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Comparison of the Diversity of Nepenthaceae, Orchidaceae and Zingiberaceae in Disturbed and Undisturbed Forests in Johor, Malaysia

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ABSTRACT
This study was carried out to compare the diversity of Nepenthaceae, Orchidaceae, and Zingiberaceae families in central Johor. The chosen locations are the Belumut Forest-Eco Park, Mo'akil Permanent Forest Reserve, and Soga-Perdana Permanent Forest Reserve, which have forest types categorized as, undisturbed forest, disturbed forest, and recovered forest, within each of the areas respectively. This research aims to compare the diversity of Nepenthaceae, Orchidaceae, and Zingiberaceae between the forest types and the study areas. A checklist of species belonging to the three families for the three study areas was created and updated and the determination of the effects of disturbance on the diversity of species that belong to the three families. The collection of data and specimens was done by the line transect method in triplicates per study site in each of the study areas (100 m long and 6 m wide). Specimens were collected, tagged along with their location and habitat details recorded. The Belumut Forest-Eco Park did not record any *Nepenthes* species out of the eight species present. The Mo'akil Permanent Forest Reserve had recorded eight species represented by all three families. The Soga-Perdana Permanent Forest Reserve had all three families represented with 6 species. Overall, twenty species from the three families were recorded (three *Nepenthes* species, five orchid species, and 13 Zingiberaceae species with three that were identified). Two of the species of Zingiberaceae are Peninsular Malaysia endemics which are *Scaphochlamys johorensis* from the Belumut Forest-Eco Park and *S. endauensis* from the Mo'akil Permanent Forest Reserve. The diversity of species varied depending on the level and the type of disturbances with the Mo'akil Permanent Forest Reserve being the most diverse for the three families due to there being environmental factors such as large variability between forest types and forest patch size.

Keywords: *Malaysia, Nepenthaceae, Orchidaceae, Undisturbed forests, Zingiberaceae*

1. INTRODUCTION

Forest degradation and the loss of biodiversity due to land-use change are the major issues being faced by many countries. Malaysia, one of the countries that are considered as a biodiversity hot spot, is currently undergoing rapid modernization and land-use changes. The effects of this land-use change have led to the mass deforestation of its lowland forests for agriculture and development [1]. This, the unprecedented rate of habitat loss could result in the fragmentation of forests, which in turn, will lead to the loss of biological diversity and genetic diversity among the species in the isolated patches left from deforestation [2].

The plant families of Nepenthaceae, Orchidaceae, and Zingiberaceae that occur in tropical rainforests are being threatened by the loss of their habitat. The loss of species from these three families will mean the loss of potential new economic and pharmacological products [3]. Aside from habitat loss, the overexploitation of plants that belong to the families of Nepenthaceae and Orchidaceae for the ornamental plant trade has made many species become threatened with extinction in the wild [4], [5]. The threats faced by orchids and *Nepenthes* are due to their popularity among plant collectors [4], [5].

This has already occurred with the local extinction of *Paphiopedilum fairrieanum* in Northeastern India which was brought on by the overcollection of wild plants [5]. Moreover, the Zingiberaceae family is mainly focused on utilization in the medical industry. Meanwhile, the Nepenthaceae and Orchidaceae have only been studied for their potential as new medicine sources, for example, *Nepenthes thorelii* is known to have anti-malarial naphthoquinones and was used as a traditional medicine in Thailand [6], and recently, studies about orchids that are used in traditional medicines were also conducted [7].

The comparison of the diversity of species of Nepenthaceae, Orchidaceae, and Zingiberaceae was conducted in the three areas of lowland forest located within the three districts in central Johor, namely Kluang, Batu Pahat, and Muar. The three locations are the Gunung Belumut Forest-Eco Park, Mo'akil Permanent Forest Reserve, and the Soga-Perdana Permanent Forest Reserve. The type of disturbances and the patch size vary between the three sites. The largest of the three sites is the Belumut Forest-Eco Park which is located within the Kluang Permanent Forest Reserve which is around 16,264 ha in area size. The area is made up of lowland dipterocarp forests below 300 m above sea level, with areas of hill dipterocarp forests and sub-montane forests found on the summit of Mt Belumut (1010 m) [8]. The Mo'akil Permanent Forest Reserve, is surrounded by agriculture and infrastructure development such as new housing estates and industrial zones. Moreover, this area is the second largest in size. This study area does not have much information on the size and area of the forest patch. The forest types that are represented within this area are lowland and hill dipterocarp forests. Furthermore, Soga-Perdana Permanent Forest Reserve is the smallest patch with an estimated size of 500 ha. This permanent forest reserve is surrounded by agriculture and development from expanding housing estates. This study area is located just 2.5 km away from Penggaram City (Batu Pahat City). The forest type that is represented within this area is lowland dipterocarp forests which are on steep hilly slopes [9].

The preliminary checklists that were done within the Kluang Permanent Forest Reserve where Belumut Forest-Eco Park is located and the Soga-Perdana Permanent Forest Reserve, had omitted the families of Nepenthaceae and Orchidaceae. However, they had included the Zingiberaceae family but had not been documented in detail [8], [9]. The Mo'akil Permanent Forest Reserve had no proper checklist of plants that belong to these three families as of recently.

This research aims to compare the diversity of Nepenthaceae, Orchidaceae, and Zingiberaceae between the forest types which were categorized as disturbed, undisturbed, and recovered forests within and between the three studies areas. A checklist of species that belong to the three families for the three study areas was created and updated. The determination of the effects of disturbance on the diversity of species that belong to the three families, was done by observing the habitat and comparing the Shannon-Wiener index value between sites and areas.

The comparative study was carried out data collection or sampling by conducting triplicate line transects per-forest sites (disturbed, undisturbed, and recovered) within the three study areas. The creation and updating of the checklist of species within these three areas, may help the future scientist to find their target species for pharmacological studies or for future ecological surveys to compare the new data with the preliminary data. So, it could be utilized to determine the changes in the composition of species and to add new records if it is founded [3]. Hence, checklist genera and population estimation are a prerequisite as a part of conservation planning.

2. METHODOLOGY

The study areas are located within central Johor, West Malaysia. These three sites that were chosen are the Belumut Forest-Eco Park, Mo'akil Permanent Forest Reserve, and the Soga-Perdana Permanent Forest Reserve. These three sites are located within the districts of Batu Pahat, Muar, and Kluang. Among the three chosen study areas, the largest is the Belumut Forest-Eco Park, which is located within the Kluang Permanent Forest Reserve at 16,264 ha and is a continuous area of

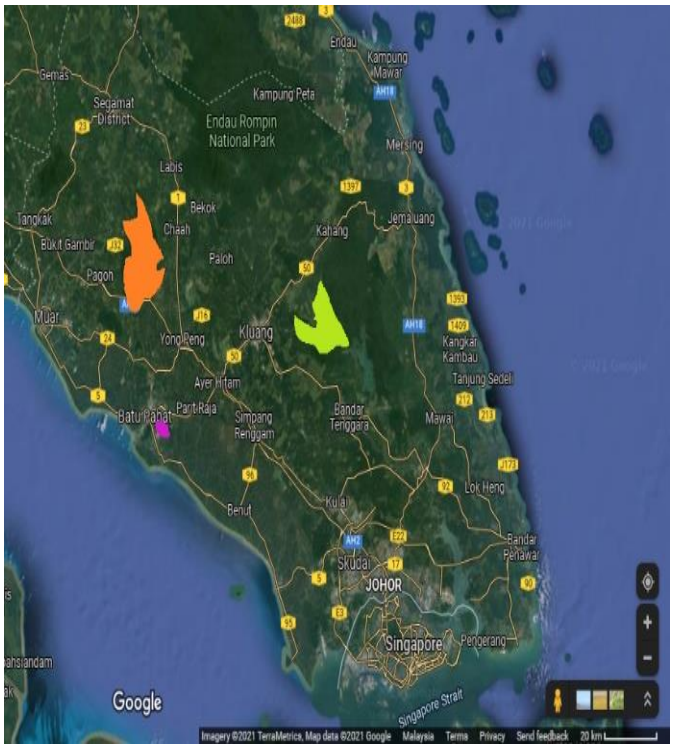

Figure 1. Location of Belumut Forest-Eco Park (light green), Mo'akil Permanent Forest Reserve (orange), and Soga-Perdana Permanent Forest Reserve (purple).

forests [3]. The second-largest study area is the Mo'akil Permanent Forest Reserve which is smaller than Kluang Permanent Forest Reserve. The third study area, which is the Soga-Perdana Permanent Forest Reserve, is the smallest and is an extremely fragmented forest patch surrounded by development [8]. The locations and the size of the three study areas are shown in Figure 1, within Johor, Malaysia. These study areas are highlighted with different colours to differentiate them. The Belumut Forest-Eco Park, located in the Kluang Permanent Forest Reserve is highlighted in light green, the Mo'akil Permanent Forest Reserve in orange, and the Soga-Perdana Permanent Forest Reserves in purple.

2.1 Collection of Specimens

The plants that belong to the three families were sampled and collected using the line transect method. This method was chosen as it is suitable for the large areas and the uneven terrain of the three study areas [10]. The transects were done in triplicates within the three study sites inside the study areas (100 meter-long and 6 meters wide). Tags and their GPS coordinates along with habitat notes, elevation, and description were recorded. Live and herbarium specimens were collected along with photos of uncommon species taken for this study. The morphological characteristics of the specimens were recorded *ex-situ*. The characteristics namely, the leaf shape, size, the shape of the margin, venation (if applicable), the presence or absence of underground rhizomes (Zingiberaceae and Orchidaceae), presence and shape of pseudobulbs (Orchidaceae), shape and characteristics of the pitcher traps (*Nepenthes*), the colour of the top side and the underside of the leaf blade and the texture of the leaf (waxy, hairy, velvety or glaucous) were recorded by close observation of the specimens. The recorded morphological characteristics were used in the identification of the species, by referring to experts that specialize in that particular plant family or from literature review [11]. The specimens were collected by uprooting them carefully, making sure their root structures were not damaged according to the standard operating procedure of voucher specimen collection [9]. The species that were collected were identified using identification keys and research papers. Species that belong to the Nepenthaceae family were identified using the book entitled "A Guide to The Pitcher Plants of Peninsular Malaysia" [12], while, the species that belong to the Orchidaceae family were identified using the orchid identification key titled "The orchids of Peninsular Malaysia and Singapore" [13]. The species that belong to the Zingiberaceae were identified using the identification key titled "The Zingiberaceae of the Malay Peninsula" and from a research paper [14], [15].

The number of species and individuals of each species that successfully recorded are including the unidentified species which was omitted from the checklists, and interpreted using the Shannon-Wiener index of diversity. The Equation (1) for the Shannon-Wiener index of diversity is shown below. *Pi* is the proportion of the total sample represented by the species, divided by the number of individuals of species by the total number of samples.

$$(H) = -\sum_{i=1}^{m} (Pi * ln(Pi)) \quad (1)$$

The Shannon-Wiener index values are used to compare the diversity between the three study areas and also between the forest types based on the categorized level of disturbance (disturbed, undisturbed, and recovered forests) within a study area.

3. RESULTS AND DISCUSSION

Within the Belumut Forest-Eco Park study area, eight species of plants were recorded (three species of Orchidaceae and five species of Zingiberaceae). There were no species that belong to the Nepenthaceae family recorded in all three study sites in this study area. Four species of plants that belong to the family Zingiberaceae and two species that belong to the Orchidaceae family were recorded from the recovered forest study site. Meanwhile, in the disturbed forest study site, three species that belong to the Orchidaceae family and two species that belong to the Zingiberaceae family were recorded. The undisturbed forest study site's forest floor that is dominated by *Licuala* palms has one species of Orchidaceae and three Zingiberaceae species that were successfully recorded. The endemic ginger species *Scaphochlamys johorensis* (Sam. Y. Y) was found within all three sites, while an epiphytic species of orchid *Ceologyne foestermanii (*Rchb. F) was only documented from the disturbed forest site. The presence of *Ceologyne foestermanii (*Rchb. F) within the disturbed forest study site, might be due to the special microclimate that the site has, because it is not present in the undisturbed and disturbed forests study sites. A study about the diversity of orchids in disturbed and undisturbed forests in Kelantan and Terengganu states in northern Malaysia, showed that there is a higher diversity of epiphytic orchid species within disturbed sites than undisturbed sites as the environmental conditions such as light intensity and airflow. This creates a suitable microclimate for epiphytic orchid species to thrive [1].

The Mo'akil Permanent Forest Reserve study site has eight species of plants from the three families respectively (two Nepenthaceae species, two Orchidaceae species, and four Zingiberaceae species) that were successfully documented. The disturbed forest study site of this study area had been logged and terraced within the last ten years. In this site, two species of *Nepenthes* were documented with one of them being a natural hybrid (*Nepenthes x tricocarpa* Miq). The recovered forest study site has a higher number of species

documented than the disturbed forest study site, with one species belonging to the Orchidaceae family and three species belonging to the Zingiberaceae family, with no *Nepenthes* species recorded. The third site is the undisturbed forest study site and has one species that belongs to the Orchidaceae family and two species that belong to the Zingiberaceae family where, *Scapochlamys endauensis* (Sam. Y. Y. & Ibrahim. H.), have been documented in this study site and nowhere else.

The Soga-Perdana Permanent Forest Reserve study area, has the least number of species that were documented within the three study sites, which are six species (one species belongs to the Nepenthaceae family, one species belongs to the Orchidaceae family and four species belong to the Zingiberaceae family). The recovered and undisturbed forests study sites have only two species that belong to the Zingiberaceae family in each of the two study sites respectively (4 species). The disturbed forest study site has three species with each being represented by one of the three target families (Nepenthaceae with one species, Orchidaceae with one species, and Zingiberaceae with one species).

3.1 Comparison of Diversity

The Shannon-Wiener index of diversity (H) between the study sites and the study areas shows noticeable differences between the disturbed, undisturbed, and recovered forests which have resulted from both anthropogenic and natural disturbances, and also between the three study areas.

The Shannon-Wiener index values for the study sites of the Belumut Forest-Eco Park study area are different from each other. The (H) value for the undisturbed forest is the highest. It is followed by disturbed forest and finally recovered forest. The trend of the increasing diversity in this area shows a difference, which is the undisturbed forest and disturbed forest are more diverse in comparison to the site of the recovered forests. This goes against the normal trend where the undisturbed forest would have the greatest diversity of species as the level of disturbance at the disturbed forest site had shown a low level of disturbance. This disturbance is the result of a natural source [1], and in this case, it is due to the topsoil layer not being damaged by the natural disturbance, which had added more organic matter to the forest floor as observed on the site.

The Shannon-Wiener index values of the three sites in the Mo'akil Permanent Forest Reserve study area show that the (H) value of the site of recovered forests is the highest among other sites. It is followed by undisturbed forests and then disturbed forests. The trend of the disturbed forests that have the lowest number of species could be explained by the lower diversity of orchid species in this area that was recently logged due to the removal of the topsoil layer [1]. The greater diversity of species within the recovered forest site compared to the undisturbed site is due to the higher number of resources present in the form of light intensity [1].

The Shannon-Wiener index values for the Soga-Perdana Permanent Forest Reserve study area show that the highest (H) value is from the disturbed forests study site, followed by undisturbed forests and the lowest is the recovered forests. Table 1 presents the comparison of the Shannon-Wiener index value (H) of the disturbed (D), undisturbed (UD), and recovered (R) sites from the three study areas of Belumut Forest-Eco Park, Mo'akil Permanent Forest Reserve, and Soga-Perdana Permanent Forest Reserve.

Table 1. Comparison of the Shannon-Wiener index values (H) of the study sites of the three study areas

Study areas	Shannon-Wiener index value (H) of the study sites		
	D	UD	R
Belumut Forest-Eco Park	1.2338	1.2471	0.8428
Mo'akil Permanent Forest Reserve	0.6616	0.8069	1.0117
Soga-Perdana Permanent Forest Reserve	0.7741	0.6365	0.4949

The varying diversity between the three study areas and their study sites is due to environmental factors such as soil fertility, the level of disturbances, and the microclimate of the study sites [1]. This trend of species diversity from site to site based on the level of disturbances is the evidence in both the undisturbed and recovered forests study sites as seen in the Belumut Forest-Eco Park study area. This is due to more species that are adapted to the disturbed forests site's conditions being found within the Soga-Perdana Permanent Forest Reserve compared to the other study areas [1]. Furthermore, a normal trend in smaller and isolated forest fragments is having a lower number of species that can thrive within them [15].

3.1.1 Overall diversity Between the Three Study Areas

The Shannon-Wiener diversity calculations for the three study areas show that, the Mo'akil Permanent Forest Reserve study site has the highest diversity followed by the Belumut Forest-Eco Park and Soga-Perdana Permanent Forest Reserve which has the smallest value. This trend shows how patch size, habitat variability, and environmental factors could affect the diversity of species [16]. The comparison of the Shannon-Wiener index value (H) of the three study areas is presented in Table 2, while Figure 2 shows the chart of

the Shannon-Wiener index value (H) against study areas in order of the increasing area size.

Table 2. Shannon-Wiener index value (H) of the three study areas

Study areas	Shannon-Wiener index value (H)
Belumut Forest-Eco Park	1.445
Mo'akil Permanent Forest Reserve	1.438
Soga-Perdana Permanent Forest Reserve	0.774

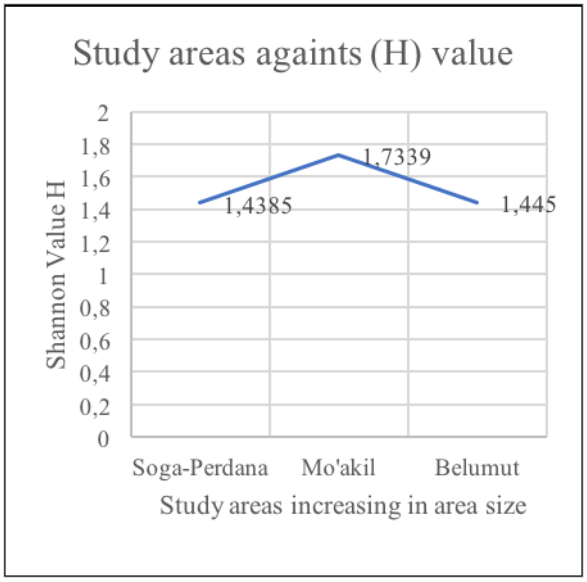

Figure 2. Chart of increasing area size and Shannon diversity index Value H

3.2 Checklist of Species of Nepenthaceae, Orchidaceae, and Zingiberaceae

Twenty species of plants from the three families were recorded within the three study areas (three species of *Nepenthes*, five genera and species of orchid, and 13 from four genera with 10 unidentified species). Two of these are Peninsular Malaysia endemics which are *Scaphochlamys johorensis* (Sam. Y. Y) that only collected from the Belumut Forest-Eco Park and *S. endauensis* (Sam. Y. Y & Ibrahim. H) that was collected from Mo'akil Permanent Forest Reserve. The checklist only includes the species that have been identified. Tables 3, 4, and 5 show the list of identified species and their distribution between the three forest types were disturbed, undisturbed, and recovered forest are abbreviated into D, UD, and R respectively.

Table 3. List of species in Belumut Forest-Eco Park study area

No	Families/ Species	Location (Study sites)		
		D	UD	R
Orchidaceae				
1	*Apotasia nuda* R. Br	√	√	√
2	*Ceologyne foestermanii* Rchb. F	√		
3	*Claderia viridiflora* Hook. F.	√		
Zingiberaceae				
4	*Scaphochlamys johorensis* Sam. Y Y.	√	√	√

Table 4. List of species in Mo'akil Permanent Forest Reserve study area

No	Families/ Species	Location (Study sites)		
		D	UD	R
Nepenthaceae				
1	*Nepenthes ampullaria* Jack.	√		
2	*Nepenthes* x *trichocarpa* Miq	√		
Orchidaceae				
3	*Apotasia nuda* R. Br		√	
4	*Corymborchis veratrifolia* Reinw.			√
Zingiberaceae				
5	*Globba pendula* Roxb		√	√
6	*Scaphochlamys endauensis* Sam.Y Y.& Ibrahim. H.		√	

Table 5. List of species in Soga-Perdana Permanent Forest Reserve study area

No	Families/ Species	Location (Study area)		
		D	UD	R
Nepenthaceae				
1	*Nepenthes gracilis* Korth.	√		
Orchidaceae				
2	*Nervilia punctata* (Blume) Makino	√		

3.2.1 Checklist of Species of Nepenthaceae, Orchidaceae, and Zingiberaceae in the three study areas

Table 6. Checklist of species and the location they were recorded in.

No	Families/ Species	Location (Study area)		
		Blm F-EP	Mk PFR	S-P PFR
Nepenthaceae				
1	*Nepenthes ampullaria* Jack.		√	
2	*Nepenthes gracilis* Korth.			√
3	*Nepenthes* x *trichocarpa* Miq		√	
Orchidaceae				
4	*Apotasia nuda* R. Br	√	√	
5	*Ceologyne foestermanii* Rchb. F	√		
6	*Claderia viridiflora* Hook. F.	√		
7	*Corymborchis veratrifolia* Reinw.		√	
8	*Nervilia punctata* (Blume) Makino			√
Zingiberaceae				
9	*Globba pendula* Roxb		√	
10	*Scaphochlamys endauensis* Sam.Y Y.& Ibrahim. H.		√	
11	*Scaphochlamys johorensis* Sam. Y Y.	√		

(Legend: √ indicate the presence of species within the study area)

Twenty species of plants were documented and about 11 species were successfully identified. For the family of Nepenthaceae, all three species were identified as well as all five species of plants that belong to the Orchidaceae family. But for species that belong to the Zingiberaceae family, only three species out of nine were identified. Most of the documented species were only recorded within a certain study area, except for *Apotasia nuda* (R. Br), which was recorded in the Belumut Forest-Eco Park and Mo'akil Permanent Forest Reserve study areas. Table 6 shows the number of species from the three families and the location where they were recorded with the abbreviations of the location name with Belumut Forest-Eco Park as (Blm F-EP), Mo'akil Permanent Forest Reserve as (Mk PFR), and Soga-Perdana Permanent Forest Reserve as (S-P PFR).

3.3 Comparison of Disturbances

All three study areas were categorized as disturbed, undisturbed, and recovered forest types. The disturbances in the Mo'akil Permanent Forest Reserve and Soga-Perdana Permanent Forest Reserve are from an anthropogenic source while the disturbance in the disturbed forest site of the Belumut Forest-Eco Park study area is from natural sources, which have a low-level disturbance. The natural disturbance that occurred at the Belumut Forest-Eco Park had occurred two years prior, when a storm damaged a patch of the forest without affecting the topsoil layer. This has led to the growth of dense stands of tree saplings and palms which dominate the site due to the gap in the area from the multiple fallen trees. The recovered forest site of Belumut Forest -Eco Park has logged around 40 years ago (From an anonymous source).

The Mo'akil Permanent Forest Reserve, has had disturbances only from anthropogenic sources as most of the area of this forest is designated as a timber production forest (From anonymous source). The disturbed forests site was logged within the last ten years. The area had been cleared and terraced, resulting in the topsoil layer being stripped off. The terraced slopes are dominated by stands of *Dicanopteris linearis* and multiple species of pioneer trees and shrubs. The recovered forests site is located within a valley, where the soil is made up of alluvial deposits. There is evidence of logging roads and formerly terraced hill slopes that had been completely overgrown by secondary forests. The estimated time where logging had taken place was between 15 to 20 years prior. The undisturbed forests site is an area of lowland dipterocarp forest, about a kilometer Southwest of the other two sites, which had not had any logging done in the location's history. The forest floor is dominated by herbaceous plants that grow on steep slopes with many streams within the study site.

The Soga-Perdana Permanent Forest Reserve is similar to the Mo'akil Permanent Forest Reserve study area, as there had been logging done in the lower slopes and the fringes of the forest patch. The fringes of this study area are dominated by the stands of *Dicanopteris linearis* and *Acacia mangium*. These species had established themselves after the area was logged during the 1980s from the clearing of a British colonial era rubber tree plantation (source, conversation with Sivarajah Ampalavanar, 2019). The inner portion of this forest patch is mostly made up of undisturbed lowland dipterocarp forests where the location for the undisturbed forests study site was chosen.

3.3.1 Comparison of Disturbed Forests Between the Three Areas

The Mo'akil Permanent Forest Reserve and the Soga-Perdana Permanent Forest Reserve study areas are comparable to each other as they both have had disturbances that came from an anthropogenic source (Logging and hill terracing). In the disturbed forests of both study areas, the topsoil layer had been stripped off due to the terracing of the hill slope. This has led to *Belukar* vegetation being dominant in both the study areas' disturbed forests sites. The fern which is known as *resam* (*Dicanopteris linearis*) is the dominant ground cover along with pioneer species of trees and shrubs. This habitat is the preferred habitat for some *Nepenthes* species such as *Nepenthes gracilis, N. ampullaria*, and their hybrids [17]. Smaller forest patches usually have a smaller number of species present as resources are limited and the core area is smaller due to the greater edge effect on the small size of the forest patch [16].

The Belumut Forest-Eco Park study area has had low-level disturbance which was the result of a storm that had affected the area two years prior. The number of trees and the canopy density were greatly reduced allowing direct sunlight to reach the forest floor. The topsoil layer had not been disturbed which had allowed the establishment of dense stands of tree saplings and palms. This site had the second-highest number of species with five species recorded. The species present within the Belumut Forest-Eco Park study area are in two plant families which are Orchidaceae, *Apotasia nuda* (R. Br), *Claderia viridiflora* (Hook. F). and Zingiberaceae, *Scaphochlamys johorensis* (Sam Y. Y.), and two unidentified ginger species.

However, the Mo'akil Permanent Forest Reserve study area, the severely degraded habitat of the disturbed forest site which is dominated by ferns of the *Dicanopteris* and *Glechnia* genera has two species of *Nepenthes*, which are, *Nepenthes ampullaria* (Jack) and the natural hybrid *N. x trichocarpa* (Miq). The disturbed forests site of Soga-Perdana Permanent Forest Reserve has three species with each being represented by the families of Nepenthaceae, Orchidaceae, and Zingiberaceae. However, the other two study sites have only two species per-site. The three species were each from one of the three families, which are *Nepenthes gracilis* (Korth), for Nepenthaceae, *Nervilia punctata* (Blume), (Makino) for Orchidaceae, and an unidentified species of ginger that belong to Zingiberaceae. Figure 3 shows the preferred habitat for some *Nepenthes* species while Figure 4 shows the condition of the forest floor of the disturbed forests at Belumut Forest-Eco Park.

3.3.2 Comparison of Recovered Forests Between the Three Areas

The recovered forests within the three study areas were logged between 10 to 40 years ago. There were no *Nepenthes* species recorded in all three of the study area's recovered forests. The recovered forests site of the Belumut Forest-Eco Park study area, has a dense layer of topsoil on the forest floor. The forest canopy is noticeably denser with there being a mix of younger and older trees. The flora diversity of the forest floor is mostly herbaceous species along with many tree saplings.

Figure 3. The preferred habitat of certain *Nepenthes* species, is the disturbed forests of Soga-Perdana Permanent Forest Reserve study area.

Figure 4. Condition of the forest floor at the disturbed forests of the Belumut Forest-Eco Park study area.

The recovered forests of the Mo'akil Permanent Forest Reserve study area have a different topography from the other two study areas as it is a swampy habitat where the soil is mainly alluvial deposits. The tree canopy is quite dense and the area is located within a valley. This study site is dominated by dense stands of rattan and herbaceous plant species. The greatest number of species of plants was documented in the recovered forests site of the Belumut Forest-Eco Park with six species present. This site unlike the disturbed forests site of Belumut Forest-Eco Park which has a low-level natural disturbance. The disturbance that had occurred in the site of the recovered forest was from anthropogenic

sources. The diversity of plants in this site is due to the spillover effect of species from the surrounding of undisturbed forests that colonize the new habitat after logging in the area had ceased around 20 to 30 years ago [15].

The Soga-Perdana Permanent Forest Reserve has many patches of recovered forest similar to the other two sites, where the forest canopy is dense and dominated by young trees. The anthropogenic disturbances are more evident in this study area due to its proximity to Penggaram City. Only two recorded species were belonging to the Zingiberaceae family on this site. The lack of species in the Soga-Perdana site due to its smaller patch size and isolation from other forested areas which does not allow for the colonization of new species and also prevents gene flow among the species present at the study area [15].

Figure 5. The forest floor of the recovered forests of the Belumut Forest-Eco Park study area.

Figure 6. A stand of unidentified Zingiberaceae ssp at Soga-Perdana Permanent Forest Reserve recovered site.

The recovered forests in this study area have patches dominated by stands of *Acacia mangium* which will cause lower species diversity due to their habit of being allelopathic [18]. The species that present within the recovered forest of the Belumut Forest-Eco Park study are from the families Orchidaceae, *Apotasia nuda* (R. Br), *Claderia viridiflora* (Hook. F.), and from the family Zingiberaceae, where the endemic *Scaphochlamys johorensis* (Sam Y. Y.) and three unidentified ginger species were recorded from. The Mo'akil Permanent Forest Reserve study area has one species belonging to the family of Orchidaceae which is *Corymborchis veratrifolia* (Reinw.) and for the Zingiberaceae family, there are *Globba pendula* (Roxb) and two unidentified species. While in Soga-Perdana Permanent Forest Reserve only two unidentified species of ginger were found. Figures 5 and 6 show the condition of the forest floor at the Belumut Forest-Eco Park and Soga-Perdana Permanent Forest Reserve study areas.

3.3.3 Comparison of Undisturbed Forests Between the Three Areas

The undisturbed forest of the three study areas have not had any logging done in any way, with the undisturbed forests site of the Mo'akil Permanent Forest Reserve study area being considered as a virgin jungle (Anonymous person. September, 2019). The patch size of these undisturbed forests varies greatly in size between the three study areas. The Soga-Perdana Permanent Forest Reserve which is the smallest in terms of area size, has small isolated patches of undisturbed forests in the core region of the forest patch. No species were belonging to the Nepenthaceae family documented within the undisturbed forests of all three of the study areas. The lack of Nepenthes species may be due to the low light levels and the habitat, from the dense tree canopy and nutrient-rich soils, which, is unsuitable for Nepenthes species to thrive [17]. There were no observable disturbances in the undisturbed forests of the Belumut Forest-Eco Park study area. The forest floor is dominated by Licuala palms and the topsoil layer remains undisturbed. The tree canopy was denser than the disturbed forests site but is more open than the recovered forests site. The density of the undergrowth on the forest floor is sparse and there is a lack of tree saplings or shrubs. The undisturbed forests site of the Mo'akil Permanent Forest Reserve, was on steep slopes in contrast to the gently sloping terrain of the Belumut Forest-Eco Park and Soga-Perdana Permanent Forest Reserve study areas. The forest floor has a high diversity of herbaceous plants, shrubs, and palms. The forest canopy was dense and similar to the canopy of the undisturbed forests of the Belumut Forest-Eco Park study area, but was scarce with species belonging to the families of Orchidaceae and Zingiberaceae. The undisturbed forests site of the Soga-Perdana Permanent Forest Reserve study area was located in the core of the forest patch, on a plateau about 156 m above sea level. There was a lack of understory plants except for a few clumps of Zingiberaceae sp. The forest canopy was dense and as with the other two sites, there was a lack of species that were recorded. The Soga-Perdana Permanent Forest Reserve's smaller patch size and isolation from other forested areas would show this trend of lower diversity of species, regardless of the level and the type of disturbances [15]. Another reason for the lower number of recorded species is due to light intensity as more

species can establish in sites with higher light levels such as the case of recovered forests compared to undisturbed forests [19].

The number of species that were recorded in all three study areas was lowest in undisturbed forests with the Belumut Forest-Eco Park study area recording the following families, Orchidaceae, with Apotasia nuda (R. Br), Zingiberaceae with Scaphochlamys johorensis (Sam Y. Y.), and one unidentified ginger species. The Mo'akil Permanent Forest Reserve study area had recorded plants in the family Orchidaceae, with Apotasia nuda (R. Br) and for Zingiberaceae family had recorded the Peninsular Malaysia endemic Scaphochlamys endauensis (Sam Y. Y.& Ibrahim H.) and Globba pendula (Roxb). For Soga-Perdana Permanent Forest Reserve, there were only two unidentified species of Zingiberaceae recorded. Figures 7, 8, and 9 show the conditions of the undisturbed forest sites of the three study areas.

Figure 7. The understory of the undisturbed forests of Belumut Forest-Eco Park study area.

Figure 8. Undisturbed forests by a small river in Mo'akil Permanent Forest Reserve study area.

Figure 9. The undisturbed forest of Soga-Perdana with minimal understory plants

3.4 Suggestion of Appropriate Conservation Plans

The effect of disturbances and land-use change will pose a major threat to the diversity of species that belong to the families Nepenthaceae, Orchidaceae, and Zingiberaceae and species from other plant families which are considered endemic or are endangered species. Endemic species such as *Scaphochlamys johorensis* (Sam Y. Y.) which has a narrow geographical range are more susceptible to extinction [20]. A multi-faceted method of conservation must be addressed as we have to consider the ecological function of the species as the current trend mainly focuses on either *in-situ*, *ex-situ*, or genetic conservation. The understanding of the interactions of the species with its habitat should be considered along with genetic conservation such as *in-vitro* propagation and the creation of germplasm [20]. *Ex-situ* conservation should be done for endemic species which are facing extinction, while *in-situ* conservation should be done for species in well-protected habitats [21]. Aside from conservation, plant-based tourism would help to instill awareness of the importance of protecting endangered species, while also helping local communities and for the protection and conservation of the target species [22].

The conclusion of the study of the diversity of Nepenthaceae, Orchidaceae, and Zingiberaceae in disturbed, undisturbed, and recovered forests show the differences in the diversity of species based on the level of disturbances, habitat variability, and patch size as was seen in the Mo'akil Permanent Forest Reserve and Soga-Perdana Permanent Forest Reserve. Forest size also plays a role in the number of species found within a location. The objectives of the studies were fulfilled as the diversity of the three families Nepenthaceae, Orchidaceae, and Zingiberaceae were calculated and compared, which have resulted in a clear difference in the diversity of species based on the study area and the level of disturbance of the study sites. The identified species

were compiled into a checklist and the observations of the disturbances and the diversity were compared between the sites of the three study areas. Future studies like this should be carried out in other study areas focusing on the same diversity or other plant families.

AUTHORS CONTRIBUTIONS

Vinod – Collected and analyzed data and compiled this research paper manuscript.

Alona – checked overall research framework, ensured research proceeded on time, secured permit, checked, and corrected manuscript.

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REFERENCES

[1] E.E. Besi, D. Nikong, M. Mustafa, R. Go, Orchid diversity in anthropogenic-induced degraded tropical rainforest, an extrapolation towards conservation, vol. 19, Lankesteriana, 2019, pp. 107-24.

[2] S. Sani, The Encyclopedia of Malaysia: The Environment. Kuala Lumpur. Forest Management.1st ed. Kuala Lumpur: Institut Penyelidikan Perhutanan Malaysia (FRIM), 1998.

[3] M. Nesbitt, R.P. McBurney, M. Broin, H.J Beentje, Linking biodiversity, food and nutrition: The importance of plant identification and nomenclature, Journal of food composition and analysis, vol. 23, 2010, pp. 486-98.

[4] T.S Susanti, I. Kencanawati, The Composition of Plants In Nepenthes Spp Community in Customary Forest of Lingkat Lake Kerinci, Proceedings of the International Conference on Green Technology, vol. 8, 2018, pp. 71-78.

[5] K. Thammasiri, S.M. Khasim, & S.N. Hedge Orchid Biology: Recent Trends & Challenges, Singapore Springer, 2020.

[6] K. Likhitwitayawuid, R. Kaewamatawong, N. Ruangrungsi, J. Krungkrai, Antimalarial naphthoquinones from Nepenthes thorelii, Planta medica, vol. 64, 1998, pp. 237-41.

[7] B Pant, Medicinal orchids and their uses: Tissue culture a potential alternative for conservation, African Journal of plant science, vol. 7, 2013, pp. 448-67.

[8] ZA. Fitri, A.A. Latiff, Preliminary checklist of flowering plants in lowland forest at Kluang Forest Reserve, Kluang, Johor, Malaysia, Malayan Nature Journal, vol. 70, 2018, pp. 29-48.

[9] Jabatan Perhutanan Negeri Johor, Pelan Konsep Pembangunan Hutan Lipur Soga-Perdana. Nusajaya, Stillgreen Recreation, 2012, pp. 2-7.

[10] S.T. Buckland, D.L. Borchers, A. Johnston, P.A. Henrys, T.A Marques, Line transect methods for plant surveys, Biometrics, vol. 63, 2007, pp. 989-998.

[11] J. Hildreth, E. Hrabeta-Robinson, W. Applequist, J. Betz, J. Miller, Standard operating procedure for the collection and preparation of voucher plant specimens for use in the nutraceutical industry, Analytical and bioanalytical chemistry, vol. 389, 2007, pp. 13-17.

[12] C. Clarke, A Guide to The Pitcher Plants of Peninsular Malaysia, Natural History Publications (Borneo), 2002.

[13] G. Seidenfaden, J.J. Wood, R.E. Holttum, Theorchids of peninsular Malaysia and Singapore, Olsen & Olsen, 1992.

[14] R.E. Holttum, The Zingiberaceae of the Malay Peninsular, Gard Bull. Singapore, 1950.

[15] Y.Y. Sam, H. Ibrahim, L.G Saw, Four new species of Scaphochlamys (Zingiberaceae) from Peninsular Malaysia, Phytotaxa, vol. 221, 2015, pp. 21-34.

[16] M.A. Munguia-Rosas, S.G. Jurado-Dzib, C.R. Mezeta-Cob, S. Montiel, A. Rojas, J.M. Pech-Canché, Continuous Forest has greater taxonomic, functional and phylogenetic plant diversity than an adjacent naturally fragmented forest, Journal of Tropical Ecology, vol. 30, 2014, pp. 323-333.

[17] J.H. Adam, C.C. Wilcock, M.D. Swaine, The ecology and distribution of Bornean "Nepenthes", Journal of Tropical Forest Science, 1992, pp.13-25.

[18] O.O. Osunkoya, F.E. Othman, R.S. Kahar, Growth and competition between seedlings of an invasive plantation tree, Acacia mangium, and those of a native Borneo heath-forest species, Melastoma beccarianum, Ecological Research, vol. 20, 2005, pp. 205-214.

[19] J. Vandermeer, D. Boucher, I. Perfecto, I.G. de la Cerda, A theory of disturbance and species diversity: evidence from Nicaragua after Hurricane Joan, Biotropica, 1996, pp. 600-613.

[20] D. Ahmad, N. Wicaksana, T. Shimazaki, A. Kikuchi, S.A. Jato, K.N. Watanabe, Environmentally safe in vitro regeneration protocol for Curcuma, Kaempferia and Zingiber, African Journal of Biotechnology, vol. 10, 2011, pp. 8584-8592.

[21] L. Merciadri, Nepenthes clipeata, 2009.

[22] H. Setiawan, Nepenthes as tourism flagship species: The conservation strategies in Dayak Seberuang settlements area, Journal of Indonesian Tourism and Development Studies, vol. 5, 2017, pp. 113-120.