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Review Article

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

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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 m^2 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

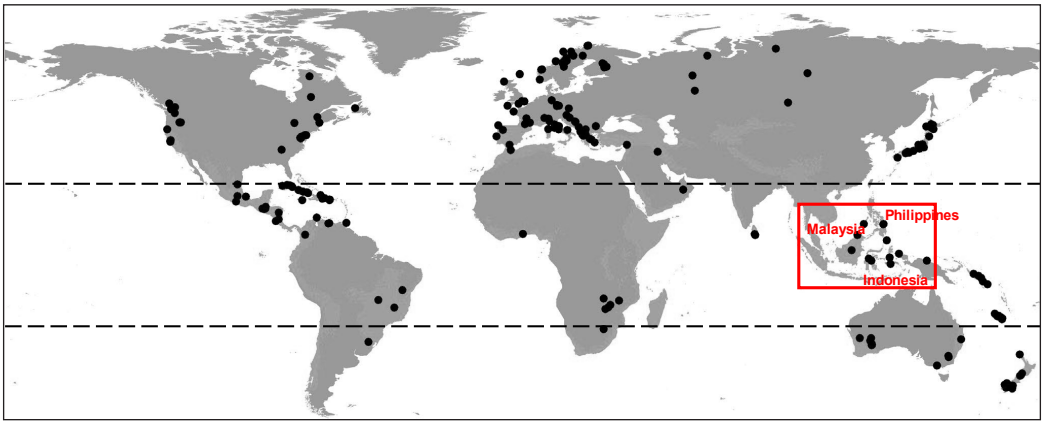

Figure 1. The distribution of ultramafic rocks worldwide. Black dotted - ultramafic formations are found on every continent; Red box - Southeast Asian countries where ultramafic rocks are distributed; Dashed lines - the Tropic of Cancer and Capricorn

Source: Modified from Hulshof and Spasojevic (2020)

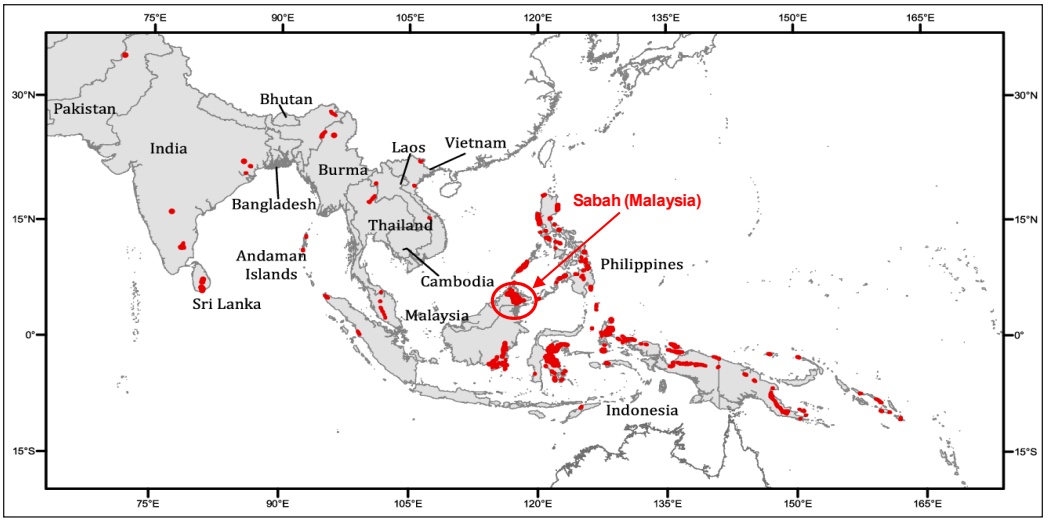

Figure 2. A close-up map of South and Southeast Asia displays the ultramafic outcrop spread throughout the area. Red circle - ultramafic outcrop spread throughout Sabah, Malaysia

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 km^2, 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 km^2 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 (km2)	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 km² (<1.5% of 423,970 km²)	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

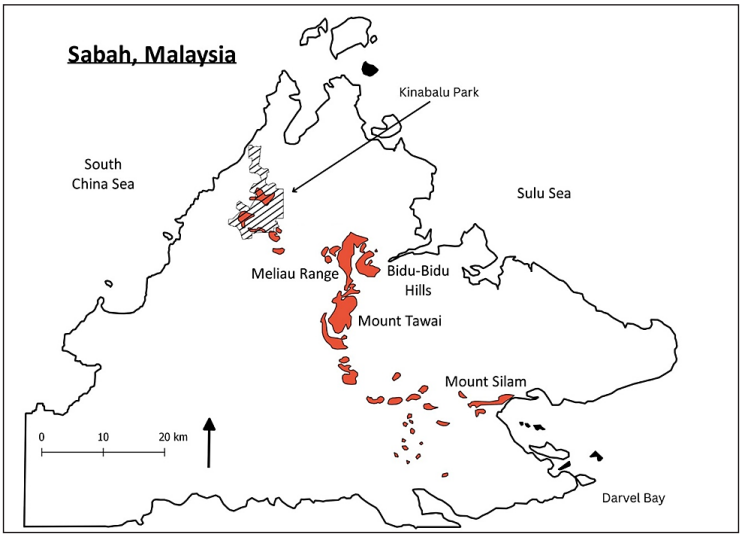

Figure 3. Igneous Rocks of Sabah, Malaysia. The line pattern fill - Kinabalu Park is situated
Source: Modified from van der Ent et al. (2011)

taxonomically unique orchid; *Bulbophyllum longhutense* J.J.Sm., endemic to Borneo and restricted to montane forests; and *Ascideria 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 Bambangan. 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 km^2

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 km^2) and Panataran Valley (30 km^2) (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, Bambangan, 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.

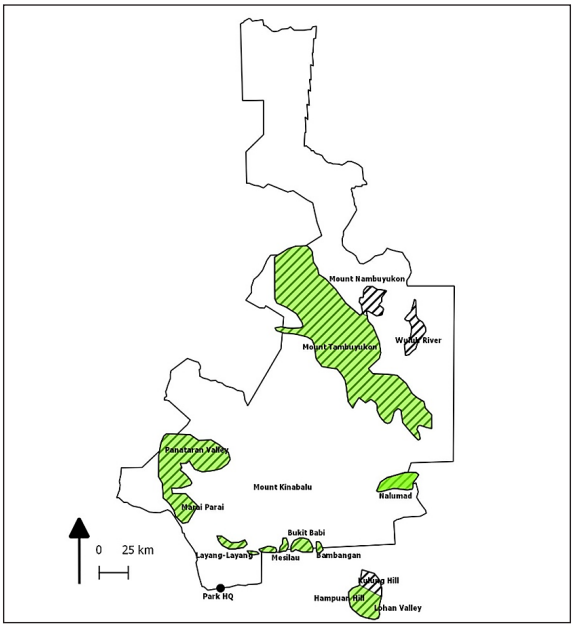

Figure 4. An overview of the major ultramafic outcrops in Kinabalu Park. The line pattern fill - regions indicate areas with ultramafic soils. These green-shaded areas represent locations where detailed records of orchid species have been found

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]	Nalumad[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]
Appendicula congesta Ridl.	✓		✓							
Appendicula linearifolia Ames & C.Schweinf.			✓							
Appendicula longirostrata Ames & C.Schweinf.			✓							
Appendicula magnibracteata Ames & C.Schwein.			✓							
Appendicula fractiflexa J.J.Wood							✓			
Appendicula foliosa Ridl. & Schltr.							✓			
Appendicula lucida Ridl.										✓
Appendicula divaricata Ames & C.Schweinf.									✓	✓
Appendicula floribunda (Schltr.) Schltr.										✓
Appendicula pendula Blume		✓	✓		✓					
Appendicula reflexa Blume									✓	
Appendicula torta Blume					✓				✓	
Appendicula undulata Blume						✓				
Arachnis breviscapa (J.J.Sm.) J.J.Sm.										✓
Arachnis flos-aeris (L.) Rchb.f.						✓				
Arachnis longisepala (J.J.Wood) Shim & A.Lamb	✓								✓	✓
Arachnis calcarata Holttum			✓							✓
Arundina graminifolia (D.Don) Hochr.			✓			✓			✓	
Appendicula tembuyukenensis J.J.Wood	✓									
Appendicula anceps Blume			✓							
Ascidieria grandis (Ridl.) J.J.Wood						✓	✓			
Ascidieria cymbidiifolia (Ridl.) W.Suarez & Cootes			✓				✓			
Ascidieria maculiflora J.J.Wood	✓									
Ascidieria cymbidiifolia var. *pandanifolia* J.J.Wood	✓									
Ascidieria longifolia (Hook.f.) Seidenf.	✓									
Anoectochilus geniculatus Ridl.	✓									
Agrostophyllum globigerum Ames & C.Schweinf.			✓							
Agrostophyllum majus Hook.f.			✓							
Apostasia nuda R.Br.			✓							
Apostasia wallichii R.Br.	✓								✓	
Aeridostachya robusta (Blume) F.G.Brieger	✓		✓							
Adenoncos parviflora Ridl.										✓
Adenoncos borneensis Schltr.										✓

Table 2 (*continued*)

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]	Nalumad[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]
Bromheadia longifolia Kruiz. & de Vogel			✓							
Bromheadia lohaniensis Kruiz. & de Vogel										✓
Bromheadia divaricata Ames & C.Schweinf.			✓							
Bulbophyllum apheles J.J.Verm.							✓			
Bulbophyllum gibbsiae Rolfe			✓							
Bulbophyllum mandibulare Rchb. f.										✓
Bulbophyllum gamosepalum (Griff.) J.J.Sm.							✓			
Bulbophyllum gibbosum (Blume) Lindl.							✓			
Bulbophyllum microglossum Ridley							✓			
Bulbophyllum apodum Hook.f.			✓			✓				
Bulbophyllum biflorum Teijsm. & Binn.										✓
Bulbophyllum breviflorum Ridl.							✓			
Bulbophyllum chanii J.J.Verm. & A.Lamb						✓				
Bulbophyllum coriaceum Ridl.			✓					✓		
Bulbophyllum dracunculus J.J.Verm.			✓							
Bulbophyllum dryas Ridl.		✓								
Bulbophyllum lambii J.J.Verm.							✓			
Bulbophyllum praetervisum J.J.Verm.										✓
Bulbophyllum sigmoideum Ames & C.Schweinf.							✓			
Bulbophyllum tortuosum (Blume) Lindl.									✓	
Bulbophyllum trifolium Ridl.									✓	
Bulbophyllum vaginatum (Lindl.) Rchb.f.						✓				
Bulbophyllum planibulbe Ridl.									✓	✓
Bulbophyllum depressum King & Pantl.							✓			✓
Bulbophyllum flavescens (Blume) Lindl.			✓		✓		✓			
Bulbophyllum vinaceum Ames & C.Schweinf.			✓							
Bulbophyllum anguliferum Ames & C.Schweinf.							✓			
Bulbophyllum aeolium Ridl.							✓			
Bulbophyllum caudatisepalum Ames & C.Schweinf.					✓		✓			
Bulbophyllum flammuliferum Ridl.									✓	
Bulbophyllum lobbii subsp. *lobbii*					✓		✓			✓
Bulbophyllum lobbii subsp. *boreoborneense* Mangal, F.Velazquez & J.J.Verm.							✓			
Bulbophyllum nubinatum J.J.Verm.	✓		✓							

Table 2 (*continued*)

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]	Nalumad[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]
Bulbophyllum coniferum Ridl.	✓				✓					
Bulbophyllum disjunctum Ames & C.Schweinf.	✓		✓				✓			
Bulbophyllum deltoideum Ames & C.Schweinf.			✓				✓			
Bulbophyllum latisepalum Ridl. & C.Schweinf.							✓			
Bulbophyllum turgidum J.J.Verm.							✓			
Bulbophyllum retrorsum J.J.Verm. & A.Lamb							✓			
Bulbophyllum membranifolium Hook.f.			✓							
Bulbophyllum montense Ridl.			✓				✓			
Dendrochilum exasperatum Ridl.			✓							
Dendrochilum lancilabium Ridl.			✓							
Dendrochilum alatum Ridl.			✓							
Dendrochilum haslamii Ridl.							✓			
Dendrochilum joclemensii Ridl.			✓							
Bulbophyllum hyalosemoides J.J.Verm. & P.O'Byrne	✓						✓			
Bulbophyllum obtusum (Blume) Lindl.							✓			
Bulbophyllum unguiculatum Rchb.f.			✓				✓			
Bulbophyllum mutabile (Blume) Lindl.			✓							
Bulbophyllum pocillum J.J.Verm.			✓							
Coelogyne latiloba de Vogel			✓							
Coelogyne chanii Gravend. & de Vogel						✓				
Coelogyne craticulilabris Carr					✓					
Coelogyne pandurata Lindl.									✓	✓
Coelogyne planiscapa var. *planiscapa*			✓		✓					
Coelogyne septemcostata J.J.Sm.		✓								
Cleisocentron abasii Cavestro			✓							
Calanthe lyroglossa Rchb.f.			✓							
Calanthe woodii P.J.Cribb								✓		
Calanthe otuhanica C.L.Chan & T.J.Barkman	✓									
Calanthe musa-amanii J.J.Wood			✓							
Calanthe kinabaluensis Rolfe					✓					
Calanthe triplicata (Willemet) Ames					✓	✓	✓			
Calanthe vestita Wall. *ex* Lindl.									✓	
Calanthe lambii P.J.Cribb			✓				✓			
Callostylis pulchella (Lindl.) S.C.Chen & Z.H.Tsi						✓				

Table 2 (*continued*)

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]	Nalumad[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]
Campanulorchis leiophylla (Lindl.) Y.P.Ng & P.J.Cribb			✓							
Ceratostylis longisegmenta Ames & C.Schweinf.							✓			
Ceratostylis pendula Hook.f.										✓
Ceratostylis ampullacea Kraenzl.	✓									
Cleisocentron merrillianum (Ridl.) Christenson	✓		✓							
Ceratostylis crassilingua Ames & C.Schweinf.			✓							
Chelonistele amplissima (Ames & C.Schweinf.) Carr							✓			✓
Chelonistele kinabaluensis (Rolfe) de Vogel							✓			
Chamaeanthus brachystachys Schltr.	✓								✓	
Chroniochilus minimus (Blume) J.J.Sm.	✓								✓	
Coelogyne radioferens Ames & C.Schweinf.				✓	✓		✓			
Coelogyne genuflexa Ames & C.Schweinf.			✓							
Coelogyne clemensii Ames & C.Schweinf.			✓				✓			
Coelogyne compressicaulis Ames & C.Schweinf.			✓							
Coelogyne kinabaluensis Ames & C.Schweinf.			✓		✓					✓
Coelogyne tenompokensis Carr							✓			
Coelogyne monilirachis Carr							✓			
Coelogyne swaniana Rolfe							✓			✓
Coelogyne exalata Ridl.							✓			
Coelogyne cuprea H.Wendl. & Kraenzl. var. *cuprea*	✓						✓			
Coelogyne cuprea var. *planiscapa* J.J.Wood & C.L.Chan	✓									
Coelogyne papillosa Ridl.	✓		✓				✓			
Coelogyne plicatissima Ames & C.Schweinf.	✓		✓		✓			✓		
Coelogyne hirtella J.J.Sm.			✓		✓		✓			
Coelogyne rupicola Carr			✓				✓			
Chroniochilus virescens (Ridl.) Holttum	✓									
Cystorchis aphylla Ridl.			✓						✓	
Cymbidium angustifolium Ames & C.Schweinf.			✓							
Cymbidium elongatum J.J.Wood, Du Puy & Shim	✓	✓	✓							
Cymbidium ensifolium (L.) Sw.							✓		✓	
Cymbidium sigmoideum J.J.Sm.	✓									
Cryptostylis acutata J.J.Sm.	✓		✓						✓	
Corybas pictus (Blume) Rchb.f.	✓		✓							
Cylindrolobus linearifolius (Merr.) J.J.Wood					✓					✓

Table 2 (*continued*)

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]	Nalumad[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]
Cylindrolobus nutans (Lindl.) J.J.Wood		✓								
Cylindrolobus jensenianus (J.J.Sm.) Rauschert	✓									
Cleisocentron merrillianum (Ames) Christenson			✓							
Cleisostoma discolor Lindl.									✓	✓
Cleisostoma striatum (Rchb.f.) N.E.Br.						✓			✓	
Cleisostoma koeteiense (Schltr.) Garay										✓
Cleisocentron abasii Cavestro	✓		✓							
Crepidium metallicum (Rchb.f.) Szlach.	✓								✓	✓
Crepidium lowii (E.Morren) Szlach.									✓	✓
Crepidium mieczyslawii Marg. & Szlach.			✓							
Crepidium kinabaluense (Rolfe) Szlach.			✓				✓			
Dimorphorchis lowii (Lindl.) Rolfe	✓									
Dimorphorchis rossii Fowlie										✓
Dendrobium aloifolium (Blume) Rchb.f.										✓
Dendrobium longirepens Ames & C. Schweinfurth			✓							
Dendrochilum alatum Ames			✓							
Dendrobium anosmum Lindl.										✓
Dendrobium beamanianum J.J.Wood & A.Lamb			✓							
Dendrobium compressum Lindl.						✓				✓
Dendrobium gracile (Blume) Lindl.			✓				✓			
Dendrobium leonis (Lindl.) Rchb.f.									✓	✓
Dendrobium macrophyllum A.Rich.									✓	
Dendrobium pachyphyllum (Kuntze) Bakh.f.									✓	✓
Dendrobium panduriferum Hook.f.										✓
Dendrobium xanthoacron Schltr.							✓			
Dendrobium acuiferum Ormerod								✓		
Dipodium pictum (Lindl.) Rchb.f.				✓						
Dendrobium tetrachromum Rchb.f.			✓							
Dendrobium lambii J.J.Wood			✓							
Dendrobium daimandaui J.J.Wood						✓				
Dendrobium hirsutifolium J.J.Wood										✓
Dendrobium serena-alexianum J.J.Wood & A.Lamb	✓									
Dendrobium angustipetalum J.J.Sm.			✓							
Dendrobium alabense J.J.Wood			✓				✓			

Table 2 (*continued*)

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]	Nalumad[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]
Dendrobium prostratum Ridl.									✓	✓
Dendrobium hirsutifolium J.J.Wood										✓
Dendrobium kiauense Ames & C.Schweinf.									✓	
Dendrobium patentilobum Ames & C.Schweinf.	✓		✓							✓
Dendrobium parthenium Rchb.f.			✓						✓	✓
Dendrobium olivaceum J.J.Sm.	✓									
Dendrobium cymbulipes J.J.Sm.	✓		✓		✓		✓			
Dendrobium minimum Ames & C.Schweinf.			✓							
Dendrobium spectatissimum Rchb.f.	✓									
Dendrobium kinabaluense Ridl.	✓									
Dendrobium tridentatum Ames & C.Schweinf.	✓		✓					✓		
Dendrochilum kinabuluense Rolfe			✓							
Dendrochilum simplex J.J.Sm.			✓							
Dendrochilum longifolium Rchb.f.			✓							✓
Dendrochilum anomalum Carr									✓	
Dendrochilum dewindtianum W.W.Sm.			✓					✓		
Dendrochilum imbricatum Ames					✓					
Dendrochilum longirachis Ames			✓							
Dendrochilum planiscapum Carr			✓							
Dendrochilum pterogyne Carr			✓					✓		
Dendrochilum fimbriatum Ridl.			✓							
Dendrochilum angustifolium Ridl.	✓		✓							
Dendrochilum crassilabium J.J.Wood	✓									
Dendrochilum corrugatum (Ridl.) J.J.Sm.			✓							
Dendrochilum cruciforme J.J.Wood var. *cruciforme*	✓									
Dendrochilum gibbsiae Rolfe	✓		✓							
Dendrochilum grandiflorum (Ridl.) J.J.Sm.	✓		✓							
Dendrochilum pallide-flavens Blume var. *pallidiflavens*			✓							
Dendrochilum kamborangense Ridl.	✓						✓			
Dendrochilum stachyodes (Ridl.) J.J.Sm.			✓					✓		
Dendrobium maraiparense J.J.Wood & C.L.Chan			✓							
Dendrochilum transversum Carr			✓							
Dendrobium piranha C.L.Chan & P.J.Cribb	✓		✓							
Dendrobium lancilabium J.J.Sm.	✓									

Table 2 (*continued*)

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]	Nalumad[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]
Dendrobium lohanense J.J.Wood										✓
Dendrobium spurium (Blume) J.J.Sm.									✓	✓
Dendrobium rosellum Ridl.										✓
Dilochia parviflora J.J.Sm.			✓							
Dilochia cantleyi (Hook.f.) Ridl.	✓		✓				✓			
Dilochia wallichii Lindl.							✓			
Dilochia beamanii Ormerod							✓			
Dilochia gracilis (Ames & C.Schweinf.) Carr			✓							
Dendrobium bifarium Lindl. Ex Hook.f.									✓	
Neuwiedia borneensis de Vogel	✓								✓	
Bromheadia brevifolia Ridl.										✓
Bromheadia acerate Ames & C.Schweinf.	✓		✓							
Eria major Stapf		✓								
Eria villosissima Rolfe			✓							
Entomophobia kinabaluensis (Ridl.) de Vogel			✓							
Epigeneium tricallosum (Ames & C.Schweinf.) J.J.Wood							✓			
Epigeneium longirepens (Ames & C.Schweinf.) Seidenf.			✓							
Epigeneium kinabaluense (Ridl.) Summerh.	✓		✓	✓						
Epigeneium suberectum (Ridl.) Summerh.			✓							
Epidendrum longirepens (C.Schweinf.) C.Schweinf.	✓									
Eria javanica (Sw.) Blume			✓							
Eria linearifolia Ridl.										✓
Eria robusta (Blume) Lindl.							✓			✓
Eria oblitterata (Blume) Rchb.f.							✓			
Eria acerate Ames & C.Schweinf.							✓			
Eria aceratedes (Blume) Lindl.							✓			
Eria major Ridl. Ex Stapf							✓			
Eulophia graminea Lindl.										✓
Flickingeria scopa (Lindl.) Brieger										✓
Flickingeria fimbriata (Blume) A.D.Hawkes						✓				✓
Flickingeria xantholeuca (Rchb.f.) A.D.Hawkes						✓				
Gastrodia javanica (Blume) Lindl.						✓				
Geodorum densiflorum (Lam.) Schltr.									✓	
Goodyera bifida (Blume) Blume							✓			

Table 2 (*continued*)

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]	Nalumad[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]
Goodyera condensata Ormerod & J.J.Wood							✓			
Goodyera rubicunda (Blume) Lindl.					✓					
Goodyera rostellata Ames & C.Schweinf.			✓				✓			
Habenaria muricata (Schauer) Rchb.f.						✓				
Hetaeria anomala Lindl.							✓			
Liparis kinabaluensis J.J.Wood										✓
Liparis viridicallus Holttum			✓						✓	
Liparis nervosa (Thunb.) Lindl.			✓							
Liparis elegans Lindl.										✓
Liparis pandurata Ridl.							✓			
Liparis kamborangensis Ames & C.Schweinf.	✓		✓							
Liparis atrosanguinea Ridl.			✓							
Lepidogyne longifolia (Blume) Blume			✓							
Malleola punctata J.J.Wood & A.Lamb									✓	✓
Micropera callosa (Blume) Garay									✓	
Micropera fuscolutea (Lindl.) Garay										✓
Mycaranthes latifolia Blume										✓
Mycaranthes magnicallosa (Ames & C.Schweinf.) J.J.Wood					✓					
Mycaranthes major (Stapf) J.J.Wood	✓		✓							
Neuwiedia borneensis de Vogel									✓	
Neuwiedia veratrifolia Blume									✓	
Neuwiedia zolingeri Rchb.f.									✓	
Nephelaphyllum flabellatum Ames & C.Schweinf.			✓						✓	
Nephelaphyllum pulchrum Blume							✓			
Nabaluia clemensii Ridl.							✓			
Nabaluia angustifolia de Vogel							✓			
Neuwiedia borneensis de Vogel	✓									
Neuwiedia zolingeri var. *javanica* (J.J.Sm.) de Vogel	✓									
Paphiopedilum lowii (Lindl.) Stein							✓			
Paphiopedilum rothschildianum (Rchb.f.) Stein	✓									
Phalaenopsis modesta J.J.Sm.										✓
Paraphalaenopsis labukensis Shim, A.Lamb & C.L.Chan	✓									
Phaius subtrilobus Ames & C.Schweinf.							✓			

Table 2 (*continued*)

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]	Nalumad[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]
Phaius pauciflorus subsp. *Sabahensis* J.J.Wood & A.Lamb	✓									
Renanthera bella J.J.Wood	✓								✓	
Calanthe speciosa (Blume) Lindl.										✓
Calanthe otuhanica C.L.Chan & T.J.Barkman	✓									
Platanthera kinabaluensis Kraenzl. Ex Rolfe	✓		✓							
Thrixspermum kocyanii J.J.Wood & A.Lamb	✓									
Hetaeria hylophiloides (Carr) Ormerod & J.J.Wood	✓									
Liparis viridiflora (Blume) Lindl.					✓					
Liparis lacerata Ridl.	✓									
Liparis tricallosa Rchb.f.	✓		✓							
Malaxis punctata J.J.Wood			✓							
Malaxis subtiliscapa (J.J.Sm.) J.J.Wood			✓							
Malaxis graciliscapa Ames & C.Schweinf.			✓							
Malaxis ophrydis (J.König) Ormerod							✓			
Nervilia plicata (Andrews) Schltr.						✓				
Nervilia borneensis (J.J.Sm.) Schltr.						✓				
Kuhlhasseltia kinabaluensis Ames & C.Schweinf.			✓							
Kuhlhasseltia javanica J.J.Sm.			✓							
Oberonia patentifolia Ames & C.Schweinf.									✓	
Oberonia microphylla (Blume) Lindl.			✓							
Paphiopedilum dayanum (Robert Stone ex J.Dix) Stein			✓							
Paphiopedilum javanicum var. *virens* (Rchb.f.) Stein							✓			
Paphiopedilum hookerae var. *volonteanum* (Sander ex Rolfe) Braem	✓			✓						
Paphiopedilum sugiyamanum Cavestro						✓				
Pomatocalpa kunstleri (Hook.f.) J.J.Sm.						✓				
Peristylus gracilis Blume			✓							
Pholidota kinabaluensis Ames			✓							
Pholidota pectinata Ridl.			✓							
Pholidota clemensii Ridl.			✓				✓			
Pholidota sigmatochilus (Rolfe) J.J.Sm.	✓									
Phreatia densiflora Lindl.							✓			
Phreatia listrophora Ridl.			✓							
Plocoglottis lowii Rchb.f.		✓								

Table 2 (*continued*)

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]	Nalumad[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]
Platanthera Stapf*ii* Kraenzl. Ex Rolfe	✓		✓							
Podochilus sciuroides Rchb.f.										✓
Podochilus tenuis Lindl.							✓			
Podochilus microphyllus Lindl.			✓							
Pteroceras teres (Blume) Holttum										✓
Peristylus hallieri J.J.Sm.			✓							
Poaephyllum podochiloides (Schltr.) Ridl.										✓
Robiquetia merrilliana (Ames) Lückel, M.Wolff & J.J.Wood			✓							
Spiranthes sinensis (Pers.) Ames			✓							
Schoenorchis buddleiflora (Schltr. & J.J.Sm.) J.J.Sm.			✓							
Schoenorchis paniculata Blume									✓	✓
Stichorkis lobongensis (Ames) J.J.Wood					✓				✓	
Stichorkis mucronata (Blume) J.J.Wood									✓	
Stichorkis pandurata (Ames) J.J.Wood					✓		✓			
Spathoglottis affinis de Vriese										✓
Spathoglottis gracilis Rolfe ex Hook.f.	✓		✓		✓					✓
Spathoglottis microchilina Kraenzl.			✓							
Spathoglottis kimballiana Hook.f.			✓							
Spathoglottis kimballiana var. *kimballiana*		✓								
Taeniophyllum rubrum Ridl.									✓	
Thelasis carnosa Ames & C.Schweinf.							✓			
Tainia purpureifolia Carr	✓									
Tainia speciosa Blume	✓									
Thrixspermum pensile Schltr.									✓	
Thrixspermum kocyanii J.J.Wood & A.Lamb	✓									
Thrixspermum triangulare Ames & C.Schweinf.	✓		✓							
Trichotosia brevipedunculata Ames & C.Schweinf.			✓				✓			
*Trichotosia aurea (*Ridl.*)* Carr	✓		✓							
Trichotosia ferox Blume			✓							
Trichoglottis smithii Carr									✓	✓
Trichoglottis maculata (J.J.Sm.) J.J.Sm.									✓	
Tropidia pedunculata Blume									✓	
Vanilla kinabaluensis Carr						✓				
Trichotosia microphylla Blume			✓							

Table 2 (*continued*)

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]	Nalumad[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]
Vanilla pilifera Holttum								✓		
Vanilla havilandii Rolfe						✓				
Zeuxine gracilis (Breda) Blume										✓
Stigmatodactylus maraiparaiensis 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), Bambangan (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, Bambangan, Mesilau), *Dilochia cantleyi* (Hook.f.) Ridl. (Mount Tambuyukon, Marai Parai, Mesilau), and *Epigeneium kinabaluense* (Ridl.) Summerh. (Mount Tambuyukon, Marai Parai, Bukit Babi).

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

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, Bambangan, 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.

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

Table S1 (*continued*)

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

Table S1 (*continued*)

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]
Dendrobium grande Hook.f.	✓				
Dendrobium linguella Rchb.f.	✓				
Dendrobium jiewhoei J.J.Wood & C.L.Chan	✓				
Dendrobium sanguinolentum Lindl.	✓				
Dendrobium cymbulipes J.J.Sm.	✓				
Grammatophyllum speciosum Blume	✓				
Habenaria koordersii J.J.Sm.	✓				
Habenaria setifolia Carr	✓				
Hetaeria hylophiloides (Carr) Ormerod & J.J.Wood	✓				
Hetaeria grandiflora Ridl.	✓				
Hetaeria rhombipetala Ormerod & J.J.Wood	✓				
Hetaeria elata Hook.f.	✓				
Hylophila lanceolata (Blume) Miq.	✓				
Jejewoodia jiewhoei (J.J.Wood & Shim) Szlach.	✓				
Lepidogyne longifolia (Blume) Blume	✓				
Liparis acaulis Schltr.	✓				
Lecanorchis multiflora J.J.Sm.	✓				
Nervilia borneensis (J.J.Sm.) Schltr.	✓				
Odontochilus hydrocephalus (J.J.Sm.) J.J.Wood	✓				
Gastrodia spatulata (Carr) J.J.Wood	✓				
Gastrodia javanica (Blume) Lindl.	✓				
Galeola nudifolia Lour.	✓				
Epigeneium treacherianum (Rchb.f. ex Hook.f.) Summerh.				✓	
Epigeneium treacherianum (Rchb.f. ex Hook.f.) Summerh.				✓	
Epipogium roseum (D.Don) Lindl.	✓				
Eulophia zollingeri (Rchb.f.) J.J.Sm.	✓				
Eulophia graminea Lindl.	✓				
Eria floribunda Lindl.	✓				
Eria augustifolia Ridl.	✓				
Eria borneensis Rolfe	✓				
Malaxis ophrydis (J. König) Ormerod	✓	✓			
Malaxis crepidium Bakh.f	✓				
Malaxis damusica (J.J.Sm.) Ames			✓		
Malaxis commelinifolia (Zoll. & Moritzi) Kuntze			✓		

Table S1 (*continued*)

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]
Chrysoglossum viridiflora Hook.f.	✓				
Chrysoglossum reticulatum Carr	✓				
Ceratostylis subulata Blume	✓				
Ceratostylis radiata J.J.Sm.	✓				
Liparis aurantiorbiculata J.J.Wood & A.Lamb	✓				
Stereosandra javanica Blume	✓				
Porrorhachis galbina (J.J.Sm.) Garay	✓				
Pholidota sigmatochilus J.J.Sm.	✓				
Pennilabium kidmancoxii J.J.Wood	✓				
Paphiopedilum kolopakingii Fowlie	✓				
Paphiopedilum sugiyamanum Cavestro	✓				
Paphiopedilum lowii (Lindl.) Stein	✓				
Peristylus candidus J.J.Sm.	✓				
Pholidota carnea (Blume) Lindl.	✓				
Pinalia latiuscula (Ames & C.Schweinf.) J.J.Wood	✓				
Phaius tankervilleae (Banks) Blume	✓				
Phaius reflexipetalus J.J.Wood & Shim	✓				
Podochilus serpyllifolius (Blume) Lindl.	✓				
Stichorkis lobongensis (Ames) J.J.Wood	✓				
Stichorkis pandurata (Ames) J.J.Wood	✓				
Spathoglottis microchilina Kraenzl.	✓				
Trichotosia aurea (Ridl.) Carr	✓				
Trichotosia brevipedunculata (Ames & C.Schweinf.) J.J.Wood	✓				
Tainia malayana J.J.Sm.	✓				
Tainia scapigera (Hook.f.) J.J.Sm.	✓				
Thrixspermum acuminatissimum (Blume) Rchb.f.	✓				
Tropidia saprophytica J.J.Sm.	✓				
Trichoglottis sitihasmahae J.J.Wood & A.Lamb	✓				
Trichoglottis tenuis Ames & C.Schweinf.	✓				
Dendrolirium ornatum Blume	✓				
Dendrobium spectatissimum Rchb.f.	✓				
Dendrobium sinsuronense J.J.Wood	✓				
Dendrobium alabense J.J.Wood	✓				
Dendrobium singulare Ames & C.Schweinf.	✓				

Table S1 (*continued*)

Species	Ultramafic Areas in Sabah			
	Mount Kinabalu[1,3,4,7,8,11,12,13,14,15,16,17]	Meliau Range[2,7,11]	Mount Tawai[3,4]	Bidu-bidu Hills[2,5,8]	Mount Silam[2,4]
Dendrobium oblongum Ames & C.Schweinf.	✓				
Dendrobium tawaiense J.J.Wood			✓		
Didymoplexiella kinabaluensis (Carr) Seidenf.	✓				
Ania borneensis (Rolfe) Senghas	✓				
Vanda helvola Blume	✓				
Macropodanthus sabahensis J.J.Wood & A.Lamb					
Mycaranthes magnicallosa (Ames & C.Schweinf.) J.J.Wood	✓				
Mycaranthes major (Stapf) J.J.Wood	✓				
Neuwiedia borneensis de Vogel	✓				
Oeceoclades pulchra (Thouars) P.J.Cribb & M.A.Clem.	✓				
Paphiopedilum rothschildianum (Rchb.f.) Stein	✓				
Phaius pauciflorus subsp. sabahensis J.J.Wood & A.Lamb	✓				
Porpax borneensis J.J.Wood & A.Lamb	✓	✓	✓		
Platanthera saprophytica J.J.Sm.	✓				
Renanthera bella J.J.Wood	✓				
*Crepidium metallicum (*Rchb.f.*)* Szlach.	✓		✓		
Dendrobium hamaticalcar J.J.Wood & Dauncey	✓				
Trichotosia mollicaulis (Ames & C.Schweinf.) J.J.Wood	✓				
Vanilla kinabaluensis Carr	✓				
Apostasia nuda R.Br.	✓		✓		
Apostasia odorata Blume	✓				
Coelogyne cuprea var. planiscapa J.J.Wood & C.L.Chan	✓				
Coelogyne monilirachis Carr	✓				
Coelogyne moultonii J.J.Sm.	✓				
Coelogyne exalata Ridl.	✓				
Coelogyne incrassata var. *valida* J.J.Sm.			✓		
Coelogyne verrucosa S.E.C.Sierra			✓		
Phalaenopsis maculata Rchb.f.			✓		
Paraphalaenopsis labukensis Shim, A.Lamb & C.L.Chan	✓	✓			
Platanthera crassinervia (Ames & C.Schweinf.) J.J.Sm.	✓				
Platanthera stapfii Kraenzl. ex Rolfe	✓				
Platanthera kinabaluensis Kraenzl. ex Rolfe	✓				
Dendrochilum planiscapum Carr	✓				
Dendrochilum angustilobum Carr	✓				

Table S1 (*continued*)

Species	Ultramafic Areas in Sabah			
	Mount Kinabalu[1,3,4,7,8,11,12,13,14,15,16,17]	Meliau Range[2,7,11]	Mount Tawai[3,4]	Bidu-bidu Hills[2,5,8]	Mount Silam[2,4]
Dendrochilum stachyodes (Ridl.) J.J.Sm.	✓				
Thecopus secunda (Ridl.) Seidenf.			✓		
Bulbophyllum placochilum J.J.Verm.	✓				
Bulbophyllum tenompokense J.J.Sm.	✓				
Bulbophyllum lambii J.J.Verm.	✓		✓		
Microssacus longicalcaratus Ames & C.Schweinf.	✓				
Bulbophyllum vinaceum Ames & C.Schweinf.	✓				
Bulbophyllum scabrum J.J.Verm. & A.Lamb	✓				
Bulbophyllum sigmoideum Ames & C.Schweinf.	✓				
Bulbophyllum lordoglossum J.J.Verm. & A.Lamb	✓				
Bulbophyllum dulitense Carr	✓				
Bulbophyllum koyanense Carr	✓				
Bulbophyllum gibbsae Rolfe	✓				
Bulbophyllum crassicaydatum Ames & C.Schweinf.	✓				
Bulbophyllum longimucronatum Ames & C.Schweinf.	✓				
Bulbophyllum minutiflorum Ames & C.Schweinf.	✓				
Bulbophyllum botryophorum Ridl.			✓		
Bulbophyllum flammuliferum Ridl.		✓			
Bulbophyllum limbatum Lindl.			✓		
Bulbophyllum sopoetanense Schltr.	✓				
Bulbophyllum lanceolatum Ames & C.Schweinf.	✓				
Bulbophyllum macrochilum Rolfe		✓			
Bulbophyllum deltoideum Ames & C.Schweinf.	✓				
Bulbophyllum reflexum Ames & C.Schweinf.	✓				
Bulbophyllum acuminatum (Ridl.) Ridl.			✓		
Bulbophyllum fascinator (Rolfe) Rolfe	✓				
Peristylus hallieri J.J.Sm.	✓				
Dendrobium pandaneti Ridl.	✓				
Corybas serpentinus J.Dransf.				✓	✓
Corybas crenulatus J.J.Sm.	✓				
Apostasia wallichii R.Br.		✓	✓	✓	✓
Liparis lingulata Ames & C.Schweinf.	✓				
Liparis anopheles J.J.Wood	✓				
Bulbophyllum flavescens (Blume) Lindl.	✓		✓		

Table S1 (*continued*)

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]
Tainia purpureifolia Carr	✓				
Schoenorchis micrantha Blume	✓				
Coelogyne rigidiformis Ames & C.Schweinf.	✓				
Coelogyne genuflexa Ames & C.Schweinf.	✓				
Coelogyne clemensii Ames & C.Schweinf.	✓				
Coelogyne clemensii var. *angustifolia* Carr	✓				
Coelogyne clemensii var. *longiscapa* Ames & C.Schweinf.	✓				
Coelogyne tenompokensis Carr	✓				
Coelogyne obtusifolia Carr	✓				
Coelogyne craticulaelabris Carr	✓				
Coelogyne compressicaulis Ames & C.Schweinf.	✓				
Liparis elegans Lindl.	✓		✓		
Corymborkis veratrifolia (Reinw.) Blume	✓				
Pholidota clemensii Ames	✓				
Dendrochilum grandiflorum J.J.Sm.	✓				
Appendicula fractiflexa J.J.Wood	✓				
Appendicula pseudofractiflexa J.J.Wood			✓		
Appendicula torta Blume	✓				
Bulbophyllum marudiense Carr			✓		
Bulbophyllum coniferum Ridl.	✓				
Lecanorchis multiflora J.J.Sm.	✓				
Dendrobium roseobellum J.J.Wood	✓				
Bulbophyllum antenniferum Rchb.f.	✓				
Dendrochilum gibbsiae Rolfe	✓				
Cyrtosia javanica Blume	✓				
Coelogyne planiscapa var. *grandis* Carr	✓				
Coelogyne planiscapa var. *plicatissima* Ames & C.Schweinf.	✓				
Liparis parviflora (Blume) Lindl.	✓				
Anoectochilus integrilabris Carr	✓				
Coelogyne hirtella J.J.Sm.	✓				
Bulbophyllum coriaceum Ridl. ex Stapf	✓				
Coelogyne longibulbosa Ames & C.Schweinf.	✓				
Oberonia kinabaluensis K.Y.Lang & D.S.Deng	✓				
Cymbidium angustifolium Ames & C.Schweinf.	✓				

Table S1 (*continued*)

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]
Cymbidium dayanum Rchb.f.	✓				
Cymbidium elongatum J.J.Wood, Du Puy & Shim	✓				
Dendrochilum sublobatum Carr	✓				
Cionisaccus procerus (Ker Gawl.) M.A.Clem. & D.L.Jones	✓				
Eria macrophylla Ames & C.Schweinf.					
Eria carnosissima Ames & C.Schweinf.	✓				
Eria magnicallosa Ames & C.Schweinf.	✓				
Eria villosissima Rolfe	✓				
Eria pseudoleiophylla J.J.Wood	✓				
Eria pseudocymbiformis var. *hirsuta* J.J.Wood	✓				
Dendrochilum scriptum Carr	✓				
Appendicula cornuta Blume			✓		
Appendicula congesta Ridl. ex Stapf	✓				
Thrixspermum centipeda Lour.	✓				
Dilochia cantleyi (Hook.f.) Ridl.	✓				
Appendicula anceps Blume	✓				
Peristylus goodyeroides (D.Don) Lindl.	✓				
Liparis viridiflora (Blume) Lindl.	✓				
Trichotosia microphylla Blume	✓				
Chelonistele sulphurea var. *sulphurea* (Blume) Pfitzer	✓				✓
Neoclemensia spathulata Carr	✓				
Nephelaphyllum flabellatum Ames & C.Schweinf.	✓				
Nephelaphyllum pulchrum Blume	✓				
Dendrochilum dewindtianum var. *dewindtianum* W.W.Sm.	✓				
Podochilus tenuis (Blume) Lindl.	✓				
Podochilus lucescens Blume	✓		✓		
Trichotosia aporina (Hook.f.) Kraenzl.	✓				
Eria grandis Ridl. ex Stapf	✓				
Appendicula foliosa Ames & C.Schweinf.	✓				
Thrixspermum tanuis Ames & C.Schweinf.					
Thrixspermum crescentiforme Ames & C.Schweinf.	✓		✓		
Pantlingia lamrii J.J.Wood & C.L.Chan	✓				
Paphiopedilum hookerae var. *volonteanum (*Sander ex Rolfe*)* Braem	✓	✓			

Table S1 (*continued*)

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]
Paphiopedilum dayanum (Rchb.f.) Pfitzer	✓				
Entomophobia kinabaluensis (Ames) de Vogel	✓				
Eria obliqua (Lindl.) Lindl.	✓				
*Bulbophyllum membranifolium sub*sp. *membranifolium*	✓				
Dendrobium microglaphys Rchb.f.			✓		
Dendrobium sculptum Rchb.f.	✓				
Coelogyne radioferens Ames & C.Schweinf.	✓				
Taeniophyllum culiciferum Ridl.	✓				
Eria major Ridl. ex Stapf	✓				
Dendrobium concinnum Miq.	✓				
Bulbophyllum lobbii Lindl.	✓				
Trichoglottis magnicallosa Ames & C.Schweinf.	✓				
Dendrochilum crassum Ridl.	✓				
Eria robusta (Blume) Lindl.	✓				
Dimorphorchis rossii Fowlie		✓			
Dimorphorchis lowii (Benth. & Hook.f.) Rolfe	✓				
Microsaccus longicalcaratus Ames & C.Schweinf.	✓				
Dendrobium crumenatum Sw.	✓				
Cymbidium chloranthum Lindl.	✓				
Dendrochilum hologyne Carr	✓				
Octarrhena condensata (Ridl.) Holttum	✓				
Thelasis macrobulbon Ridl.	✓				
Eulophia spectabilis (Dennst.) Suresh	✓				
Spathoglottis kimballiana Hook.f.		✓		✓	
Spathoglottis plicata Blume	✓				
Bulbophyllum comberi J.J.Verm.	✓				
Phaius subtrilobus Ames & C.Schweinf.	✓				
Phaius tankervilleae (Banks ex L'Hér.) Blume	✓				
Dendrobium tridentatum Ames & C.Schweinf.	✓				
Bulbophyllum cornutum (Lindl.) Rchb.f.	✓				
Kuhlhasseltia kinabaluensis Ames & C.Schweinf.	✓				
*Acriopsis liliiflora (*J. Koenig) Ormerod	✓				
Malaxis kinabaluensis (Rolfe) Ames & C.Schweinf.	✓				
Dendrochilum subintegrum Ames	✓				

Table S1 (*continued*)

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

Table S1 (*continued*)

Species	Ultramafic Areas in Sabah			
	Mount Kinabalu[1,3,4,7,8,11,12,13,14,15,16,17]	Meliau Range[2,7,11]	Mount Tawai[3,4]	Bidu-bidu Hills[2,5,8]	Mount Silam[2,4]
Eria monophylla Schltr.	✓				
Thrixspermum amplexicaule (Blume) Rchb.f.	✓				
Dendrochilum pterogyne Carr	✓				
*Nervilia punctata (*Blume*)* Makino	✓				
Bromheadia divaricata Ames & C.Schweinf.	✓				
Bromheadia borneensis J.J.Sm. var. *borneensis*			✓		
Bromheadia brevifolia Ridl.	✓				
Peristylus gracilis Blume	✓				
Bulbophyllum obtusum (Blume) Lindl.	✓				
Spathoglottis aurea Lindl.	✓				
Phreatia densiflora (Blume) Lindl.	✓				
Coelogyne rupicola Carr	✓				
Dendrochilum transversum Carr	✓				
Paphiopedilum javanicum Pfitzer	✓				
*Eria ornata (*Blume*)* Lindl.	✓				
Bulbophyllum eximium Ames & C.Schweinf.	✓				
Bulbophyllum pergracile Ames & C.Schweinf.	✓				
Bulbophyllum cuneifolium Ames & C.Schweinf.	✓				
Bulbophyllum caudatisepalum Ames & C.Schweinf.	✓				
Dendrobium orbiculare J.J.Sm.	✓				
Goodyera rostellata Ames & C.Schweinf.	✓				
Habenaria setifolia Carr	✓				
Habenaria damaiensis J.J.Sm.	✓				
Trichoglottis collenetteae J.J.Wood, C.L.Chan & A.Lamb	✓				
Macodes limii J.J.Wood & A.Lamb		✓			
*Macodes petola (*Blume*)* Lindl.	✓				
Dendrochilum conopseum Ridl. ex Stapf	✓				
Nabaluia angustifolia de Vogel	✓				
Appendicula recondita J.J.Sm.	✓				
Flickingeria dura (J.J.Sm.) A.D.Hawkes	✓				
Trichoglottis kinabaluensis Rolfe	✓				
Ceratostylis ampullacea Kraenzl.	✓				
Coelogyne naja J.J.Sm.	✓				
Erythrodes latifolia Blume	✓				

Table S1 (*continued*)

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]
Microsaccus longicakaratus Ames & C.Schweinf.	✓				
Appendicula linearifolia Ames & C.Schweinf.	✓				
Vanda gibbsiae Rolfe	✓				
Chelonistele sulphurea var. *crassifolia (*Blume*)* Pfitzer	✓				✓
Arachnis longisepala (J.J.Wood) Shim & A.Lamb	✓	✓			
Arachnis flosaeris var. *gracilis* (L.) Rchb.f.	✓				
Agrostophyllum globigerum Ames & C.Schweinf.	✓				
Agrostophyllum saccatum Ridl.			✓		
Agrostophyllum stipulatum (Griff.) Schltr.			✓		
Agrostophyllum glumaceum Hook.f.			✓		
Agrostophyllum bicuspidatum J.J.Sm.	✓				
Bulbophyllum dryas Ridl.	✓				
Thrixspermum pensile Schltr.	✓				
Chelonistele amplissima (Ames & C.Schweinf.) Carr	✓				
Dendrobium lamelluliferum J.J.Sm.	✓				
Anoectochilus monicae J.J.Wood	✓				
Goodyera rubicunda (Blume) Lindl.	✓				
Bulbophyllum hemiprionotum J.J.Verm. & A.Lamb	✓				
Bulbophyllum heldiorum J.J.Verm.	✓				
Oberonia triangularis Ames & C.Schweinf.	✓				
Oberonia patentifolia Ames & C.Schweinf.	✓				
Oberonia affinis Ames & C.Schweinf.	✓				
Bulbophyllum dracunculus J.J.Verm.	✓				
Flickingeria bicarinata (Ames & C.Schweinf.) A.D.Hawkes	✓				
Calanthe ovalifolia Ridl.	✓				
Calanthe tenuis Ames & C.Schweinf.	✓				
Calanthe cuneata Ames & C.Schweinf.	✓				
Calanthe kinabaluensis Rolfe.	✓				
Calanthe pulchra (Blume) Lindl.	✓				
Calanthe gibbsiae Rolfe	✓				
Bulbophyllum apodum Hook.f.	✓				
Nabaluia clemensii Ames	✓				
Dendrobium bifarium Lindl.	✓				
Appendicula pendula Blume	✓				

Table S1 (*continued*)

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]
Peristylus grandis Blume	✓				
Bulbophyllum alatum J.J.Verm.	✓				
Cleisostoma inflatum (Rolfe) Garay	✓				
Cleisostoma striatum (Rchb.f.) Garay	✓				
Taeniophyllum obtusum Blume	✓				
Spathoglottis gracilis Rolfe ex Hook.f.	✓	✓			
Coelogyne rochussenii de Vriese	✓				
Liparis grandis Ames & C.Schweinf.	✓				
Thrixspermum pardale (Ridl.) Schltr.	✓				
Neuwiedia zolingeri var. *javanica* (J.J.Sm.) de Vogel		✓			
Neuwiedia veratrifolia Blume	✓				
Phalaenopsis amabilis (L.) Blume	✓				
Bulbophyllum rhizomatosum Ames & C.Schweinf.	✓				
Bulbophyllum pugilanthum J.J.Wood	✓				
Liparis caespitosa (Thouars) Lindl.	✓				
Eria hyacinthoides (Blume) Lindl.	✓				
Phreatia monticola Schltr.	✓				
Eria leiophylla Lindl.	✓				
Eria nutans Lindl.	✓				
Eria kinabaluensis Rolfe	✓				
Coelogyne rhabdobulbon Schltr.	✓				
Bulbophyllum mandibulare Rchb.f.	✓				
Geodorum densiflorum (Lam.) Schltr.	✓				
Dendrobium maraiparense Wood & C.L.Chan	✓				
Bulbophyllum anguliferum Ames & C.Schweinf.	✓				
Bulbophyllum latisepalum Ames & C.Schweinf.	✓				
Trichotosia ferox Blume	✓				
Bulbophyllum purpurascens Teijsm. & Binn.	✓				
Dendrochilum lancilabium Ames	✓				
Aphyllorchis pallida Blume	✓				
Taeniophyllum stella Carr	✓				
Gastrodia grandilabris Carr	✓				
Bulbophyllum kestron J.J.Verm. & A.Lamb	✓				
Liparis lobongensis Ames	✓				

Table S1 (*continued*)

Species	Ultramafic Areas in Sabah			
	Mount Kinabalu[1,3,4,7,8,11,12,13,14,15,16,17]	Meliau Range[2,7,11]	Mount Tawai[3,4]	Bidu-bidu Hills[2,5,8]	Mount Silam[2,4]
Appendicula divaricata Ames & C.Schweinf.	✓				
Dendrobium kurashigei T. Yukawa	✓				
Dendrochilum alatum Ames	✓				
Ceratostylis longisegmenta Ames & C.Schweinf.					
Ceratostylis crassilingua Ames & C.Schweinf.	✓				
Pholidota gibbosa (Blume) de Vriese	✓				
Coelogyne kinabaluensis Ames & C.Schweinf.	✓				
Coelogyne radioferens Ames & C.Schweinf.	✓				
Taeniophyllum rubrum Ridl.	✓				
Thelasis carnosa Ames & C.Schweinf.	✓				
Robiquetia transversisaccata (Ames & C.Schweinf.) J.J.Wood	✓				
Dendrochilum pallideflavens Blume	✓				
Dendrobium patentilobum Ames & C.Schweinf.	✓				
Dendrochilum tenompokense Carr	✓				
Oberonia rubra Ridl.	✓				
Coelogyne subintegra J.J.Sm.					✓
Tainia paucifolia (Breda) J.J.Sm.	✓				
*Dilochia rigida (*Ridl.*)* J.J.Wood	✓				
Schoenorchis juncifolia Reinw.	✓				
Coelogyne tenompokensis Carr	✓				
Cryptostylis clemensii J.J.Sm.	✓				
Didymoplexis kinabaluensis Carr	✓				
Phreatia plantaginifolia (K.D.Koenig) Ormerod	✓				
Dendrobium villosulum Lindl.	✓				
Peristylus ciliatus Carr	✓				
Appendicula maggnibracteata Ames & C.Schweinf.	✓				
Appendicula longirostrata Ames & C.Schweinf.	✓				
Flickingeria fimbriata (Blume) A.D.Hawkes	✓				
Corybas kinabaluensis Carr	✓				
Eria saccifera Hook.f.	✓		✓		
Bulbophyllum catenarium Ridl.	✓				
Bulbophyllum apheles J.J.Verm.	✓				
Spiranthes sinensis (Pers.) Ames	✓				
Flickingeria pseudoconvexa (Ames) A.D.Hawkes	✓				

Table S1 (*continued*)

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]
Goodyera ustulata Carr	✓				
Cleisocentron merrillianum (Ames) Christenson	✓				
Dendrochilum joclemensii Ames	✓				
Coelogyne papillosa Ridl.	✓				
Thelasis pygmaea (Griff.) Blume	✓				
Nephelaphyllum verruculosum Carr	✓				
Coelogyne pulverula Teijsm. & Binn.	✓				
Phreatia sulcata (Blume) J.J.Sm.	✓				
Dendrochilum acuiferum Carr	✓				
Bulbophyllum montense Ridl. ex Stapf	✓				
Bromheadia finlaysoniana (Lindl.) Miq.	✓		✓		
Bulbophyllum lissoglossum J.J.Verm.	✓				
Thecostele alata (Roxb.) C.S.P.Parish & Rchb.f.	✓				
Bulbophyllum scheffleri Schltr.	✓				
Myrmechis kinabaluensis Carr	✓				
Dendrochilum dewindtianum W.W.Sm.	✓				
Dendrochilum pallideflavens var. *pallidiflavens* Blume	✓				
Calanthe speciosa (Blume) Lindl.	✓				
Dendrochilum lacteum Carr	✓				
Bulbophyllum membranaceum Teijsm. & Binn.	✓				
Cryptostylis arachnites (Blume) Hassk.	✓				
Chelonistele kinabaluensis (Rolfe) de Vogel	✓				
Octarrhena parvula Thwaites	✓				
Coelogyne plicatissima Ames & C.Schweinf.	✓		✓		
Bromheadia truncata Seidenf.	✓				
Bulbophyllum ceratostylis J.J.Sm.	✓				
Liparis viridicallus Holttum	✓				
Dendrobium ventripes Carr	✓				
Bulbophyllum salaccense Rchb.f.	✓				
Eria pseudocymbiformis var. *hirsuta* J.J.Wood	✓				
Aerides odorata Lour.	✓				
Pholidota carnea var. *carnea* (Blume) Lindl.	✓				
Appendicula minutiflora Ames & C.Schweinf.	✓				
Pteroceras spathibrachiatum (J.J.Sm.) Garay	✓				

Table S1 (*continued*)

Species	Ultramafic Areas in Sabah			
	Mount Kinabalu[1,3,4,7,8,11,12,13,14,15,16,17]	Meliau Range[2,7,11]	Mount Tawai[3,4]	Bidu-bidu Hills[2,5,8]	Mount Silam[2,4]
Eria cymbidifolia Ridl.	✓				
Bulbophyllum disjunctum Ames & C.Schweinf.	✓				
Oberonia equitans (Thouars) Schltr.	✓				
Mischobulbum scapigerum (Hook.f.) Schltr.	✓				
Dendrochilum imbricatum Ames	✓				
Eria farinosa K.Y.Lang & D.S.Deng	✓				
Pholidota pectinata Ames	✓				
Peristylus brevicalcar Carr	✓				
Zeuxine strateumatica (L.) Schltr.	✓				
Dendrochilum angustipetalum Ames	✓				
Taeniophyllum esetiferum J.J.Sm.	✓				
Calanthe triplicata (Willemet) Ames	✓				
Goodyera kinabaluensis Rolfe	✓				
Malleola kinabaluensis Ames & C.Schweinf.	✓				
Arundina graminifolia (D.Don) Hochr.	✓				
Liparis latifolia (Blume) Lindl.	✓				
Zeuxine benguetensis (Ames) Ames	✓				
Bulbophyllum hyalosemoides J.J.Verm. & P.O'Byrne	✓				
Bulbophyllum lobbii subsp. *borneoborneense*	✓				
Eria latiuscula Ames & C.Schweinf.	✓				
Bulbophyllum mahakamense J.J.Sm.	✓				
Bulbophyllum trifolium Ridl.	✓				
Liparis atrosanguinea Ridl.	✓				
Peristylus kinabaluensis Carr	✓				
Platanthera gibbsiae Rolfe	✓				
Platanthera crassinervia, (Ames & C.Schweinf.) J.J.Sm.	✓				
Platanthera borneensis (Ridl.) J.J.Wood	✓				
Platanthera angustata (Blume) Lindl.	✓				
Bromheadia ensifolia J.J.Sm.	✓				
Aphyllorchis borneensis Schltr.	✓				
Phaius baconii J.J.Wood & Shim	✓				
Appendicula kinabaluensis J.J.Sm.	✓				
Pteroceras biserratum (Ridl.) Holttum	✓				
Dendrobium minimum Ames & C.Schweinf.	✓				

Table S1 (*continued*)

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]
Bulbophyllum muscohaerens J.J.Verm. & A.Lamb	✓				
Dendrobium salaccense (Blume) Lindl.	✓				
Dendrobium singkawangense J.J.Sm.	✓				
Dendrochilum exasperatum Ames	✓				
Eria cepifolia Ridl.	✓				
Dendrobium cymbulipes J.J.Sm.	✓				
Acriopsis javanica Reinw. ex Blume var. *javanica*			✓		
Acriopsis indica Wight	✓				
Eria oblitterata (Blume) Rchb.f.	✓				
Malaxis punctata J.J.Wood	✓				
Malaxis subtiliscapa (J.J.Sm.) J.J.Wood	✓				
Dendrochilum corrugatum J.J.Sm.	✓				
Bulbophyllum pocillum J.J.Verm.	✓				
Liparis condylobulbon Rchb.f.	✓				
Cryptostylis acutata J.J.Sm.	✓				
Eria pseudocymbiformis J.J.Wood	✓				
Dendrochilum minimiflorum Carr	✓				
Epigeneium radicosum (Ridl.) Summerh.	✓				
Malaxis multiflora Ames & C.Schweinf.	✓				
Malaxis graciliscapa Ames & C.Schweinf.	✓				
Malaxis variabilis Ames & C.Schweinf.	✓				
Bulbophyllum minutulum Ridl. ex Burkill & Holttum	✓				
Eria jenseniana J.J.Sm.	✓				
Bulbophyllum nubinatum 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]