<i>Nephelaphyllum pulchrum</i> Blume	✓	
<i>Dendrochilum dewindtianum</i> var. <i>dewindtianum</i> W.W.Sm.	✓	

Table S1 (continued)

<i>Podochilus tenuis</i> (Blume) Lindl.	✓		
<i>Podochilus lucescens</i> Blume	✓		✓
<i>Trichotosia aporina</i> (Hook.f.) Kraenzl.	✓		
<i>Eria grandis</i> Ridl. ex Stapf	✓		
<i>Appendicula foliosa</i> Ames & C.Schweinf.	✓		
<i>Thrixspermum tanuis</i> Ames & C.Schweinf.			
<i>Thrixspermum crescentiforme</i> Ames & C.Schweinf.	✓		✓
<i>Pantlingia lamrii</i> J.J.Wood & C.L.Chan	✓		
<i>Paphiopedilum hookerae</i> var. <i>volonteanum</i> (Sander ex Rolfe) Braem	✓	✓	
<i>Paphiopedilum dayanum</i> (Rchb.f.) Pfitzer	✓		
<i>Entomophobia kinabaluensis</i> (Ames) de Vogel	✓		
<i>Eria obliqua</i> (Lindl.) Lindl.	✓		
<i>Bulbophyllum membranifolium</i> subsp. <i>membranifolium</i>	✓		
<i>Dendrobium microglaphys</i> Rchb.f.			✓
<i>Dendrobium sculptum</i> Rchb.f.	✓		
<i>Coelogyne radioferens</i> Ames & C.Schweinf.	✓		
<i>Taeniophyllum culiciferum</i> Ridl.	✓		
<i>Eria major</i> Ridl. ex Stapf	✓		
<i>Dendrobium concinnum</i> Miq.	✓		
<i>Bulbophyllum lobbii</i> Lindl.	✓		
<i>Trichoglottis magnicallosa</i> Ames & C.Schweinf.	✓		
<i>Dendrochilum crassum</i> Ridl.	✓		
<i>Eria robusta</i> (Blume) Lindl.	✓		
<i>Dimorphorchis rossii</i> Fowlie			✓
<i>Dimorphorchis lowii</i> (Benth. & Hook.f.) Rolfe	✓		
<i>Microsaccus longicalcaratus</i> Ames & C.Schweinf.	✓		
<i>Dendrobium crumenatum</i> Sw.	✓		
<i>Cymbidium chloranthum</i> Lindl.	✓		
<i>Dendrochilum hologyne</i> Carr	✓		
<i>Octarrhena condensata</i> (Ridl.) Holttum	✓		
<i>Thelasis macrobulbon</i> Ridl.	✓		
<i>Eulophia spectabilis</i> (Dennst.) Suresh	✓		
<i>Spathoglottis kimballiana</i> Hook.f.		✓	✓
<i>Spathoglottis plicata</i> Blume	✓		
<i>Bulbophyllum comberi</i> J.J.Verm.	✓		
<i>Phaius subtrilobus</i> Ames & C.Schweinf.	✓		
<i>Phaius tankervilleae</i> (Banks ex L'Hér.) Blume	✓		
<i>Dendrobium tridentatum</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum cornutum</i> (Lindl.) Rchb.f.	✓		

Table S1 (continued)

<i>Kuhlhasseltia kinabaluensis</i> Ames & C.Schweinf.	✓	
<i>Acriopsis liliiflora</i> (J. Koenig) Ormerod	✓	
<i>Malaxis kinabaluensis</i> (Rolfe) Ames & C.Schweinf.	✓	
<i>Dendrochilum subintegrum</i> Ames	✓	
<i>Dendrochilum fimbriatum</i> Ames	✓	
<i>Dendrochilum kamborangense</i> Ames	✓	
<i>Bulbophyllum anaclastum</i> J.J.Verm.	✓	
<i>Bulbophyllum lygeron</i> J.J.Verm.	✓	
<i>Thrixspermum trichoglottis</i> (Hook.f.) Kuntze	✓	
<i>Coelogyne cuprea</i> H.Wendl. & Kraenzl.	✓	✓
<i>Epigeneium tricallosum</i> Ames & C.Schweinf.	✓	
<i>Epigeneium longirepens</i> Ames & C.Schweinf.	✓	
<i>Epigeneium kinabaluense</i> (Ridl.) Summerh.	✓	
<i>Dendrochilum longirachis</i> Ames	✓	
<i>Coelogyne venusta</i> Rolfe	✓	
<i>Thrixspermum magnicallosa</i> Ames & C.Schweinf.	✓	
<i>Thrixspermum triangulare</i> Ames & C.Schweinf.	✓	
<i>Vrydagzynea grandis</i> Ames & C.Schweinf.	✓	
<i>Vrydagzynea bicostata</i> Carr	✓	
<i>Vrydagzynea argentistriata</i> Carr	✓	
<i>Vrydagzynea elata</i> Schltr.	✓	
<i>Grammatophyllum kinabaluense</i> Ames & C.Schweinf.	✓	
<i>Bulbophyllum mutabile</i> (Blume) Lindl.	✓	
<i>Thelasis variabilis</i> Ames & C.Schweinf.	✓	
<i>Dendrochilum alpinum</i> Carr	✓	
<i>Zeuxine papillosa</i> Carr	✓	
<i>Dendrochilum gracilipes</i> Carr	✓	
<i>Dendrochilum graminoides</i> Carr	✓	
<i>Vanilla kinabaluensis</i> Carr		✓
<i>Vanilla sumatrana</i> J.J.Sm.	✓	
<i>Dendrochilum haslamii</i> Ames	✓	
<i>Chelonistele lurida</i> Pfitzer	✓	
<i>Liparis kinabaluensis</i> J.J.Wood		
<i>Liparis kamborangensis</i> Ames & C.Schweinf.	✓	
<i>Robiquetia crockerensis</i> Wood & Lamb	✓	
<i>Bulbophyllum breviflorum</i> Ridl.	✓	
<i>Dendrobium beamanianum</i> J.J.Wood & A.Lamb	✓	
<i>Liparis pandurata</i> Ames	✓	
<i>Eria monophylla</i> Schltr.	✓	
<i>Thrixspermum amplexicaule</i> (Blume) Rchb.f.	✓	

Table S1 (continued)

<i>Dendrochilum pterogyne</i> Carr	✓		
<i>Nervilia punctata</i> (Blume) Makino	✓		
<i>Bromheadia divaricata</i> Ames & C.Schweinf.	✓		
<i>Bromheadia borneensis</i> J.J.Sm. var. <i>borneensis</i>			✓
<i>Bromheadia brevifolia</i> Ridl.	✓		
<i>Peristylus gracilis</i> Blume	✓		
<i>Bulbophyllum obtusum</i> (Blume) Lindl.	✓		
<i>Spathoglottis aurea</i> Lindl.	✓		
<i>Phreatia densiflora</i> (Blume) Lindl.	✓		
<i>Coelogyne rupicola</i> Carr	✓		
<i>Dendrochilum transversum</i> Carr	✓		
<i>Paphiopedilum javanicum</i> Pfitzer	✓		
<i>Eria ornata</i> (Blume) Lindl.	✓		
<i>Bulbophyllum eximium</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum pergracile</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum cuneifolium</i> Ames & C.Schweinf.	✓		
<i>Bulbophyllum caudatisepalum</i> Ames & C.Schweinf.	✓		
<i>Dendrobium orbiculare</i> J.J.Sm.	✓		
<i>Goodyera rostellata</i> Ames & C.Schweinf.	✓		
<i>Habenaria setifolia</i> Carr	✓		
<i>Habenaria damaiensis</i> J.J.Sm.	✓		
<i>Trichoglottis collenetteae</i> J.J.Wood, C.L.Chan & A.Lamb	✓		
<i>Macodes limii</i> J.J.Wood & A.Lamb			✓
<i>Macodes petola</i> (Blume) Lindl.	✓		
<i>Dendrochilum conopseum</i> Ridl. ex Stapf	✓		
<i>Nabalua angustifolia</i> de Vogel	✓		
<i>Appendicula recondita</i> J.J.Sm.	✓		
<i>Flickingeria dura</i> (J.J.Sm.) A.D.Hawkes	✓		
<i>Trichoglottis kinabaluensis</i> Rolfe	✓		
<i>Ceratostylis ampullacea</i> Kraenzl.	✓		
<i>Coelogyne naja</i> J.J.Sm.	✓		
<i>Erythrodes latifolia</i> Blume	✓		
<i>Microsaccus longicakaratus</i> Ames & C.Schweinf.	✓		
<i>Appendicula linearifolia</i> Ames & C.Schweinf.	✓		
<i>Vanda gibbsiae</i> Rolfe	✓		
<i>Chelonistele sulphurea</i> var. <i>crassifolia</i> (Blume) Pfitzer	✓		✓
<i>Arachnis longisepala</i> (J.J.Wood) Shim & A.Lamb	✓	✓	
<i>Arachnis flosaeris</i> var. <i>gracilis</i> (L.) Rech.f.	✓		
<i>Agrostophyllum globigerum</i> Ames & C.Schweinf.	✓		

Table S1 (continued)

<i>Agrostophyllum saccatum</i> Ridl.		✓
<i>Agrostophyllum stipulatum</i> (Griff.) Schltr.		✓
<i>Agrostophyllum glumaceum</i> Hook.f.		✓
<i>Agrostophyllum bicuspidatum</i> J.J.Sm.	✓	
<i>Bulbophyllum dryas</i> Ridl.	✓	
<i>Thrixspermum pensile</i> Schltr.	✓	
<i>Chelonistele amplissima</i> (Ames & C.Schweinf.) Carr	✓	
<i>Dendrobium lamelluliferum</i> J.J.Sm.	✓	
<i>Anoectochilus monicae</i> J.J.Wood	✓	
<i>Goodyera rubicunda</i> (Blume) Lindl.	✓	
<i>Bulbophyllum hemiprionotum</i> J.J.Verm. & A.Lamb	✓	
<i>Bulbophyllum heldiorum</i> J.J.Verm.	✓	
<i>Oberonia triangularis</i> Ames & C.Schweinf.	✓	
<i>Oberonia patentifolia</i> Ames & C.Schweinf.	✓	
<i>Oberonia affinis</i> Ames & C.Schweinf.	✓	
<i>Bulbophyllum dracunculus</i> J.J.Verm.	✓	
<i>Flickingeria bicarinata</i> (Ames & C.Schweinf.) A.D.Hawkes	✓	
<i>Calanthe ovalifolia</i> Ridl.	✓	
<i>Calanthe tenuis</i> Ames & C.Schweinf.	✓	
<i>Calanthe cuneata</i> Ames & C.Schweinf.	✓	
<i>Calanthe kinabaluensis</i> Rolfe.	✓	
<i>Calanthe pulchra</i> (Blume) Lindl.	✓	
<i>Calanthe gibbsiae</i> Rolfe	✓	
<i>Bulbophyllum apodum</i> Hook.f.	✓	
<i>Nabalua clemensii</i> Ames	✓	
<i>Dendrobium bifarium</i> Lindl.	✓	
<i>Appendicula pendula</i> Blume	✓	
<i>Peristylus grandis</i> Blume	✓	
<i>Bulbophyllum alatum</i> J.J.Verm.	✓	
<i>Cleisostoma inflatum</i> (Rolfe) Garay	✓	
<i>Cleisostoma striatum</i> (Rchb.f.) Garay	✓	
<i>Taeniophyllum obtusum</i> Blume	✓	
<i>Spathoglottis gracilis</i> Rolfe ex Hook.f.	✓	✓
<i>Coelogyne rochussenii</i> de Vriese	✓	
<i>Liparis grandis</i> Ames & C.Schweinf.	✓	
<i>Thrixspermum pardale</i> (Ridl.) Schltr.	✓	
<i>Neuwiedia zolingeri</i> var. <i>javanica</i> (J.J.Sm.) de Vogel		✓
<i>Neuwiedia veratrifolia</i> Blume	✓	
<i>Phalaenopsis amabilis</i> (L.) Blume	✓	

Table S1 (continued)

<i>Bulbophyllum rhizomatosum</i> Ames & C.Schweinf.	✓
<i>Bulbophyllum pugilanthum</i> J.J.Wood	✓
<i>Liparis caespitosa</i> (Thouars) Lindl.	✓
<i>Eria hyacinthoides</i> (Blume) Lindl.	✓
<i>Phreatia monticola</i> Schltr.	✓
<i>Eria leiophylla</i> Lindl.	✓
<i>Eria nutans</i> Lindl.	✓
<i>Eria kinabaluensis</i> Rolfe	✓
<i>Coelogyne rhabdobulbon</i> Schltr.	✓
<i>Bulbophyllum mandibulare</i> Rchb.f.	✓
<i>Geodorum densiflorum</i> (Lam.) Schltr.	✓
<i>Dendrobium maraiparense</i> Wood & C.L.Chan	✓
<i>Bulbophyllum anguliferum</i> Ames & C.Schweinf.	✓
<i>Bulbophyllum latisepalum</i> Ames & C.Schweinf.	✓
<i>Trichotosia ferox</i> Blume	✓
<i>Bulbophyllum purpurascens</i> Teijsm. & Binn.	✓
<i>Dendrochilum lancilabium</i> Ames	✓
<i>Aphyllorchis pallida</i> Blume	✓
<i>Taeniophyllum stella</i> Carr	✓
<i>Gastrodia grandilabris</i> Carr	✓
<i>Bulbophyllum kestron</i> J.J.Verm. & A.Lamb	✓
<i>Liparis lobongensis</i> Ames	✓
<i>Appendicula divaricata</i> Ames & C.Schweinf.	✓
<i>Dendrobium kurashigei</i> T. Yukawa	✓
<i>Dendrochilum alatum</i> Ames	✓
<i>Ceratostylis longisegmenta</i> Ames & C.Schweinf.	
<i>Ceratostylis crassilingua</i> Ames & C.Schweinf.	✓
<i>Pholidota gibbosa</i> (Blume) de Vriese	✓
<i>Coelogyne kinabaluensis</i> Ames & C.Schweinf.	✓
<i>Coelogyne radioferens</i> Ames & C.Schweinf.	✓
<i>Taeniophyllum rubrum</i> Ridl.	✓
<i>Thelasis carnosa</i> Ames & C.Schweinf.	✓
<i>Robiquetia transversisaccata</i> (Ames & C.Schweinf.) J.J.Wood	✓
<i>Dendrochilum pallideflavens</i> Blume	✓
<i>Dendrobium patentilobum</i> Ames & C.Schweinf.	✓
<i>Dendrochilum tenompokense</i> Carr	✓
<i>Oberonia rubra</i> Ridl.	✓
<i>Coelogyne subintegra</i> J.J.Sm.	✓
<i>Tainia paucifolia</i> (Breda) J.J.Sm.	✓

Table S1 (continued)

<i>Dilochia rigida</i> (Ridl.) J.J.Wood	✓	
<i>Schoenorchis juncifolia</i> Reinw.	✓	
<i>Coelogyne tenempokensis</i> Carr	✓	
<i>Cryptostylis clemensii</i> J.J.Sm.	✓	
<i>Didymoplexis kinabaluensis</i> Carr	✓	
<i>Phreatia plantaginifolia</i> (K.D.Koenig) Ormerod	✓	
<i>Dendrobium villosulum</i> Lindl.	✓	
<i>Peristylus ciliatus</i> Carr	✓	
<i>Appendicula maggnibracteata</i> Ames & C.Schweinf.	✓	
<i>Appendicula longirostrata</i> Ames & C.Schweinf.	✓	
<i>Flickingeria fimbriata</i> (Blume) A.D.Hawkes	✓	
<i>Corybas kinabaluensis</i> Carr	✓	
<i>Eria saccifera</i> Hook.f.	✓	✓
<i>Bulbophyllum catenarium</i> Ridl.	✓	
<i>Bulbophyllum apheles</i> J.J.Verm.	✓	
<i>Spiranthes sinensis</i> (Pers.) Ames	✓	
<i>Flickingeria pseudoconvexa</i> (Ames) A.D.Hawkes	✓	
<i>Goodyera ustulata</i> Carr	✓	
<i>Cleisocentron merrillianum</i> (Ames) Christenson	✓	
<i>Dendrochilum joclemensii</i> Ames	✓	
<i>Coelogyne papillosa</i> Ridl.	✓	
<i>Thelasis pygmaea</i> (Griff.) Blume	✓	
<i>Nephelaphyllum verruculosum</i> Carr	✓	
<i>Coelogyne pulverula</i> Teijsm. & Binn.	✓	
<i>Phreatia sulcata</i> (Blume) J.J.Sm.	✓	
<i>Dendrochilum acuiferum</i> Carr	✓	
<i>Bulbophyllum montense</i> Ridl. ex Stapf	✓	
<i>Bromheadia finlaysoniana</i> (Lindl.) Miq.	✓	✓
<i>Bulbophyllum lissoglossum</i> J.J.Verm.	✓	
<i>Thecostele alata</i> (Roxb.) C.S.P.Parish & Rchb.f.	✓	
<i>Bulbophyllum scheffleri</i> Schltr.	✓	
<i>Myrmechis kinabaluensis</i> Carr	✓	
<i>Dendrochilum dewindtianum</i> W.W.Sm.	✓	
<i>Dendrochilum pallideflavens</i> var. <i>pallidiflavens</i> Blume	✓	
<i>Calanthe speciosa</i> (Blume) Lindl.	✓	
<i>Dendrochilum lacteum</i> Carr	✓	
<i>Bulbophyllum membranaceum</i> Teijsm. & Binn.	✓	
<i>Cryptostylis arachnites</i> (Blume) Hassk.	✓	
<i>Chelonistele kinabaluensis</i> (Rolfe) de Vogel	✓	

Table S1 (continued)

<i>Octarrhena parvula</i> Thwaites	✓	
<i>Coelogyne plicatissima</i> Ames & C.Schweinf.	✓	✓
<i>Bromheadia truncata</i> Seidenf.	✓	
<i>Bulbophyllum ceratostylis</i> J.J.Sm.	✓	
<i>Liparis viridicallus</i> Holttum	✓	
<i>Dendrobium ventripes</i> Carr	✓	
<i>Bulbophyllum salaccense</i> Rehb.f.	✓	
<i>Eria pseudocymbiformis</i> var. <i>hirsuta</i> J.J.Wood	✓	
<i>Aerides odorata</i> Lour.	✓	
<i>Pholidota carnea</i> var. <i>carnea</i> (Blume) Lindl.	✓	
<i>Appendicula minutiflora</i> Ames & C.Schweinf.	✓	
<i>Pteroceras spathibrachiatum</i> (J.J.Sm.) Garay	✓	
<i>Eria cymbidifolia</i> Ridl.	✓	
<i>Bulbophyllum disjunctum</i> Ames & C.Schweinf.	✓	
<i>Oberonia equitans</i> (Thouars) Schltr.	✓	
<i>Mischobulbum scapigerum</i> (Hook.f.) Schltr.	✓	
<i>Dendrochilum imbricatum</i> Ames	✓	
<i>Eria farinosa</i> K.Y.Lang & D.S.Deng	✓	
<i>Pholidota pectinata</i> Ames	✓	
<i>Peristylus brevicealcar</i> Carr	✓	
<i>Zeuxine strateumatica</i> (L.) Schltr.	✓	
<i>Dendrochilum angustipetalum</i> Ames	✓	
<i>Taeniophyllum esetiferum</i> J.J.Sm.	✓	
<i>Calanthe triplicata</i> (Willemet) Ames	✓	
<i>Goodyera kinabaluensis</i> Rolfe	✓	
<i>Malleola kinabaluensis</i> Ames & C.Schweinf.	✓	
<i>Arundina graminifolia</i> (D.Don) Hochr.	✓	
<i>Liparis latifolia</i> (Blume) Lindl.	✓	
<i>Zeuxine benguetensis</i> (Ames) Ames	✓	
<i>Bulbophyllum hyalosemoides</i> J.J.Verm. & P.O'Byrne	✓	
<i>Bulbophyllum lobbii</i> subsp. <i>borneoborneense</i>	✓	
<i>Eria latiuscula</i> Ames & C.Schweinf.	✓	
<i>Bulbophyllum mahakamense</i> J.J.Sm.	✓	
<i>Bulbophyllum trifolium</i> Ridl.	✓	
<i>Liparis atrosanguinea</i> Ridl.	✓	
<i>Peristylus kinabaluensis</i> Carr	✓	
<i>Platanthera gibbsiae</i> Rolfe	✓	
<i>Platanthera crassinervia</i> , (Ames & C.Schweinf.) J.J.Sm.	✓	
<i>Platanthera borneensis</i> (Ridl.) J.J.Wood	✓	

Table S1 (continued)

<i>Platanthera angustata</i> (Blume) Lindl.	✓					
<i>Bromheadia ensifolia</i> J.J.Sm.	✓					
<i>Aphyllorchis borneensis</i> Schltr.	✓					
<i>Phaius baconii</i> J.J.Wood & Shim	✓					
<i>Appendicula kinabaluensis</i> J.J.Sm.	✓					
<i>Pteroceras biserratum</i> (Ridl.) Holttum	✓					
<i>Dendrobium minimum</i> Ames & C.Schweinf.	✓					
<i>Bulbophyllum muscohaerens</i> J.J.Verm. & A.Lamb	✓					
<i>Dendrobium salaccense</i> (Blume) Lindl.	✓					
<i>Dendrobium singkawangense</i> J.J.Sm.	✓					
<i>Dendrochilum exasperatum</i> Ames	✓					
<i>Eria cepifolia</i> Ridl.	✓					
<i>Dendrobium cymbulipes</i> J.J.Sm.	✓					
<i>Acriopsis javanica</i> Reinw. ex Blume var. <i>javanica</i>						✓
<i>Acriopsis indica</i> Wight	✓					
<i>Eria oblitterata</i> (Blume) Rchb.f.	✓					
<i>Malaxis punctata</i> J.J.Wood	✓					
<i>Malaxis subtiliscapa</i> (J.J.Sm.) J.J.Wood	✓					
<i>Dendrochilum corrugatum</i> J.J.Sm.	✓					
<i>Bulbophyllum pocillum</i> J.J.Verm.	✓					
<i>Liparis condylobulbon</i> Rchb.f.	✓					
<i>Cryptostylis acutata</i> J.J.Sm.	✓					
<i>Eria pseudocymbiformis</i> J.J.Wood	✓					
<i>Dendrochilum minimiflorum</i> Carr	✓					
<i>Epigeneium radicosum</i> (Ridl.) Summerh.	✓					
<i>Malaxis multiflora</i> Ames & C.Schweinf.	✓					
<i>Malaxis graciliscapa</i> Ames & C.Schweinf.	✓					
<i>Malaxis variabilis</i> Ames & C.Schweinf.	✓					
<i>Bulbophyllum minutulum</i> Ridl. ex Burkill & Holttum	✓					
<i>Eria jenseniana</i> J.J.Sm.	✓					
<i>Bulbophyllum nubinatum</i> J.J.Verm.	✓					
	563	527	13	31	5	7

*Sources: (BRAHMS: Singapore Herbarium, 2024)¹; (Chung, 2006)²; (Naturalis Bioportal, 2024)³; (Wood & Cribb, 1994)⁴; (van der Ent & Wood, 2013)⁵; (Wood et al., 2011a)⁷; (GBIF.org, 2017)⁸; (Wood et al., 2011b)¹¹; (Natural History Museum, 2025)¹²; (Harvard University Herbaria & Libraries, 2025)¹³; (Royal Botanic Gardens, Kew, 2025)¹⁴; (JACQ - Virtual Herbaria, 2020)¹⁵; (Juiling et al., 2020)¹⁶; (Wood et al, 1993)¹⁷