

Review Article

The Jewel Orchids of Crocker Range Park, Sabah, Malaysia: A Review

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ABSTRACT

Jewel orchids are usually recognised by their distinctive foliar and can be found in undisturbed habitats, such as Crocker Range Park, Sabah. The pristine habitat in the park provided a suitable condition for jewel orchids to thrive in their habitat. In Malaysia, jewel orchids are appreciated for their ornamental value due to their uniqueness. At the same time, in other countries, it was reported that jewel orchids are used as medicinal plants due to their medicinal properties. Although jewel orchids have been recorded in Sabah, specific studies and species checklists have yet to be made for the Crocker Range Park due to insufficient data. Moreover, the current conservation status of all recorded jewel orchid species in Sabah remains unknown. Therefore, this study comprises a review of information on jewel orchid species in the park, including other general or worldwide diversity, economic importance, conservation status, and action plans. This review used secondary data, including fieldwork collections, checklists, published journals, and available online data. From the review, eight genera and ten species of jewel orchids have been recorded in the park. Three endemic species were found from all recorded species: *Anoectochilus monicae* J. J. Wood, *Goodyera condensata* Ormerod & J. J. Wood, and *Goodyera rostellata* Ames & C. Schweinf. The outcome of this study can be utilised in the upcoming diversity study on jewel orchids in the park while providing the baseline for a management plan for the conservation of jewel orchids in the park.

Keywords: Borneo, checklist, conservation, endemic, Goodyerinae, IUCN, Orchidaceae

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INTRODUCTION

Borneo is notable for its richness of orchid diversity, which includes 2,500–3,000 species, or 10% of all orchid species worldwide and 75% of the Malesian orchid

flora (Lamb, 1991). Crocker Range Park (Figure 1), close to Kinabalu National Park, is renowned for having high biodiversity within its forest ecosystem. Crocker Range Park, situated at the northern edge of Mount Kinabalu, has largely intact vegetation. Crocker Range Park is one of the largest protected areas in East Malaysia, covering around 139,919 ha. The park was denoted as a state park in 1984 to preserve the region’s ecosystem and natural resources. The highest peak of this park is 1,670 m a.s.l, and it also consists of mountains, hills and small basins resulting from a dissected deep river valley.

The highest point of Crocker Range Park is Mount Alab (1,951 m), which extends to Tenom town. Crocker Range Park has become one of the interesting spots for wild

orchid study in Sabah because it still has an undisturbed mixed Dipterocarp Forest and stretches of montane mossy forest near the summit. The higher slopes of the park are dominated by moss forests, rhododendrons, and a variety of wild orchids (Das, 2006).

Orchid belongs to the family Orchidaceae and is notably known for its remarkable floral diversity and its ability to adapt to attract pollinators. Amongst all flowering plants, Orchidaceae is considered one of the largest and most diverse families, which comprises 736 genera with around an estimated 27,000 species overall (Chase et al., 2015). It has various vegetative and floral morphology, which confers a high taxonomic and ornamental importance. The presence of jewel orchids in Crocker Range Park has been recorded in various

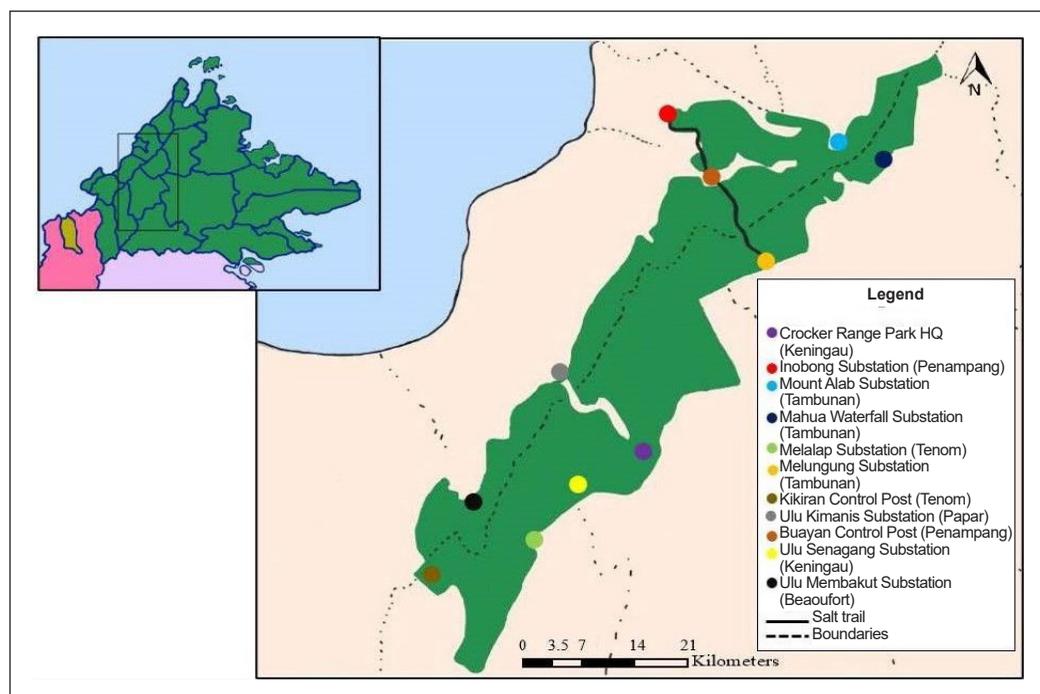


Figure 1. Map of Crocker Range Park in Sabah
 Note. This map was adapted from Suleiman et al. (2017)

documentation, as included in Majit et al. (2014), Wood (2004), Wood and Cribb (1994), Wood et al. (1993) as well as Seidenfaden and Wood (1992). However, no comprehensive and exclusive checklist for jewel orchids has been made from Crocker Range Park.

Therefore, this study intends to compile all known data on jewel orchids in Crocker Range Park, including fieldwork collections by various authors over several years, accompanied by additional general information such as their economic importance, conservation status, and conservation action plan. The outcome of this study can be utilised in the upcoming diversity study on jewel orchids in Crocker Range Park while also providing baseline data for the conservation of jewel orchids in the park to preserve the biodiversity of jewel orchids. The data used for this study was gathered from secondary data. The data was extracted from various documents such as literature, checklists, journals, and available online data. The validity of species names and distribution of genera was referred according to the World Flora Online Plant List (WFO), Global Biodiversity Information Facility (GBIF), and Plants of The World Online (POWO), while the status of species is referred to the International Union for Conservation of Nature (IUCN).

SPECIES RICHNESS OF WILD ORCHIDS IN CROCKER RANGE PARK

Ridley published the first-ever Bornean orchids list in 1896, in which he described

49 new species and recorded 224 species in 62 different genera, followed by Masamune in 1942. The number of species found increased to 1,203 in 99 genera. In 1994, Wood and Cribb (1994) listed over 1,400 species of orchids in 149 genera. The most recent compilation of Mount Kinabalu orchids was by Wood et al. (2011), which listed 866 taxa of orchids in 134 different genera. In Crocker Range Park, the first orchid was reported by Cribb and Vermeulen (1991), followed by Chan et al. (1994), which reported 16 species of orchids in 15 genera and was continued by Wood (2001).

The first scientific expedition at Crocker Range Park was dated back in 1999, as reported by Latiff et al., where the authors reported three species of orchids from Mount Alab (Latiff et al., 2001). The second scientific expedition was done in 2002 by Rimi et al., who reported 12 species of orchids from Ulu Kimanis (Rimi et al., 2004). The next expedition was in 2004 by Miadin et al. called the Melalap Scientific Expedition. The expedition recorded 37 orchid species in 23 genera (Miadin et al., 2005). The most recent expedition in Crocker Range Park in the past ten years was reported by Majit et al. (2011), where 149 species in 33 genera were recorded, while in 2014, the authors updated the checklist and currently, a total of 342 species in 102 genera of wild orchids were documented in Crocker Range Park. One of the documented orchids subtribes is Goodyerinae, commonly known as the jewel orchids. Jewel orchids have been documented in various documentation, and some species are considered endemic species for Borneo.

Checklist of Jewel Orchids in Crocker Range Park

The most recent study on wild orchids in the Crocker Range Park was conducted by Majit et al. (2014). Up until recently, species of jewel orchids in the park were included in several publications or checklists such as in Majit et al. (2014), Seidenfaden and Wood (1992), Wood (2004), Wood and Cribb (1994) as well as Wood et al. (1993).

Hence, based on the record of wild orchids in Crocker Range Park, eight different genera and ten species of jewel orchids are recorded in the park area. The recorded genera are *Anoectochilus* Blume, *Cystorchis* Blume, *Goodyera* R. Br. in W. T. Aiton, *Hetaeria* Blume, *Hylophila* Lindl., *Lepidogyne* Blume, *Vrydagzynea* Blume, and *Zeuxine* Lindl. Some species recorded are endemic to Borneo and Sabah (Table 1).

Table 1
Genus and species recorded in Crocker Range Park

Genus	Species	General distribution	IUCN (2022)	References
<i>Anoectochilus</i>	<i>Anoectochilus monicae</i> J. J. Wood*	Sabah	NE	Majit et al. (2014); Wood (2004)
<i>Cystorchis</i>	<i>Cystorchis variegata</i> Blume	Sabah, Peninsular Malaysia, Sumatra, Java, and Vanuatu	NE	Majit et al. (2014); Wood et al. (1993)
<i>Goodyera</i>	<i>Goodyera condensata</i> Ormerod & J. J. Wood*	Sabah	NE	
	<i>Goodyera rostellata</i> Ames & C. Schweinf*	Sabah	NE	Wood et al. (1994)
	<i>Goodyera procera</i> Hook.	Borneo, India, Sri Lanka, Myanmar (Burma), Thailand, Indonesia, China, Taiwan, Japan, and Philippines	NE	
<i>Hetaeria</i>	<i>Hetaeria alta</i> Rindl.	Borneo (Sabah), Peninsular Malaysia, and Peninsular Thailand	NE	Majit et al. (2014); Seidenfaden and Wood (1992)
<i>Hylophila</i>	<i>Hylophila lanceolata</i> (Blume) Miq.	Sabah, Kalimantan, Thailand, Sumatra, Java, Flores, and the Philippines, and is newly recorded in Peninsular Malaysia	NE	Majit et al. (2014); Wood and Cribb (1994)
<i>Lepidogyne</i>	<i>Lepidogyne longifolia</i> (Blume) Blume	Sabah, Peninsular Malaysia, east to Philippines, and New Guinea	NE	
<i>Vrydagzynea</i>	<i>Vrydagzynea albidia</i> (Blume) Blume	Borneo, India, Thailand, Vietnam, Peninsular Malaysia to the Philippines, and New Guinea	NE	Majit et al. (2014); Seidenfaden and Wood (1992)
<i>Zeuxine</i>	<i>Zeuxine gracilis</i> (Breda) Blume	Sumatra, Java, and Krakatau, as well as in Borneo and Peninsular Malaysia	NE	Majit et al. (2014); Seidenfaden and Wood (1992); Wood and Cribb (1994)

Note. * = Endemic species to Sabah; NE = Not Evaluated

Genus *Anoectochilus* Blume. Genus *Anoectochilus* is a terrestrial herb and can be spotted by its green leaves with colourful silvery or red nerves. Their flower is usually white or pink flushed and has a short peduncle inflorescence with few flowers. Only one species from this genus has been recorded in the park. *Anoectochilus monicae* J. J. Wood is a Sabah endemic terrestrial orchid found in hill and lower montane forests within the altitudinal range of 200–900 m (Wood, 2013). This species has very dark green leaves. The nerve on the leaf is gold, sometimes red or pink, reticulate on the above of the leaf, while it can be pinkish purple on the underside of the leaf. In addition, *A. monicae* also has hairy, showy flowers with pink or white sepals and white petals.

Genus *Cystorchis* Blume. Another genus recorded is genus *Cystorchis*. This genus is also a terrestrial herb with a few leaves on its stems. They have green, purplish and sometimes variegated leaves. In contrast, in a saprophytic species, the leaves on the stem are brown scale leaves. The inflorescence is dense with few to many flowers and has small flowers. *Cystorchis variegata* Blume is the only species in this genus recorded in the Crocker Range Park. This species of orchid has a vast distribution. It is a terrestrial orchid found on hills or lower montane forests with a 600–1,500 m elevation range. The leaves of *C. variegata* are light green with a dark green network and have a slightly undulating margin. The erected inflorescence is covered with short hairs, while their flower is white to off-white (Lok et al., 2011).

Genus *Goodyera* R. Br. in W. T. Aiton. Among all recorded genera in the Crocker Range Park, *Goodyera* is the only one that recorded more species than other genera. Orchids in the genus *Goodyera* are terrestrial and rarely epiphytic. Their leaves are ovate, asymmetric, and sometimes variegated, while their flower colour can be white, pale green or pink to purplish. *Goodyera condensata* Ormerod & J. J. Wood is a species from this genus that was recorded in the park. This species inhabits rocky terrain covered in alluvial soil close to waterfalls in deep mixed lower montane *Castanopsis/Lithocarpus* forests, which range in elevation from 1,400 to 2,700 m (Hu et al., 2016). They have green leaves with fine white reticulate nerves on the upper surface of the leaf with white coloured flowers and have a musky scent. Another species that was found is *Goodyera rostellata* Ames & C. Schwein. It is a terrestrial orchid in the lower montane forest about 900–2,700 m elevational range. Both *G. condensata* and *G. rostellata* is endemic to Sabah. Apart from these two species, another recorded species from this genus is *Goodyera procera* Hook. Like the other species in this genus, *G. procera* is also a terrestrial orchid. It can be found in the upper montane forest with a 2,200–2,400 m elevation range along the forest trails or on a moss-covered rock.

Genus *Hetaeria* Blume. Genus *Hetaeria* is another genus recorded in the park. They are usually terrestrial herbs and have broad, ovate to elliptic, asymmetric green leaves

with small flowers and raceme inflorescence (Wood & Cribb, 1994). Only one species in this genus was recorded. *Hetaeria alta* Rindl. lives in humus and can be found in lowland and hill forests (limestone) with a 100-500 m elevation range. They have ovate to elliptic leaves and have short, hairy yellow flowers.

Genus *Hylophila* Lindl. Genus *Hylophila* is another additional genus to all recorded genera in the park. Species in this genus are terrestrial with fleshy and creeping rhizomes. Their leaves are dark green, ovate to elliptic, and often asymmetric with small, pale greenish or reddish orange, softly hairy flowers, and dense terminal flower inflorescence. Only one species in this genus was recorded. *Hylophila lanceolata* (Blume) Miq. can be found in a damp and shady area on a mossy rock in the hilly or lower montane forest with 900–1,500 m of elevation range (Wood et al., 1993).

Genus *Lepidogyne* Blume. Another recorded genus is the *Lepidogyne*. They are tall terrestrial orchids. Their leaves are grouped at the base and elliptic with reddish-brown flowers and dense inflorescence (Niissalo & Choo, 2021; Wood et al., 1993). *Lepidogyne longifolia* (Blume) Blume is the only species in this genus that has ever been recorded in the park. Their natural habitat is in hill and lower montane forests (oak-laurel) with an elevation of 900-1,500 m and can be found on the ultramafic substrate.

Genus *Vrydagzynea* Blume. Species in the genus *Vrydagzynea* are usually terrestrial

orchids with decumbent rhizomes and root nodes. They have weak, fleshy stem with few green and median white strip leaves. Their flower is small, resupinate, and has a short, dense inflorescence (Schuiteman et al., 2015). Only one species of this genus has ever been recorded in the park. *Vrydagzynea albida* (Blume) Blume can be found on limestone soils along stream banks in hill and montane forests with an elevational range of 300-1,500 m. Flowers of *V. albida* are pale greenish and white.

Genus *Zeuxine* Lindl. Last but not least, the recorded genus in Crocker Range Park is the ‘grass-like’ herbs genus *Zeuxine*. Like the genus *Vrydagzynea*, *Zeuxine* is a terrestrial orchid with a decumbent rhizome and root nodes. They also have a similar weak, fleshy stem. However, the general characteristics of the leaves and flowers of these two genera are different. Leaves of the genus *Zeuxine* are green or purplish, ovate, linear, or elliptic with the coloured median nerve, while their flowers are white or green, small, and hardly open with dense, terminal hairy inflorescence. The only recorded species from this genus is *Zeuxine gracilis* (Breda) Blume. This species inhabits low-elevation oak-laurel forests, mixed-dipterocarp forests, secondary forests, and occasionally ultramafic substrates (Ormerod, 2018).

GENERAL CHARACTERISTICS AND DISTRIBUTION OF JEWEL ORCHIDS

The most recent phylogenetic position of the subtribe Goodyerinae results from the

persistent study on this subtribe for over 40 years. The first ever hypothesis about this subtribe was made by Dressler (1982), which proposed that Goodyerinae were related to the Tropicidae because of their long rhizomes and scattered roots. However, these plants have since been demonstrated to be in the family Epidendroideae (Cameron et al., 1999; Chase et al., 2015). It was then discovered that Goodyerinae is related to Cranichidae due to the similarity of their floral characteristics (Chen et al., 2019). The members of the jewel orchids are closely related to each other as they are all members of the subfamily Orchidoideae, tribe Cranichideae, and Subtribe Goodyerinae (Hayden, 2016). However, despite their prominent criteria, it does not represent a specific genus in the group (Indan et al., 2021).

Commonly, orchids are noticeable because of their appealing, showy flower, but some are appreciated for their alluring foliage. Jewel orchids are usually distinguished by their distinct leaf shape, colour, and venation (Bhattacharjee & Chowdhery, 2012). The distinctive feature of reticulate venation combined with plain green or various colours of its leaves contributes to the name 'jewel orchid' (Smidt et al., 2021), sometimes known as the 'marbled jewel orchid'. They are mostly terrestrial and lithophytic, which explains why they can be found on rocks and are seldom epiphytes (Juswara, 2010). They are usually easy to be noticed due to their distinctive habit. They have a prostrate rhizome that produces moniliform and

hairy roots from their node, which appears as a creeping rhizome, which allows them to attach to the media (Dressler, 1993). However, some species may only possess rhizoids and have no roots. The rhizome also produces a relatively thinner stem compared to the rhizome. Depending on the species, the stem will produce leaves in a spiral arrangement, either sessile or with the petiole. The flower of the jewel orchid is small (about 0.5–150 mm long) and has a variety of colours, such as white, pale green, yellowish, brownish, and pinkish flowers. Nevertheless, most of the time, the colour of the flower is white to pale green.

Genera of Goodyerinae subtribe can be found across the continent due to their vast distribution in Asia, South America and North America (Smidt et al., 2021), as shown in Table 2. Asia has the most significant distribution of jewel orchids, with 29 genera and 510 species (Ormerod, 2008), followed by Nearctic and Neotropical America, with nine native genera and 280 species (Ormerod, 2013). Based on Table 2, 16 genera of jewel orchids can be found in Malaysia.

The distribution of the genera is highly influenced by geography and local climate. Based on the Global Biodiversity Information Facility (GBIF) database, 16 genera of Goodyerinae subtribe have been recorded in Malaysia in recent years. Eight genera have been recorded in Peninsular Malaysia, while 14 are in Sabah and Sarawak. From the record, the genus *Dossinia* C. Morren has the most abundant distribution in Malaysia compared to other

countries that have recorded the genus, such as Vietnam, Indonesia, India, and Chinese Taipei. Most species recorded in Malaysia are also recorded in other countries. In contrast, some species can only be found in Malaysia or are endemic to Malaysia—for example, *Anoetochilus monicae* J. J. Wood and *Dossinia marmorata* C. Morren.

Table 2

Genus of subtribe Goodyerinae listed based on Chase et al. (2015) as well as Wood and Chan (2003) and their general distribution according to Royal Botanic Kew Gardens, Plants of The World Online

Genus	General distribution
<i>Aenhenrya</i> Gopalan	India
<i>Anoetochilus</i> Blume*	Ranging from Tropical and Subtropical Asia to the Pacific
<i>Aspidogyne</i> Garay	Ranging from Tropical and Subtropical America
<i>Chamaegastrodia</i> Makino & F. Maek.	Ranging from Assam to Japan
<i>Cheirostylis</i> Blume*	Ranging from Tropical & South Africa to the West Pacific
<i>Cystorchis</i> Blume*	Ranging from Thailand to the West Pacific.
<i>Danhatchia</i> Garay & Christenson	New South Wales, New Zealand North, New Zealand South
<i>Dossinia</i> C. Morren*	Borneo
<i>Erythrodes</i> Blume*	Ranging from Tropical and Subtropical Asia to the Southwest Pacific
<i>Eurycentrum</i> Schltr.	Ranging from Papuaia to Vanuatu
<i>Gonatostylis</i> Schltr.	New Caledonia
<i>Goodyera</i> R.Br. in W.T.Aiton*	Ranging from Europe, Madeira, Mozambique, and the West Indian Ocean to the Pacific, North and Central America, and Hispaniola.
<i>Halleorchis</i> Szlach. & Olszewski	Cameroon, Gabon
<i>Herpysma</i> Lindl.	Ranging from the Himalayas to South Central China and Sumatera
<i>Hetaeria</i> Blume*	Ranging from West Tropical Africa to Tanzania, the West Indian Ocean, Tropical and Subtropical Asia to the West Pacific
<i>Hylophila</i> Lindl.*	Ranging from Taiwan and Thailand to Papuaia
<i>Kreodanthus</i> Garay	Ranging from Tropical and Subtropical America
<i>Lepidogyne</i> Blume*	Ranging from Malesia to New Guinea
<i>Ludisia</i> A.Rich.*	Ranging from South China to West and Central Malesia
<i>Macodes</i> Lindl.*	Ranging from South Nansi-shoto, Vietnam, to Vanuatu
<i>Microchilus</i> C.Presl	Ranging from Mexico to Tropical America
<i>Odontochilus</i> Blume*	Ranging from the Himalayas to the Kuril Islands and Southwest Pacific
<i>Orchipedum</i> Breda*	Ranging from Indochina to West and Central Malesia
<i>Pachyplectron</i> Schltr.	New Caledonia
<i>Papuaea</i> Schltr.	New Guinea
<i>Rhomboda</i> Lindl.*	Ranging from Tropical and Subtropical Asia to the Southwest Pacific
<i>Schuitemanina</i> Omerod	Philippines
<i>Stephanothelys</i> Garay	Ranging from Tropical and Subtropical America
<i>Vrydagzynea</i> Blume*	Ranging from Tropical and Subtropical Asia to the West Pacific
<i>Zeuxine</i> Lindl.*	Ranging from Tropical Africa to Central Asia and the West Pacific

Note. * = Found in Malaysia

ECOLOGY OF JEWEL ORCHIDS

The jewel orchid is a terrestrial plant that grows from the ground. Naturally, they grow well in damp conditions with low-medium-intensity sunlight. They are keen on the tropical environment and are mostly found in Indochina and Pacific Islands jungle forests, including Malaysia (Krumov et al., 2022).

Due to the natural mountainous landscape in Crocker Range Park, the forest zoning in Crocker Range Park can be divided into their respective vegetational zone according to their elevational zone above sea level (Lowland dipterocarp forest, below 300 m a.s.l; Hill dipterocarp forest, 300–800 m a.s.l; Upper dipterocarp forest, 800–1,300 m a.s.l; Lower montane forest, 900–1,800 m; Upper montane forest, above 1,800 m) (Majit et al., 2014). Even though the exact localities of jewel orchids distribution in Crocker Range Park are unspecified, the recent evidence of jewel orchids' presence in the area has been documented in a preliminary checklist by Majit et al. (2014). Due to their ideal environment and habitat, jewel orchids live well in the park area. They typically reside on the forest floor in shaded, cool, humid, wet, but well-drained forests. The thick forest canopy provides enough shade for the jewel orchids. Additionally, the build-up of green-black mosses and dead tree leaves creates a thick layer of decomposing humus favourable for terrestrial orchids like jewel orchids (Besi et al., 2021). Correspondingly, the constant humidity in the tropics continuously adds water from the air to the forests.

The undisturbed ecology in the park also provides an excellent environment for jewel orchids. Since Crocker Range Park was gazetted as a forest reserve through the Sabah Park Enactment 1984, the park's governance has been authorised by Sabah Park. As the gazettelement of forest reserves, the rights of communities living within the boundaries of national parks are extinguished (Toh & Grace, 2005). It means there is no external intervention or exclusive rights for an outsider to do illegal activities such as logging, cultivation, extracting forest products, and others without permission. However, specifically for the management of Crocker Range Park, communities are permitted to stay in their traditional areas and collaborate with Sabah Park to establish traditional use zones within the parking area, which will be covered in the park's management plan. It is because several local villages are located inside the park boundaries to create a 'win-win' situation between the authorities and villagers (Ioki et al., 2019). Nevertheless, the strategy worked very well in creating the ideal ecosystem for conserving flora and fauna in the region. As a result, the presence of jewel and terrestrial orchid species in a forest area signifies an ideal environment.

CONSERVATION STATUS OF JEWEL ORCHIDS

Based on the IUCN Red List status for 2022 in Table 1, all recorded jewel orchid species in the Crocker Range Park are rated as Not Evaluated (NE). As a result, the

current status of the recorded jewel orchids is still being determined. This matter raised concerns because some species may be endangered and extinct in the wild without a proper conservation plan. Nowadays, numerous species are rapidly going extinct globally due to increasing anthropogenic activities such as rising human populations, urbanisation, habitat fragmentation, and greater reliance of the global population on finite natural resources (Woodruff, 2001). Along with the current trend of forest deforestation, overharvesting and changes in the Earth's surface, immediate action must be taken to ensure the livelihood of jewel orchids in the country. Globally, jewel orchids are categorised as an endangered species. For example, in Vietnam, jewel orchids have been included in the Vietnam Red Book of endangered species (Tran et al., 2022), while *Anoectochilus koshunensis* is categorised as an endangered species by CITES checklist (<https://checklist.cites.org>). This situation is alarming as it may lead to the global extinction of jewel orchids, not only in Malaysia.

The main factor that hinders the conservation of jewel orchids in Malaysia is the need for more available data. It happened due to insufficient attention given to oversee this matter. The negligence of authorities in providing enough data regarding the status and well-being of jewel orchids may be damaging the situation more since no measures were made to minimise the impact of the threat (Wraith et al., 2020). With the unknown current status of the jewel orchids and lack of data on the

exact locality, it is hard to determine the population of jewel orchids in the Crocker Range Park.

ECONOMIC IMPORTANCE OF JEWEL ORCHIDS

Although jewel orchids are uncommon in Malaysia, globally, jewel orchids have a variety of functions with great potential to generate economic growth. For instance, in Asia countries like China, Sri Lanka, Taiwan, and Vietnam, certain species of *Anoectochilus* have been used as local medicine widely for a very long time (Pridgeon et al., 2004), as shown in Table 3. The most famous medicinal *Anoectochilus* species is *Anoectochilus formosanus* Hayata. The tuber of *A. formosanus* has anti-cancer, anti-inflammatory, anti-diabetic, and antioxidant properties to prevent hepatitis, hypertension, and cancer due to kinsenoside (De et al., 2013; Kayalvizhi et al., 2020). Apart from that, the whole part of *Goodyera schlechtendaliana* Rchb. f. can be used as a tonic to cure internal injuries, improve blood circulation to clear heat, and remove toxins in Traditional Chinese Medicine (TCM) (Dai et al., 2021; Kayalvizhi et al., 2020). Therefore, due to their importance in the medicinal field, they are considered expensive folk medicine (Tseng et al., 2006). Besides their medicinal value, certain species of *Anoectochilus* leaves are also used as vegetables, particularly in Indonesia and Malaysia (De et al., 2013).

Although not all jewel orchids have medicinal properties, most species are appreciated for their beauty and aesthetic

Table 3
Species of jewel orchid and their medicinal properties

Species	Medicinal properties
<i>Anoectochilus koshunensis</i> Hayata	Anti-inflammatory
<i>Anoectochilus formosanus</i> Hayata	Anti-cancer/tumour, convulsive disease, anti-inflammatory, antioxidant, anti-diabetic, high endurance capacity, ameliorative, maturation
<i>Anoectochilus roxburghii</i> (Wall.) Lindl.	Antioxidant
<i>Goodyera schlechtendaliana</i> Rehb.f.	Prevent convulsive disease, remove toxins, prevent fever

value. An example is *Macodes petola* (Blume) Lindl., widely cultivated as a potted and indoor plant (de Loubresse, 2021). With the development of technology and a better understanding of each species, hybrid breeding for jewel orchids is common among jewel orchid breeders. The hybrid's uniqueness will capture the orchid collectors' attention and have its market value.

POTENTIAL THREATS AND CONSERVATION ACTION PLANS

The current situation regarding the country's declining population of orchids has become more concerning as time passes. Sabah, the richest state with orchids, has an estimated 1,300 orchid species with 250 endemic species (Sabah Forestry Department, 2023). Meanwhile, Sabah has lost 39.5% of its forest cover during the past 40 years (Gaveau et al., 2014) and is threatening the population of orchids in Sabah. The main threats that may lead to the extinction of orchid species are logging, land clearance and illegal collection.

Logging

Logging activities, whether legal or illegal, are not a rare scene in Malaysia. Malaysia

harvests 128,000 acres and produces 350 million cubic feet of wood annually, making it Malaysia's second highest-earning export after petroleum (Teoh, 2019). The survival of the ground layer's shade-loving plants is directly impacted by the detrimental consequences of opening up the forest canopy, erosion, and stream silting. This act destroys the habitat of orchids and alters the local microclimate and wild orchids' micro-temperature. Wild orchids, like jewel orchids, are susceptible to environmental changes and may decrease their chances of survival. Currently, due to extensive logging, many unique orchid species, such as *Phalaenopsis gigantea* J. J. Sm, *Paraphalaenopsis denevei* (J. J. Sm) A.D. Hawkes, and *Paphiopedilum rothschildianum* (Rehb. f.) Stein, although they are not jewel orchid species, disappeared from the East Malaysia forest (Teoh, 2019).

Land Clearance

The growth of the human population demands a more extensive development area. In developing countries, land areas are cleared for agriculture, traditional farming, and infrastructure. However, timber extraction led to the loss of host trees

and terrestrial orchids' habitats (Teoh, 2019). For example, in some areas of Sabah, local farmers still practice shifting cultivation and clearing land yearly to cultivate cash crops. Additionally, fire is used while clearing land to remove nearby vegetation, which affects the survival of epiphytes and terrestrial orchids (Swarts & Dixon, 2009).

Illegal Collections

Orchid is widely known for its unique features and has an established fan base for its collectors. Therefore, it is unsurprising that orchids are often smuggled or over-collected to meet market demand. Some species of orchids, including jewel orchids, were commonly sold at the roadside and nurseries from Kundasang to Ranau. Also, some foreign researchers and travellers were apprehended while attempting to transport some rare wild orchids from Malaysia into another country (Go et al., 2020). With the convenience of e-commerce such as Shopee and Lazada, the orchid market has grown even more significantly, advertising various orchid species for sale and ready to be shipped to their customer. For endemic species, the orchids are collected by locals and sold to nurseries before being exported to other countries. In the long run, the number of orchid species, especially the endemic species, will decrease and eventually become extinct in their natural habitat.

The degrees of these threats may eventually lead to the extinction of jewel orchids. Hence, an efficient conservation action plan is crucial to ensure the survival of wild jewel orchids in their natural habitat. It

includes proper conservation management, aiding with political intervention for total enforcement. The conservation of jewel orchids can be carried out either through *in-situ* conservation or *ex-situ* conservation.

***In-situ* Conservation.** An *in-situ* conservation or habitat conservation plan involves intensive management of the selected area. Habitat conservation is sometimes complicated and calls for common sense, keen observation, and in-depth study of management measures' timing, intensity, and interrelation (Pacicco et al., 2018). This area must not be prone to flooding and must be cleared of any form or disturbance, such as agricultural activities, construction, logging, land clearance, trespasses, orchid poachers, and other potential threats. The area's ecology, namely its temperature range and relative humidity, must be optimum and suitable for jewel orchids' vegetation. Several initiatives can be done in the conservation area, such as reintroducing jewel orchid species in their original habitat or relocating the species if the area is threatened by other means. It can be done by replanting wild orchid seedlings with their symbiotic mycorrhiza. Orchid seeds usually need a specific mycorrhizal fungus to germinate because fungal elicitors from mycorrhiza promote cell proliferation, seedling development, and metabolite synthesis, while phytoalexins from mycorrhiza protect orchids from pathogens (Teoh, 2019).

In addition, wild orchids also need a particular insect pollinator and a specific

group of plants to complete their life cycle (Seaton et al., 2013). Another initiative is to design an allotted harvesting area or collect forest resources. Rural communities often rely on forest resources for food, crafts, medicine, and more to sustain their living. However, the total restriction within the conservation area may hinder their norms. Therefore, by allocating a specific area for these people to collect forest resources, they can obtain them without disturbing the whole area.

Ex-situ Conservation. *Ex-situ* conservation refers to the conservation mode that is not taken in the original habitat. It can be done in other places, such as in botanical gardens and nurseries, with means to preserve the species. This method must be done thoroughly, considering the site's ecology. An altered and unsuitable ecology may destroy the orchids as they may not adapt to the new place. An estimated one-third of botanic gardens maintain orchid collections or scientific programmes, making them traditional focal points for orchid research and presentation (Swarts & Dixon, 2009). For example, the Royal Botanic Garden Kew and New York Botanical Garden have collected a large collection of living orchid specimens for display and research. Therefore, all these botanical gardens and nurseries act as the primary organisations participating in programmes for the conservation and reintroduction of orchids and are a global conservation resource with a long history of excellence in horticultural and taxonomic science.

Another conventional method in *ex-situ* conservation is by creating a germplasm gene bank. Gene banks play a significant role in orchid conservation by preserving orchids' genetic material, especially threatened orchid species (Merritt et al., 2014). These germplasms are mostly collected either in or outside their natural habitat. In India, ICAR-NRC for Orchids, Pakyong focuses solely on orchid breeding and the development of high-quality planting materials, both of which are thought to be important bottlenecks in the growth of the orchid industry in the country (Meitei et al., 2019). This institute is essential for the orchid study conducted to collect, characterise, evaluate, conserve, and utilise the genetic resources accessible in the nation, particularly in the northeastern region of India (De & Pathak, 2018).

Moreover, all these genetic materials can also be used to clone orchid species *in vitro* and reintroduce them to their original habitat to ensure their longevity (Brundrett et al., 2003). Also, orchids produced via *in vitro* can be used as stock plants, decreasing the need to collect orchids in the wild, especially for medicinal orchids such as *A. formosanus*. Most of the time, after determining the targeted orchid species' natural habitats, their seeds are gathered, and the plants may be reintroduced to the specified habitat after being multiplied in large numbers by tissue or seed culture to establish the population and allow multiplication under natural conditions (Medhi et al., 2012). However, due to the heterozygous and diverse genetic structure

of orchids, along with a very high degree of cross-fertilisation, the genetic structure of distinct accession of a species cannot be preserved (Davies, 2009). Therefore, this technique is likely suitable for preserving orchid species' biodiversity.

CONCLUSION

Eight genera and ten species of jewel orchids have been recorded in Crocker Range Park. Among all recorded species, three species are endemic to Sabah. They are *Anoectochilus monicae*, *Goodyera condensata*, and *Goodyera rostellata*. It highlighted the importance of law enforcement in Crocker Range Park by Sabah Parks and Sabah authorities.

Extensive studies in Crocker Range Park regarding orchid diversity, especially for jewel orchids, must be done in the future, considering that the latest study of orchids in the park was almost ten years ago. Apart from that, until this date, there has yet to be a complete checklist of jewel orchids in the park or Sabah generally. It raises concern about the status of these documented and undocumented orchids as they need to be updated. They may be endangered due to illegal logging, overharvesting, or other internal or external factors. Thus, systematic studies about orchids must be done to conserve the flora.

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