UNIVERSITI PUTRA MALAYSIA

ORCHID DIVERSITY IN DISTURBED FORESTS OF TERENGGANU AND KELANTAN, MALAYSIA, AS INFERENCE FOR CONSERVATION

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By

EDWARD ENTALAI ANAK BESI

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

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Professor Rusea Go, PhD
Faculty : Science

The uncontrolled logging in Peninsular Malaysia and the resulting mud floods in the lowland areas has been perilous, not to just human but also to other biodiversity, including the wild orchids. Their survival in these highly depleted areas has been minimally outweighed due to the inaccessibility and harsh environment. In relative to their uses commercially and their inclusion as one of the conservation objective, a detailed research on the diversity and ecology of orchids in the disturbed forest is crucial in strengthening the conservation framework. A botanical rescue missions within the Terengganu and Kelantan regions were done from November 2016 until May 2018, including study site selection, from existing logging sites in the Kenyir Lake area and disturbed secondary forests (DSFs) in the Kuala Koh and Tanah Merah areas. The herbarium specimens were processed and the living plants were rescued to *ex-situ* conservatory, and cultivated for further identification and phenological study. A total of 109 orchid species belonging to 39 genera was saved from their extremely disturbed habitats. The DSFs had a higher orchid density than the logging sites as the habitat conditions and energy productions were more reliable. However, the logged forests harboured higher diversity of orchids (H = 4.50 and D = 0.99) with 11 rare species were found along with four endemic species, and dominated by epiphytic orchids, which this was determined to be strongly influenced by the densities of fallen trees, durations of exposure to the dryness stress and unfavourable soil conditions. From this current study, 38 species are recorded as new records to Terengganu, four species are new records to Kelantan. A total of 280 orchid species from earlier collections from the disturbed forests of the Terengganu region are also listed in the checklist with a total of 86 species are new records to Terengganu, and one species is a new record to Malaysia; *Dendrobium agamense*; and another one species is a new record to Peninsular Malaysia; *Crepidium oculatum*. Foremost is the discovery of nine new species to science with five species are successfully described as *Bromheadia petuangensis*, *Dendrobium ainiae*, *Dendrobium ruseae*, *Dendrobium mizanii*, and *Pinalia domii*. This study also aimed to evaluate the resilience of wild orchids towards the environmental anthropogenic disturbances. The wild orchids employed two water-balance mechanisms in their

reactions to the dryness-heat stress and water deficit in the disturbed forests; the 'drought avoidance' and 'drought escape' mechanisms. The wild orchids rescue mission to *ex-situ* conservatory was proven effective as all the rescued orchids were recovering well with 70.6% of them been recorded flowering or fruiting with an indication of a possibility of cross-pollination occurrence amongst them. Ten rare species were proposed under threatened categories according to IUCN Red List Categories and Criteria version 13 (March 2017). A conservation strategy was drafted for the orchids of disturbed forests with recommendations on the sustainable practices to avoid their local extinctions.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia Sebagai memenuhi keperluan untuk ijazah Master Sains

KEPELBAGAIAN ORKID DI HUTAN TERGANGGU TERENGGANU DAN KELANTAN, MALAYSIA, SEBAGAI KESIMPULAN UNTUK PEMULIHARAAN

Oleh

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November 2018

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Pembalakan hutan yang tidak terkawal di kawasan Semenanjung Malaysia dan banjir lumpur yang melanda kawasan tanah rendah, berbahaya tidak hanya manusia tetapi juga kepada biodiversiti yang lain, termasuk orkid liar. Kesejahteraan mereka di hutan-hutan yang terganggu ini menerima kurang perhatian kerana persekitarannya yang panas dan kering. Kepentingan orkid dalam dunia komersial dan status pemuliharaannya telah menjadikan penyelidikan yang terperinci dalam kepelbagaian dan ekologi orkid-orkid dalam hutan terganggu sebagai keutamaan bagi mengukuhkan rangka kerja pemuliharaan mereka. Satu misi botani untuk menyelamat orkid-orkid dari hutan-hutan terganggu di Terengganu dan Kelantan telah dilakukan dari bulan November 2016 hingga bulan May 2018 yang juga turut melibatkan proses-proses pemilihan tapak penyelidikan di kawasan pembalakan di Tasik Kenyir dan hutan sekunder terganggu (HST) di kawasan Kuala Koh dan Tanah Merah. Spesimen herbarium telah diproses dan orkid-orkid liar yang hidup diselamatkan ke *ex-situ* konservatori, dan ditanam untuk proses pengenalan dan kajian fenologi. Sebanyak 109 spesies orkid milik 39 genera telah diselamatkan dari habitat mereka yang terganggu. HST mempunyai kepadatan orkid yang lebih tinggi daripada tapak pembalakan kerana keadaan habitat dan proses penjanaan tenaganya lebih baik. Walau bagaimanapun, hutan yang ditebang memiliki kepelbagaian orkid yang lebih tinggi (H = 4.50 dan D = 0.99) dengan 11 spesies yang jarang ditemui bersama-sama dengan empat spesies endemik, dan didominasi oleh orkid epifit, dimana kejadian ini dipengaruhi oleh jumlah pokok-pokok tumbang, jangka masa pendedahan kepada tekanan kekeringan dan keadaan tanah yang tidak subur. Daripada kajian semasa ini, 38 spesies direkodkan sebagai rekod baru untuk Terengganu dan empat spesies adalah rekod baru untuk Kelantan. Selain itu, 280 spesies orkid dari koleksi awal di hutan terganggu di negeri Terengganu yang juga turut disenaraikan dengan sejumlah 86 spesies orkid adalah rekod baru untuk Terengganu, dan satu spesies adalah rekod baru untuk Malaysia; *Crepidium oculatum*; dan satu spesies adalah rekod baru bagi Semenanjung Malaysia;, *Dendrobium agamense*. Menariknya, sembilan spesies baru juga turut dijumpai, di

mana lima spesies siap dihuraikan; *Bromheadia petuangensis*, *Dendrobium ainiae*, *Dendrobium ruseae*, *Dendrobium mizanii*, dan *Pinalia domii*. Kajian ini juga bertujuan untuk menilai daya tahan orkid liar dalam menghadapi gangguan alam sekitar yang berpunca dari aktiviti manusia. Orkid liar menggunakan dua mekanisme pengimbangan air dalam tindak balas mereka kepada tekanan dari kekeringan, haba dan kekurangan air atau kelembapan di hutan terganggu, iaitu mekanisme "elak kemarau" dan mekanisme "lari kemarau". Misi menyelamatkan orkid liar ke *ex-situ* konservatori telah terbukti berkesan kerana semua orkid yang diselamatkan telah hidup dengan 70.6% daripada mereka telah direkodkan berbunga atau berbuah beserta dengan petunjuk kemungkinan pendebungaan silang berlaku di kalangan mereka. Sepuluh spesies telah dicadangkan di bawah kategori terancam mengikut Senarai Merah Kategori dan Kriteria IUCN versi 13 (Mac 2017). Strategi pemuliharaan juga telah digubal untuk orkid hutan terganggu dengan cadangan mengenai amalan mampan dalam pengurusan hutan untuk mengelakkan kepupusan tempatan orkid liar ini.

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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 Master of Science. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

%Ao	Relative Abundance of the Orchid Species
%Ff	total number of flowering or fruiting occurrences of an orchid species
Δ	Elevation
µmol $m^{-2}s^{-1}$	micro moles per square meter per second of Photosynthetically Active Radiation (PAR)
26S rDNA	large-subunit (LSU) ribosomal DNA
a.s.l	above sea level
atpB	ATP synthase subunit beta
ANOVA	Analysis of variance
APG	Angiosperm Phylogeny Group
ARH	Air Relative Humidity
BERNAMA	Berita Nasional Malaysia
c.	Circa (about)
CAM	Crassulacean acid metabolism
cf.	'confer' or a possible identity, or at least a significant resemblance
CITES	Convention on International Trade in Endangered Speciesof Wild Fauna and Flora
CM	Common species
CR	Critically Endangered
D	Simpson Diversity Index
DD	Data Deficiency
DNA	Deoxyribonucleic acid
DSFs	Disturbed Secondary Forests

E	Evenness
E (cardinal direction)	East
ED(PM)	Endemic species to Peninsular Malaysia
EW	Extinct in the Wild
Ex	Extinct
Ff	number of flowering or fruiting occurrences of an orchid species
FRIM	Forest Research Institute Malaysia
GPS	Global Positioning System
H	Shannon Diversity Index
HSK	Hutan Simpan Kekal
IUCN	International Union for Conservation of Nature
IUCN/SSC	IUCN Species Survival Commission
Jhr	Johor
Kd	Kedah
Kl	Kelantan
Km	Kalimantan
LAT	Latitude
LC	Least Concern
LI	Light Intensity
LONG	Longitude
Lux	SI derived unit of illuminance and luminous emittance, measuring luminous flux per unit area
Lx	Lux unit
M	Malaysia
matK	Maturase K gene

Ml	Melaka
N (cardinal direction)	North
Nad1	Nicotiana alata Defensin 1
NATIP	National Timber Industry Policy
NE	Not Evaluated
NFA	National Forestry Act
NFP	National Forestry Policy
NT	Near Threatened
PERHILITAN	Jabatan Perlindungan Hidupan Liar dan Taman Negara Semenanjung Malaysia or Department of Wildlife and National Parks Peninsular Malaysia
PFR	Permanent Forest Reserve
Ph	Pahang
pi	proportion (n/N) of individuals of *i*th species found (n) divided by the total number
Pk	Perak
plants/m^2	total number of plants per square metre
plbs	protocorm-like bodies
PM	Peninsular Malaysia
Pn	Penang
psaB	Photosystem I P700 chlorophyll a apoprotein A2
r	bivariate correlation value in Pearson's Correlation Coefficient
rbcL	Ribulose-bisphosphate carboxylase gene
RR	Rare species
s or S	number of species in the community
Sbh	Sabah

SINAR	a Malay language daily newspaper or articles published in Shah Alam, Selangor, Malaysia
Sl	Selangor
SM	Soil Moisture
Swk	Sarawak
Tg	Terengganu
trnL-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
WCSP	World Checklist of Selected Plant Families
Xdh	Xanthine dehydrogenase gene

CHAPTER 1

INTRODUCTION

1.1 General

The largest and commonly visited ecotourism areas in the Peninsular Malaysia's National Park region are the Kuala Koh and Kenyir Lake areas. Kuala Koh is located in the National Park's northern entrance 85 km east of Gua Musang continent and borders Kelantan in the west and Pahang in the south. Meanwhile, Kenyir Lake is an artificial lake located in Hulu Terengganu, Terengganu. Both areas have been gazetted as a protected forest reserve and registered under the National Park Enactment itself. Here are plenty of attractions in terms of both geologically and biologically (Hairul, Ramle, Mohamad, and Asmawi, 2016). Geographically, before it was being disturbed, the Kuala Koh, its surrounding areas, and Tanah Merah were made up of riverine or riparian forest, hill dipterocarp forest, and largely lowland dipterocarp forest. The shaded and humid environment encourages mosses to grow on the trees, makes the trees to be fully occupied by epiphytes, the moister-loving plant, largely orchids (Zotz and Winkler, 2013). In undisturbed forest vegetation, orchids also can be found on the ground as terrestrial and rock as lithophytes and relying on dead debris as saprophytes. However, both terrestrial and epiphytic orchids (mostly) have experienced population decreases mainly because of habitat loss and trees extraction activities, which these have driven many species close to extinction (Larson, 1992; Rauh, 1992; Dimmitt, 2000; Mondragon and Calvo-Irabien, 2006).

1.2 Problem Statement

The issue of logging is rampant throughout Peninsular Malaysia, mostly, in the permanent nature forest reserve and in the surrounding areas near the permanent forest reserve, the National Parks. The land clearance within Peninsular Malaysia is evidenced by both licensed and illegal activities. Lately, the beauty of the diversity in the Kuala Koh, its surrounding areas, and Tanah Merah was interrupted by some of the forbidden activities that have directly threatened the sustainability of the species. These areas now have the 'distinction' of being the area with the highest rate of deforestation in Peninsular Malaysia (Lye, 2000, 2005; Hairul *et al*., 2016). The forest clearing has also extensively spread to the Kenyir Lake in Hulu Terengganu, the nearest surrounding area of Kuala Koh. The logging activities were observed spreading to the area around the Kenyir Lake, including Gawi and Petuang areas, and are still rampant until today. The uncontrolled forest exploitation by timber industry, either legally or illegally, and excessive logging, and the natural disaster has posed a great threat to wild orchid species diversity. Normally, along jungle trails, these orchids are hardly to be seen as they are perched higher up on the tree branches seeking sunlight. But when the trees fall, plentiful of the epiphytic orchids all come tumbling down and being exposed to the direct sunlight or solar radiation and

dryness, and have gradually putting them at peril. In conjunction of the rampant forest destruction in the surrounding areas, the flood events have negatively affected the ecosystem balance, especially for the terrestrial orchids. Sadly, the well-being of orchid community in these such unprotected and depleted areas received less concern from people, including the government organizations and conservation biologist, partly due to the extreme and risky environment which have reduced the accessibility to these areas.

1.3 Objectives of Study

Originally, the idea was to evaluate the orchid diversity and conservation status in both disturbed and undisturbed forest in the Kuala Koh area. However, the permission was not granted by PERHILITAN to collect any biological materials or herbarium specimens from the primary forest within Taman Negara region, which this step is absolutely necessary prior to the taxonomic evaluation. Hence, the focus of this study was only on the diversity and distribution of orchid at risk in the disturbed area surrounding the Taman Negara region, concentrating mainly on disturbed secondary forests in Kuala Koh and Tanah Merah areas in Kelantan, and logging sites in Kenyir Lake area, Hulu Terengganu in Terengganu to provide inference for *ex-situ* conservation efforts.

Thus, the objectives of this study were:

1. to document orchids species that inhabit the the disturbed forests of Kuala Koh, its surrounding areas, and Tanah Merah
2. to examine the diversity and richness of orchids in the the disturbed forests of Kuala Koh, its surrounding areas, and Tanah Merah
3. to construct taxonomic keys to the species identified based on morphological characters
4. to evaluate the resilience of the orchids and their ability to colonize the disturbed habitats in the mentioned area based their habits and morphological characters and the habitat's ecology variations
5. to assess conservation status of orchids found in the disturbed forest according to IUCN Red List of Endangered Species Categories and Criteria version 13 (March, 2017) with inference for conservation.

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BIODATA OF STUDENT

Edward Entalai was born in a rural area in Nanga Gaat, Kapit, Sarawak, on 7th September 1992. He is the youngest child in the family and raised by a single mother since he was in the secondary school. He spent his early childhood in a lumber camp in Nanga Gaat when his father was working as a timber truck driver in the lumber camp, and they often lived a migratory life until he and his family were permanently settled in Kapit in 1997. He acquired his primary education in Sekolah Kebangsaan Sungai Kapit and his secondary education in Sekolah Menengah Kebangsaan Kapit. Then, he started his tertiary education by entering one-year pre-university preparatory programme in the Labuan Matriculation College in 2010. After that, he was offered a four years Bachelor Degree programme in Universiti Malaysia Pahang, studying Industrial Biotechnology, until he was graduated in 2015. He has always in love with botany field ever since he was an undergraduate student. Six months after his graduation, in March 2016, he was offered a Master of Science programme by Universiti Putra Malaysia. Pursuing an advanced degree is challenging, especially financially, but he holds to his dream to become a botanist and always believing in his passion as much as his mother does believe in him.

LIST OF PUBLICATIONS

Besi, E.E., Dome, N., Mustafa, M. and Go, R. (2018). Two new species of *Dendrobium* Sect. *Calcarifera* (Orchidaceae) from Terengganu, Peninsular Malaysia. *Malayan Nature Journal, 70*(3): 251-259.

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