UNIVERSITI PUTRA MALAYSIA

DIVERSITY, TAXONOMY AND CONSERVATION OF ORCHIDS IN PENINSULAR MALAYSIA

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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DIVERSITY, TAXONOMY AND CONSERVATION OF ORCHIDS IN PENINSULAR MALAYSIA

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July 2022

Chairman : Professor Rusea Go, PhD
Faculty : Science

As an attempt to examine the causes of forest disturbance and degradation of the orchid community, a comparative study on diversity and ecology in eight undisturbed (Padang 7, Bukit Rongkit, Taman Rimba Komanwel, Bukit Batu Kapal, Lata Kekabu, Lata Lawin, Lata Tanjung Kala, Bukit Pedu) and ten disturbed (Bukit Sekayu, Gunung Perlis, Bukit Batu Kapal, Tanah Merah, Hulu Setiu, Kuala Koh, Logging Bukit Batu Kapal, Bintang Hijau, Gawi, Petuang) forests in Peninsular Malaysia was conducted. The study reported 239 orchid species belonging to 65 genera, inclusive of not just the rare and endemic species, but also five new record species. Species richness, abundance, density and diversity of orchids varied across the localities. A higher density of orchids (2.433 plants/km^2) occurred exclusively in the undisturbed forests than in the disturbed forests (0.228 plants/km^2). As with the character of undisturbed forests, the temperature was between 27.8±0.3 ^{o}C and 31.2±0.2 ^{o}C, humid (77.1±1.2 %–89.6±0.9 %) and low light intensity (23.8±3.3 µmol m^{-2}s^{-1}–171.7±18.8 µmol m^{-2}s^{-1}) thus supporting the high density of the plants. Disturbed forests harboured higher diversity (H=4.934 and 1-D=0.990) and abundance (183 species of 57 genera) that determined to be highly influenced by the higher abundance of epiphytic orchids on the fallen trees and ease of accessibility in the logged forests. The lower diversity of orchids in the undisturbed forests supported by the higher dominance (D=0.015) of most abundant species. However, terrestrial and mycoheterotroph orchids were lower in density and abundance in the disturbed habitat indicating a gradual reduction in their niche availability following the disturbance. Also, the ecology data shows the microclimate conditions of the canopy-covered forest influenced by proximity to the logged area. Furthermore, the results show the composition of orchid communities in the undisturbed and disturbed forests associated with the host plant characteristics. Host types and bark texture preference were apparent for the epiphytic orchid species with certain types and textures hosting more orchid species than others. To further obtain an accurate estimate of the orchid floristic composition, integrative methods of

macromorphology, micromorphology and molecular genetics are necessary to solve the taxonomic uncertainty and resolve species complexes at the infrageneric level. Floral micromorphology of three critically endangered *Paphiopedilum* were analysed concerning either infrageneric taxonomy or physioecological demands. Using scanning electron microscopy (SEM), surface of the dorsal sepal, synsepal, lateral petals, pouch or labellum, and staminode were investigated. Amongst the investigated features were epicuticular waxes, epicuticular ornamentation, trichome distribution and type, pustular glands, and papillae. The finding supports the distinction of *P. barbatum* from *P. callosum* var. *sublaeve*, which belong to subgenus *Paphiopedilum*, and from *P. niveum*, a species belonging to subgenus *Brachypetalum*, a separated monophyletic clade. From the physioecological view, the absence of glandular trichomes, and the low occurrence of papillae and stomata on the floral parts explain the unscented flowers of *P. barbatum* and *P. callosum* var. *sublaeve*. In this study, other than morphology, efficacy of the nuclear and chloroplast regions in discriminating the uncertain taxa of *Dendrobium* Sect. *Calcarifera* species were examined. For barcoding, nrITS, *rbc*L, *mat*K, and *psb*A-*trn*H regions of 60 samples, including six samples of unknown identity, were sequenced except for *D. corydaliflorum* where only *rbc*L was reproducible. Amongst the single barcode regions, nrITS showed a high sequence quality (100%), high discriminatory power (99.7%), clear resolution of species in Maximum-Likelihood phylogenetic tree, and high congruence with the morphology data. Combined markers showed a high species resolution with the conspecific individuals all grouped together, especially any combinations with nrITS, due to the added sequence variation. Eighteen species were assessed using the internationally accepted IUCN criteria and categories. Of the 18 species, eight are classified as threatened (Endangered, Critically Endangered, or Vulnerable). Furthermore, 30 species are included in a poster on Endangered, Threatened and Rare Wild Orchids of Malaysia (Part 1 and 2) in collaboration with the Forestry Department of Peninsular Malaysia as an effort to increase awareness on the importance of orchid conservation between the public and the effectiveness of the current monitoring on illegal trade. The monitoring effort is now supported by DNA barcoding work which has so far included 74 entries for four barcode markers belonging to 43 endemic and rare species.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KEPELBAGAIAN, TAKSONOMI, DAN STRATEGI PEMULIHARAAN BAGI ORKID DI SEMENANJUNG MALAYSIA

Oleh

EDWARD ENTALAI ANAK BESI

Julai 2022

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Dalam usaha untuk mengenalpasti pendorong bagi kehilangan habitat dan kemusnahan komuniti orkid, satu kajian membandingkan kepelbagaian dan ekologi di lapan hutan yang tidak terganggu (Padang 7, Bukit Rongkit, Taman Rimba Komanwel, Bukit Batu Kapal, Lata Kekabu, Lata Lawin, Lata Tanjung Kala, Bukit Pedu) dan terganggu (Bukit Sekayu, Gunung Perlis, Bukit Batu Kapal, Tanah Merah, Hulu Setiu, Kuala Koh, Logging Bukit Batu Kapal, Bintang Hijau, Gawi, Petuang) telah dijalankan di Semenanjung Malaysia. Kajian ini melaporkan 239 spesies orkid dari 65 genera, bukan hanya spesies yang jarang ditemui dan endemik, malah juga termasuk dengan lima spesies sebagai rekod baru. Kekayaan spesies, taburan, kepadatan, dan kepelbagaian orkid adalah berlainan mengikut kawasan kajian. Kepadatan orkid lebih tinggi (2.433 pokok/km^2) direkod di hutan yang tidak terganggu berbanding hutan yang terganggu (0.228 pokok/km^2). Hutan yang tidak terganggu memiliki suhu antara 27.8±0.3 ºC dan 31.2±0.2 ºC, lembap (77.1±1.2 %–89.6±0.9 %), dan intensiti cahaya yang rendah (23.8±3.3 µmol m^{-2}s^{-1}–171.7±18.8 µmol m^{-2}s^{-1}) yang mengalakkan pertumbuhan orkid. Hutan terganggu memiliki kepelbagaian (H = 4.934 dan 1-D = 0.990) dan taburan (183 spesies 57 genera) orkid yang lebih tinggi yang dipengaruhi oleh banyak orkid epifit pada pokok-pokok yang tumbang, dan pokok-pokok tumbang ini secara langsung meningkatkan akses kepada orkid di hutan-hutan ditebang. Kepelbagaian orkid yang lebih rendah di hutan yang tidak terganggu juga disebabkan oleh dominasi yang lebih tinggi (D = 0.015) oleh spesies yang paling dominan. Walau bagaimanapun, kepadatan dan taburan orkid terestrial dan mycoheterotroproph lebih rendah di habitat yang terganggu menunjukkan terdapat pengurangan kualiti persekitaran akibat gangguan. Data ekologi menunjukkan keadaan mikroklimat di hutan yang ditutupi kanopi turut dipengaruhi oleh jarak hutan tersebut dengan kawasan yang hutan yang ditebang. Selain itu, penemuan ini juga menunjukkan komposisi komuniti orkid di hutan yang tidak terganggu dan terganggu berkait rapat dengan ciri-ciri tumbuhan perumah. Jenis-jenis tumbuhan perumah dan tekstur kulitnya sangat penting untuk spesies

orkid epifit dimana jenis dan tekstur yang tertentu kerap menjadi kegemaran orkid. Bagi mendapatkan anggaran yang tepat mengenai komposisi floristik orkid, kaedah integratif makromorfologi, mikromorfologi dan genetik molekul adalah perlu untuk menyelesaikan kekeliruan taksonomi dan menghuraikan kompleks spesies di peringkat infragenerik. Micromorphologi analisis untuk bahagian bunga bagi tiga spesis *Paphiopedilum* yang terancam dijalankan sama ada untuk merungkai taksonomi atau fisiologinya. Menggunakan teknik Mikroskop Imbasan Elektron (SEM), kami menyiasat permukaan kelopak, kantung atau lidah, dan staminod. Di antara ciri-ciri yang dilihat ialah lilin epikutikular, hiasan epikutikular, taburan dan jenis trikom, kelenjar pustular, dan papila. Kajian kami menyokong perbezaan *P. barbatum* dari *P. callosum* var. *sublaeve*, yang tergolong dalam Subgenus *Paphiopedilum*, dan perbezaan dari *P. niveum*, spesies milik Subgenus *Brachypetalum*, yang juga berada di cabang monophyletik berlainan. Dari pandangan fisiologi, ketiadaan kelenjar trikom, dan taburan papila dan stomata yang rendah di bahagian bunga menjelaskan ketiadaan wangi pada bunga *P. barbatum* dan *P. callosum* var. *sublaeve*. Dalam kajian ini, selain daripada morfologi, kami mengkaji keberkesanan lokus nuklear dan kloroplas dalam membezakan spesis-spesis dalam kumpulan infragenerik *Dendrobium* Sect. *Calcarifera*, yang susah untuk dibezakan menggunakan morfologi. Untuk kerja DNA barkoding, jujukan genetik bagi gen nrITS, *rbc*L, *mat*K, and *psb*A-*trn*H dari 60 sampel, termasuk enam sampel yang identitinya yang tidak diketahui, telah didapatkan, kecuali untuk *D. corydaliflorum* di mana hanya *rbc*L yang berhasil. Di antara barkod gen tunggal, nrITS menunjukkan kualiti jujukan yang tinggi (100%), kuasa diskriminasi yang tinggi (99.7%), resolusi spesis yang jelas bagi rangka phylogenetik Maximum Likelihood, dan persamaan yang tinggi dengan data morfologi. Gabungan barkod gen menghasil resolusi spesis yang tinggi dengan semua individu konspesifik dikelompokkan bersama, terutamanya mana-mana gabungan dengan nrITS, disebabkan oleh variasi tambahan dalam jujukan. Lapan belas spesis dinilai berdasarkan Kriteria dan Kategori IUCN yang diterima di peringkat antarabangsa. Daripada 18 spesies, lapan diklasifikasikan sebagai terancam (terancam, terancam dengan kritikal, atau terdedah kepada ancaman). Tambahan lagi, 30 spesies dimasukkan ke dalam poster orkid liar yang terancam, terancam dan jarang berlaku di Malaysia (Bahagian 1 dan 2) dengan kerjasama Jabatan Perhutanan Semenanjung Malaysia sebagai usaha untuk meningkatkan kesedaran tentang kepentingan pemuliharaan orkid dikalangan masyarakat dan keberkesanan pemantauan semasa terhadap perdagangan haram bagi spesis terancam. Usaha pemantauan kini disokong dengan kerja DNA barkoding yang setakat ini melibatkan 74 kemasukan untuk empat barkod penanda bagi 43 spesis endemik dan spesis yang memiliki taburan jarang.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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α	Alpha, level of significance
%Ao	Relative Abundance of the Orchid Species
Δ	Elevation
μmol $m^{-2}s^{-1}$	micro moles per square meter per second of Photosynthetically Active Radiation (PAR)
a.s.l.	above sea level
*atp*B	ATP synthase subunit beta
*atp*F-*atp*H	An intergenic spacer between *atp*F and *atp*H encode ATP synthase subunits CFO I and CFO III
ANOVA	Analysis of variance
AOO	Area of Occupancy
bp	Base pairs
BLAST	Basic Local Alignment Search Tool
BK	Bukit Batu Kapal
BK(M)	Bukit Batu Kapal (forest margin)
BOLD	Barcode of Life Data System
BP	Bukit Pedu
BR	Bukit Rongkit
BS	Bukit Sekayu
ca.	Circa (about)
CAM	Crassulacean acid metabolism
CBD	Convention on Biological Diversity
CBOL	Consortium for the Barcode of Life
cf.	'confer' or a possible identity, or at least a significant resemblance

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CM	Common species
CR	Critically Endangered
CRNP	Crocker Range National Park
D	Simpson Diversity Index
DD	Data Deficiency
DNA	Deoxyribonucleic acid
dNTPs	Deoxyribonucleotide triphosphate
df	Degree of freedom
E	Evenness
ED(PM)	Endemic species to Peninsular Malaysia
EN	Endangered
EOO	Extent of Occurrence
EP	Epiphytic
EtBr/EtB	Ethidium Bromide
EW	Extinct in the Wild
Ex	Extinct
FDPM	Forest Department of Peninsular Malaysia
FRIM	Forest Research Institute Malaysia
GeoCAT	Geospatial Conservation Assessment Tool
GP	Gunung Perlis
GPS	Global Positioning System
H	Shannon Diversity Index
Ha	Hectares

HCVF	High Conservation Value Forest
HSK	Hutan Simpan Kekal
IBM	International Business Machines Corporation
IUCN	International Union for Conservation of Nature
IUCN SSC	IUCN Species Survival Commission
ITS	Internal transcribed spacer
K2P	Kimura-2-parameter
KB	Lata Kekabu
KH	Kuala Koh
LAT	Latitude
LB	Bintang Hijau (Logged forest)
LBK	Bukit Batu Kapal (Logged forest)
LC	Least Concern
LG	Gawi (Logged forest)
LHS	Hulu Setiu (Logged forest)
LI	Light Intensity
LONG	Longitude
LP	Petuang (Logged forest)
Lux	SI derived unit of illuminance and luminous emittance, measuring luminous flux per unit area
LW	Lata Lawin
Lx	Lux unit
*mat*K	Maturase K gene
Max	Maximum value
Mean±SE	Means with standard error of each parameter

MH	Mycoheterotroph
Min	Minimum value
ML	Maximum Likelihood
*Nad*1	Nicotiana alata Defensin 1
NCBI	National Center for Biotechnology Information
NE	Not Evaluated
NFP	National Forest Policy 1978
NGO	Non-government association
NT	Near Threatened
OSG	Orchid Specialist Group
PAST4	PAleontological STatistics Version 4.04
PCA	Principal Component Analysis
PCR	Polymerase Chain Reaction
PG7	Padang 7 (Endau-Rompin)
PERHILITAN	Jabatan Perlindungan Hidupan Liar dan Taman Negara Semenanjung Malaysia or Department of Wildlife and National Parks Peninsular Malaysia
PPFD	Photo-synthetic photon flux density
PRF	Permanent Reserved Forests
p	p-value
pi	Proportion (n/N) of individuals of *i*th species found (n) divided by the total number
plants/m^2	Total number of plants per square metre
*psa*B	Photosystem I P700 chlorophyll a Apoprotein A2
*psb*A-*trn*H	An intergenic spacer located between the *psb*A gene and the gene of histidine transfer RNA (*trn*H)
*rbc*L	Ribulose-bisphosphate carboxylase gene

rDNA	Ribosomal DNA
RLA	Red List Authorities
RFLPs	Restriction Fragment Length Polymorphism
*rpo*B	A gene encodes the β subunit of bacterial RNA polymerase
*rpo*C1	Cyanobaterial DNA-dependent RNA polymerase gamma subunit
SCBD	Secretariat of the Convention on Biological Diversity, Canada
SE	Standard Error
SEM	Scanning electron microscope
SPSS	Statistical Package for the Social Sciences
TK	Lata Tanjung Kala
TM	Tanah Merah
TPA	Totally Protected Areas
TR	Terrestrial
TRK	Taman Rimba Komanwel
*trn*L-F	It consists of the *trnL* gene, a group I intron, and the trnL-F intergenic spacer located in the large single-copy region of the chloroplast genome
*trn*L-*trnL*F	A spacer consists of the transfer RNA genes $trnL^{UAA}$ and $trnF^{GAA}$ arranged in tandem and separated by non-coding spacer regions
*trn*S-G	A spacer consists of the transfer RNA genes *trn*S and *trn*G
UK	United Kingdom
UPGMA	Unweighted Pair Group Method with Arithmetic Mean
VU	Vulnerable

WCSP	World Checklist of Selected Plant Families
Xdh	Xanthine dehydrogenase gene
*ycf*1	Yeast Cadmium Factor gene

CHAPTER 1

INTRODUCTION

1.1 General

Orchids belong to the family Orchidaceae is the most valuable group of flowering plants that advanced in the floral variation with visually stunning blooms among the monocotyledons. Orchids are adapting to various types of ecosystems, including dry conditions. Malaysia's rainforests are considered 'hot spots' of orchid diversity with a high conservation priority. At the latest count, Peninsular Malaysia is now having 972 species in 159 genera (Ong et al., 2017) and about 20% of these orchid species are endemic (Ong et al., 2011a). Sabah and Sarawak harbour about 3,000 species of wild orchids with Mount Kinabalu, alone owning about 2,000 species, and Sarawak has about 1,000 species (Go & Hamzah, 2008; Go & Pungga, 2018).

In general, primary forests or undisturbed forests offer favourable habitats for orchid species because of the diverse canopy structure and undisturbed ground vegetation. Oftentimes, natural forest stands are well-endowed with species in contrast to managed forests (Webb & Sah, 2003; Song et al., 2010). National Parks in Malaysia encompass an ecosystem across five vegetation types: montane forest, lower montane forest, upper dipterocarp forest, hill dipterocarp forest, oak-laurel and lowland dipterocarp forest (Saw, 2010; Majit et al., 2011; Md Isa et al., 2018). In Borneo, Kinabalu and Crocker Range National Parks emerge as one of the most interesting areas for orchid diversity studies in northern part of the island (Majit et al., 2014). Also, the orchids collections resulting from seven major expeditions in the Mount Mulu area (Mulu National Park) between 1961 and 1978 harboured 170 taxa in 54 genera (Wood, 1984a; Beaman et al., 2001). The plants communities gradually change along elevation gradients. The diverse ecosystems of protected forests assure a large number of orchids and presence of the rare species (Ummul-Nazrah et al., 2011; Md Isa et al., 2018).

Besides Cambodia and Paraguay, Malaysia is a country with the highest national deforestation rates. More than 80% of tropical forests in Sarawak and Sabah have been severely affected by logging (Bryan et al., 2013; Yong, 2014). The issue of logging is exigent throughout Malaysia, customarily, in the permanent nature forest reserve and in the surrounding areas near the Permanent Reserved Forest (PRF), the National Parks. However, there are also pockets of disturbed forests in the protected area (Usui et al., 2006; Hairul et al., 2016). The deforestation within Malaysia is evidenced by both concessioned and illegal activities (Besi et al., 2019b). Malaysian tropical rainforest is very thick, and some fragments are located far off deep into the forest and involve vast areas hidden from the attention of public, monitoring agencies, and media (Gani, 2013). Hence, detection of misconduct and arrest of forest offenders is low in some areas (Gani et al., 2013). Unsustainable logging

activities and the natural disaster that follows has been a controversy and a threat, not merely to just human but also to the wild orchids. In the logged forests, the orchids are being exposed to the intense heat and dryness which had slowly killed them (Besi et al., 2019b).

Logged forests generally have lower orchid density if compared to disturbed secondary forests but still harbouring a higher diversity of which most are epiphytes on fallen trees (Besi et al., 2019b). The high richness of epiphytic orchids and large difference of their densities are significantly influenced by the densities of fallen trees hosting orchid(s), disturbance-induced dryness stresses, durations of exposure to disturbance, and altered soil conditions due to vegetation clearance by tractor (Wan Mohd Shukri et al., 2007; Besi et al., 2019b). Secondary moist tropical forests regenerating after clear-cutting show shrinking species abundance if compared to mature forests (Kromer & Gradstein, 2003). Orchids in logged forests experience extreme ecological conditions with higher surrounding temperature and lower humidity than in canopy-covered secondary forests (Werner & Gradstein, 2009). The canopy disruption caused by felling affect the temperature, humidity, and light conditions inside forests, making it unfavourable for shade-adapted species (Benítez et al., 2012; Besi et al., 2019b). Species density is correlated with crown closure suggesting strong influence of microclimate on patterns of diversity and floristic composition (Werner & Gradstein, 2009). The more shade-adapted epiphytes that are susceptible to desiccation are often substituted by sun-loving ones. Open forests are generally drier, warmer and windier compared with closed forests, where moisture content is higher and less variable (Gradstein, 2008; Benítez et al., 2012, Besi et al., 2019b). Logging pose imminent impacts on the occurrence of epiphyte due to the removal of host plant species (Gradstein, 2008). Host plant characteristics (e.g., size, bark roughness, and bark pH) play an important role in epiphyte colonisation (Adhikari et al., 2017; Timsina et al., 2016) and most likely due to greater bark surface available for colonisation on large trees that also creates additional microhabitats (Ranius et al., 2008; Fritz et al., 2009). Host position and type, and growth of epiphytic species are influenced by microclimate conditions such as annual precipitation, humidity, and light intensity (Timsina et al., 2016; Adhikari et al., 2016). Determining the degree of host specificity is also significant in a conservation context because host specialist species are more vulnerable to habitat alterations and climate change (Clavel et al., 2011), and are threatened by co-extinction with their hosts (Colwell et al., 2012a).

Cryptic species, product of rapid evolutionary radiations within a single genus, can form suites of morphologically similar taxa that are indistinguishable both in the field and the herbarium (Elliot & Davies, 2014). In order to understand better the overall discriminatory power of the plant barcoding loci, future work on systematics and taxonomy should focus on intergeneric or infrageneric groups that experienced rapid evolutionary radiations, for example, the closely related but distinct species within a single genus (Yan et al., 2015). Discovering the potential presence of cryptic species, species complexes and/or lineages is an important application of DNA barcoding, and this remains within the domain of taxonomy (DeSalle et al., 2005).

1.2 Problem Statement

The rapid extinction of species is associated with the declining of populations diminished by anthropogenic disturbances and of unviability of populations in small forest fragments (Turner et al., 1994). Species richness and abundance of epiphytic orchids are lessining because of deforestation, illegal collection and trade, resulting in high rates of species loss, population depletion, and genetic erosion (Rajbhandari et al., 2000; Go & Besi, 2020). As shown by biodiversity studies of tropical forests on forest fragmentation and clear-felling effects on epiphyte and terrestrial communities, factors including microclimate (Gradstein, 2008; Werner & Gradstein, 2009; Benítez et al., 2012), host plant characteristics (Adhikari et al., 2017), distance (Werner & Gradstein, 2009) and habitat quality (Gradstein, 2008; Werner & Gradstein, 2009; Benítez et al., 2012; Besi et al., 2019b), and microbiome (Tsavkelova et al., 2001; Herrera et al., 2021) could explain floristic impoverishment in tropical forests. Also, the systematics and taxonomic usefulness of DNA barcoding has been tested in orchid groups that containing a high number of cryptic species (Yan et al., 2015a).

However, these baseline studies are currently lacking for most Malaysian rainforest and ecosystems. Tropical rainforest owns undisturbed forest differing in tree composition, stature, and microclimate regimes. Disturbance regimes of forest in Malaysia own a wide range of temporal and spatial scales of frequency and magnitude. Understanding the degree of host specificity of host-dependent species and rapid radiation evolution in such a distinctive forest ecosystem is wanting in biodiversity. The importance is to avoid biases in uncovering the significance of ecological alterations on the orchid community, and to provide insights on the success of current forest management interventions in reducing the threats. An extensive and comparative study on orchid diversity, systematics, and conservation in both undisturbed and disturbed forest is new. This particular report is the first real attempt to fill in this gap and to advocate the global conservation initiatives laid by the IUCN SSC Orchid Specialist Group by analysing the problems and developing solutions to the crisis.

Thus, the current diversity and conservation study includes several forest types, vegetation types, and disturbance regimes. The current conservation plan determines the suitability of the plants especially trees as protectors and homes to epiphytic plants along with the threats and limiting factors. Disturbance effects on the host plants and epiphytes relationship and the orchids-host plants specificity are poorly known, especially when the impacts come under different disturbance regimes. Distance to the undisturbed and canopy-covered forests would have effects on the species density and microclimatic conditions. Unfortunately, the forest depletion in Malaysia has reached alarming rates which leaves narrow time and space for ecological restoration and reintroduction programme. Therefore, in order to avoid the extinction of these endangered orchid species, a continual rescue mission along with diversity, taxonomy, and conservation studies in vary types of undisturbed and disturbed forests are absolutely necessary.

The botanical 'rescue mission' harboured a number of unidentified species, seems to be undergoing incipient speciation, and contains cryptic species. Another problem is raised in determining the accurate identity of these orchids even with the help of flower structures. Presumably, the variations might be formed naturally through intergeneric hybridisation in the wild or just morphotypes of a single species under influence of environment conditions, but scattered orchids distribution influenced by the positions of the fallen trees in the forest, poor documentation on the morphological description, lack of floral structures, and lack of individuals caused difficulty to validate the taxonomic status based on morphological characters alone. Thus, DNA barcoding is the presentably one of the best methods to unveil the mystery of each species complex. A study on floral anatomy is also suggestable to delimit each species at the infrageneric level. Furthermore, studies on microstructures of floral parts of orchids of Malaysia prior to an accurate species delimitation are lacking documentation.

1.3 Objectives

This research is a part of a conservation effort, the rescue mission of Orchids of Disturbed Forests in Malaysia. A comparative study on orchid diversity and conservation in both disturbed and the undisturbed forest is included. 'Undisturbed' forest is either primary or protected forests that have experienced little to no recent human disturbance, whereas 'disturbed' forest is categorised as forest that have experienced disastrous and large disturbance such as deforestation, extreme floods, tree falls, and human trampling. In general, this study reports on direct and underlying agents and causes of the habitat losses and extinctions of the orchid community in Malaysia and aimed to support the global conservation efforts carried by IUCN SSC Orchid Specialist Group by examining the problems and develop the solutions. Therefore, the objectives are:

1. to evaluate the diversity and richness of orchids in both undisturbed and disturbed forests in Malaysia
2. to evaluate the resilience of the orchids and their ability to adapt the disturbed habitats in the mentioned area based on their habits and morphological characters and the habitat's ecological variations
3. to define and delimit taxonomic characters of the uncertain and flagship taxa based on morphological-based and genetic-based evidence
4. to assess conservation status of the selected flagship orchid species according to the IUCN Red List of Endangered Species Categories and Criteria hence propose the appropriate actions to protect the populations.

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