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Tree Species Composition, Diversity and Above Ground Biomass of Two Forest Types at Redang Island, Peninsula Malaysia

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Abstract

A study was conducted to determine the tree species composition, diversity and above ground biomass at Redang Island, Terengganu. Two plots of 0.1 ha were established at the inland forest and coastal forest of the island. As the result, a total of 387 trees ≥ 5 diameters at breast height (DBH) were recorded. The coastal forest recorded 167 individuals representing 48 species from 37 genera and 26 families while the inland forest had 220 individuals representing 50 species from 43 genera and 25 families. *Shorea glauca* (Dipterocarpaceae) was the most important species at the coastal forest with a Species Importance Value Index (SIV_i) of 10.5 % while *Dipterocarpus costulatus* (Dipterocarpaceae) was the most important species at the inland forest with 13.8 %. Dipterocarpaceae was the most important family in both forest plots with FIV_i at 20.4 % in the coastal and 21.5 % in the inland forest. The Shannon-Weiner Diversity Index (H') was considered high in both forest plots with 3.4 (H'_{max} = 3.9) at the coastal forest and 3.5 (H'_{max} = 4.0) at the inland forest. Sorenson's Community Similarity Coefficient (CCs) showed that tree species communities between the two forest plots had moderate similarity with CC = 0.5. The Shannon Evenness Index (*J*') in the two forest plots was 0.89. The total above ground biomass at the coastal forest was 491 t/ha and at the inland forest it was 408 t/ha. From all the species recorded in this study, 11 species were listed as threatened species by IUCN Red Data Book, of which four were listed as endangered and critically endangered, six were listed as lower risk and one species was listed as vulnerable.

Keywords: Peninsular Malaysia, Redang Island, tree species diversity, above ground biomass, floristic variation

Introduction

Redang Island is the second largest island of Peninsular Malaysia. Redang Island is located in the South China Sea off the northeast coast of Peninsular Malaysia within 5°44' - 5°50' North latitude and 102°59' - 103°5' East longitude (**Figure 1**). It lies approximately 45 km north-northeast of Kuala Terengganu, the state capital of Terengganu, and about 22 km off Tanjung Merang, the closest point on the mainland. The Redang Island Archipelago comprises nine islands. The main island is one of the two inhabited islands of the Redang Island Archipelago with at present 1,300 or so inhabitants from more than 200 families which are primarily engaged in traditional fishing-related activities (Ridzwan & Sharifah [1]).

In 1991, Redang Island was declared a Marine Park in Malaysia and is currently managed by the Ministry of Natural Resources and Environment (NRE), Malaysia. Redang Island consists of lowland, coastal and mangrove forest. Forests contributed many socioeconomic benefits in terms of goods and services (such as forestry

and fisheries resources) [1]. They also serve as critical biodiversity conservation storehouses and provide refuge for many species of plants and animals [2-4]. According to Whitmore [20] forests are important in the hydrological cycle, breaking the impact of heavy rainstorms on the soil, increasing penetration of water into the soil, slowing water run-off and minimizing erosion. The forest of Redang Island is currently the largest 'land use' in the island. Some parts of the Redang Island forest have been cleared for agriculture (coconut, clove and rubber plantations) but they failed due to the thin layer of topsoil and scarcity of water [1]. In 2003, an airport was developed at Redang Island to create an easy access point for tourists visiting this island.

The development of the airport, settlements and resorts has led to habitat destruction for the flora and fauna of Redang Island. The first resorts on Redang Island appeared around the late 80s. In 2007 a total of 14 resorts were already operational [5]. For a sustainable tourism industry development at this island it is important that the flora and fauna be well protected. A study on the vegetation of Redang Island was conducted by the Marine Park of Malaysia in 1996 to determine the biodiversity of Redang Island [1]. However, this study focused more on marine biodiversity with just a few surveys on the plants of Redang Island carried out. As part of the Terengganu State Park, a lot of baseline data are needed to effectively manage and conserve this area. Thus, the objective of this study was to determine the trees species composition, diversity and above ground biomass in the lowland forest of Redang Island. The data and information on the tree species community structure and diversity from this study can also be used as a guideline for future ecological studies on the forests of Redang Island.

Materials and method

The area of Redang Island is 1909 ha^2 and it is surrounded by Pinang Island, Ling Island, and Ekor Tebu Island. The total area of forest cover at Redang Island is 1,200 ha^2 [1]. Most of Redang Island is below 300 m above sea level. The Redang Island Archipelago experiences a tropical climate and is strongly influenced by the north-east monsoon (November to March) which brings heavy rain, strong winds and big waves. The rainfall measurements for the month of December can reach 615 mm compared to only 120 mm in April [1].

We chose to establish the study plots at two different areas, and in each site we established a plot of 0.1 ha which consisted of five subplots of 20 × 10 m. The two areas comprised: (1) the coastal forest which we classified as the forest where the trees were within 100 m from the sea and (2) the inland forest which was located in the island's interior (**Figure 2**). The plots were established in a forest area, i.e., the shrub vegetation along the coast was avoided. All trees with a diameter at breast height (DBH) of 5 cm and above were measured, identified, and leaf samples were collected. These samples were later identified using the *Tree Flora of Malaya* [6-9] and by comparison with the voucher specimens present at the National University of Malaysia Herbarium (UKMB).

The above ground biomass of trees in the study plots was estimated using the regression formula proposed by Kato *et al.* [10] which was developed from the data that they gathered in a study using destructive sampling methods at the Pasoh Forest Reserve, a lowland dipterocarp forest. The formula uses the tree diameter to calculate basal area (BA), tree height (H), the biomass of stems (W_s), branches (W_b) and leaves (W_l). To express the structure of the plant community, several characteristics were taken into consideration, including species composition, species diversity and species relative abundance. Parameters used to determine species abundances were density, dominance, frequency, and Importance Value Index (IV_i) at species and family levels [11]. Species diversity considers both the number of species in a defined sampling unit (species richness) and the distribution of individuals among species (species evenness) to show relative abundance of the species. In this study, species diversity was measured using the Shannon-Weiner Index of Diversity. The Margalef Richness and Shannon Evenness Indices were also calculated, based on Magurran [12].

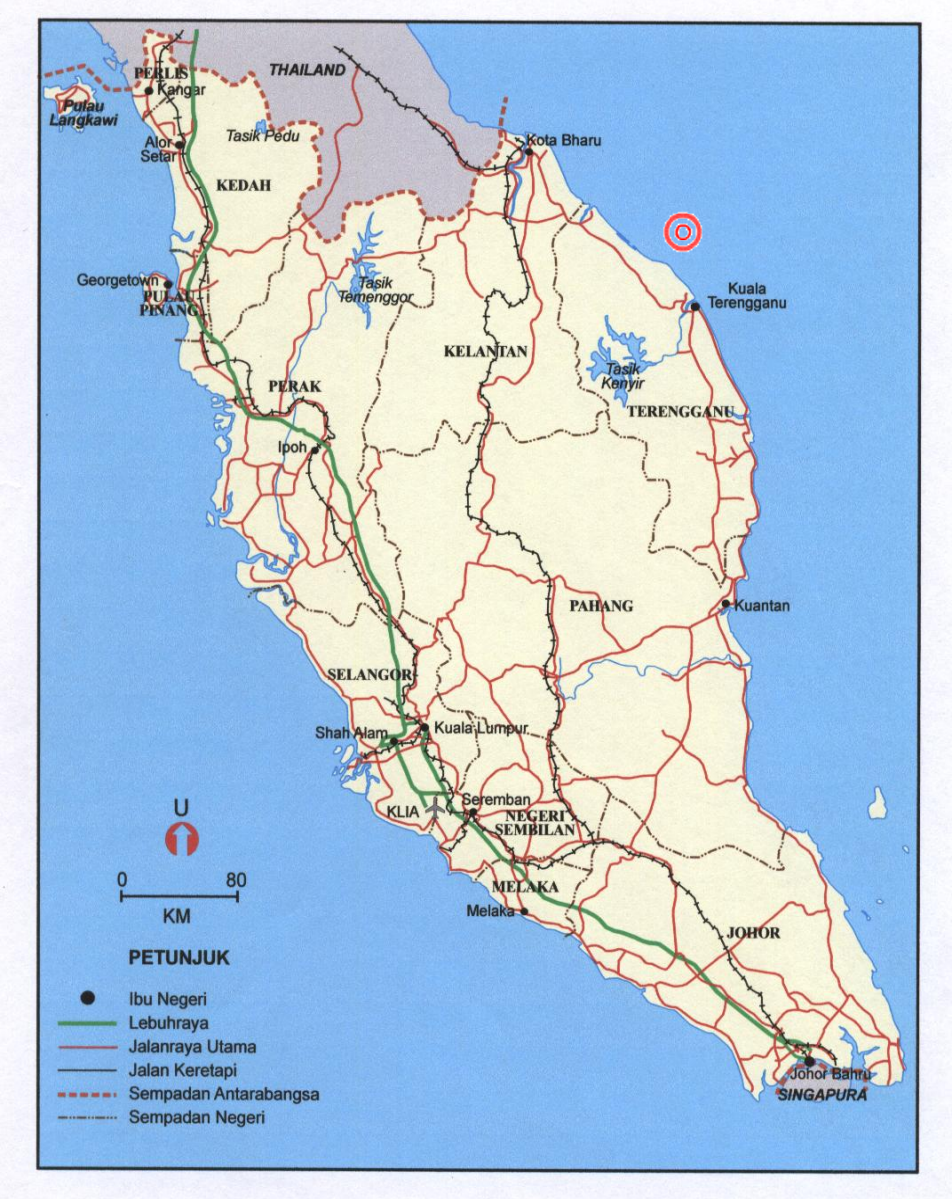

Figure 1 The location of Redang Island, indicated by the red circles off the coast of Terengganu.

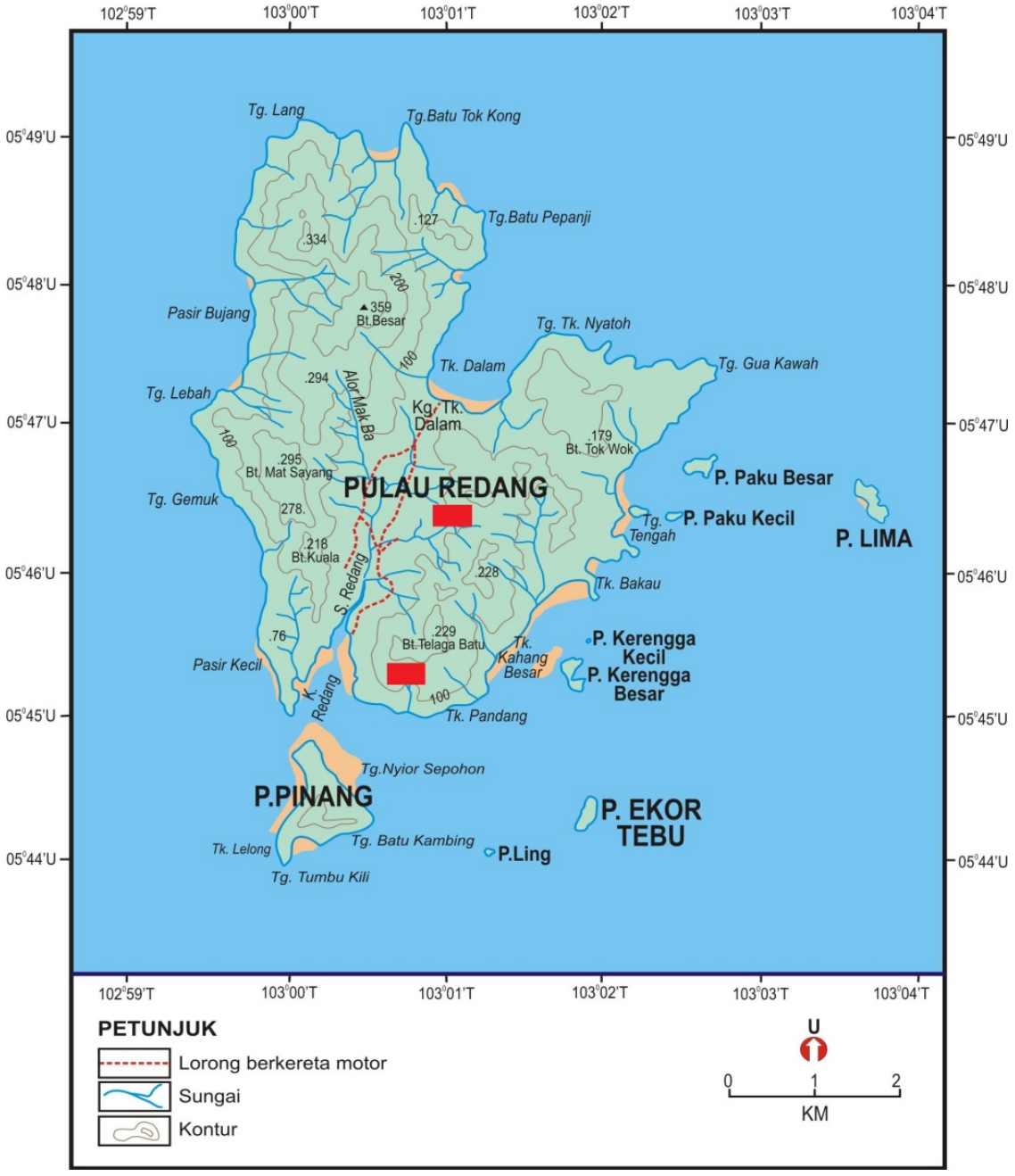

Figure 2 The location of the study sites, indicated by the red squares.

Results

Taxonomic composition

The study recorded a total of 387 trees of 72 species from 54 genera and 31 families. A total of 167 individuals of 48 species from 37 genera and 26 families were recorded in the coastal forest. In the inland forest, a total of 220 individuals of 50 species from 43 genera and 25 families were recorded (**Table 1**). In terms of stand density, a total of 1,670 ind/ha were recorded in the coastal forest and 2,200 ind/ha in the inland forest. Dipterocarpaceae had the highest density at the coastal and inland forest with 380 ind/ha and 360 ind/ha respectively. Based on species, *Vatica cinerea* had the highest density at the coastal forest with 240 ind/ha followed by *Shorea glauca*, *Mesua ferrea* and *Diospyros pilosanthera* var. *oblonga* with 110 ind/ha, respectively. At the inland plot, *Vatica cinerea* also had the highest density with 220 ind/ha, followed by *Garcinia nigrolineata* with 180 ind/ha and *Palaquium rostratum* with 130 ind/ha. The density of families and species at the two forest plots is shown in **Table 2**.

Table 1 List of taxonomic composition in the two forest plots at Redang Island, Terengganu.

Family	Coastal plot			Inland plot		
	Genera	Species	Ind	Genera	Species	Ind
Anacardiaceae	1	1	5	3	3	13
Annonaceae	1	1	1	nil	nil	nil
Burseraceae	1	2	10	1	2	7
Celastraceae	1	1	2	nil	nil	nil
Chrysobalanceae	2	2	2	nil	nil	nil
Cluisaceae	3	3	22	3	4	31
Dipterocarpaceae	2	3	38	3	3	36
Dracaenaceae	1	1	3	1	1	7
Ebenaceae	1	1	11	1	1	9
Euphorbiaceae	4	5	7	5	6	14
Fagaceae	1	2	2	1	1	1
Icacinaceae	nil	nil	nil	1	1	1
Lauraceae	2	3	5	3	3	4
Lecythidaceae	1	1	2	1	1	1
Loganaceae	nil	nil	nil	1	1	1
Melastomataceae	1	1	4	1	1	3
Moraceae	1	1	1	nil	nil	nil
Myrtaceae	2	4	10	2	4	17
Ochnaceae	nil	nil	nil	1	1	7
Opiliaceae	1	1	7	1	1	11
Polygalaceae	1	2	4	1	1	2
Rubiaceae	2	2	8	3	3	8
Santalaceae	1	1	1	1	1	1
Sapindaceae	1	1	1	nil	nil	nil
Sapotaceae	2	4	11	2	4	26
Simaraoubaceae	1	1	1	1	1	3
Sterculiaceae	nil	nil	nil	2	2	2
Symplocaceae	1	1	4	1	1	6
Theaceae	nil	nil	nil	1	1	5
Ulmaceae	1	1	1	nil	nil	nil
Verbenaceae	1	1	4	2	2	4

Table 2 Families and species with the highest density in the two forest plots at Redang Island, Terengganu.

Area	Family	Ind/ha	Species	Ind/ha
Coastal	Dipterocarpaceae	380	*Vatica cinerea*	240
	Clusiaceae	220	*Shorea glauca*	110
	Ebenaceae	110	*Mesua ferrea*	110
			Diospyros pilosanthera var. *oblonga*	110
Inland	Dipterocarpaceae	360	*Vatica cinerea*	220
	Clusiaceae	310	*Garcinia nigrolineata*	180
	Myrtaceae	170	*Palaquium rostratum*	130

Forest structure

Shorea glauca (Dipterocarpaceae) was the most important species in the coastal forest (**Table 3**) with a Species Importance Value Index (SIV_i) of 10.5 % followed by *Dacryodes rostrata* (Burseraceae) with 9.9 % and *Vatica cinerea* (Dipterocarpaceae) with 8.4 %. In the inland forest, *Dipterocarpus costulatus* (Dipterocarpaceae) was the most important species with a SIV_i of 13.8 %, followed by *Palaquium rostratum* (Sapotaceae) with 6.3 % and *Vatica cinerea* (Dipterocarpaceae) with 5.9 %, respectively. Dipterocarpaceae was the most important family in the coastal forest with a FIV_i of 20.4 %, followed by Burseraceae with 10.4 % and Myrtaceae with 10.3 %. In the inland forest, Dipterocarpaceae was also the most important family with a FIV_i of 21.5 %, followed by Sapotaceae with 12.2 % and Clusiaceae with 10.9 %.

Table 3 Dominant species and families based on the Importance Value Index (*IVi*) in the two forest plots at Redang Island, Terengganu.

	Coastal plot	Value (%)	Inland plot	Value (%)
Species (SIV_i)	*Shorea glauca*	10.5	*Dipterocarpus costulatus*	13.8
	Dacryodes rostrata	9.9	*Palaquium rostratum*	6.3
	Vatica cinerea	8.4	*Vatica cinerea*	5.9
Family (FIV_i)	Dipterocarpaceae	20.4	Dipterocarpaceae	21.5
	Burseraceae	10.4	Sapotaceae	12.2
	Myrtaceae	10.3	Clusiaceae	10.9

Species diversity and community similarity

The Shannon-Weiner Diversity index (H'), calculated using BIODAP software [13-15], for the coastal forest was 3.4 (H'_{max}= 3.9) and in the inland forest was 3.5 (H'_{max}= 4.0) (**Table 4**). The diversity of the tree species in both forests was nearly similar. According to Magurran [12], the value of H' usually lies between 1.5 and 3.5, although in exceptional cases, the value can exceed

4.5 and above. Therefore, the values found for the two types of forest were moderate. Based on the Shannon Evenness Index (J'), the two forest types have similar values, i.e. 0.88 versus 0.89. The Margalef Richness Index (R') revealed that the tree species richness in the coastal forest was 46.7 while in the inland forest it was 49.7. Similarity coefficients were used to measure the similarity of the species composition between the two sites and these indices are designed equal 1.0 in cases of complete similarity. Sorenson's Community Similarity Index value (CCs) as calculated for the two forest types was 0.512. This means that the two forest types share 51 % of the tree species. The occurrence of trees species in the two forest types is shown in **Table 5**.

Table 4 Species diversity indices for the two forest plots at Redang Island.

Indices	**Coastal plot**	**Inland plot**
Shannon-Weiner Diversity Index, H'	3.40	3.50
Shannon Evenness Index, J'	0.88	0.89
Margalef Richness Index, R'	26.7	29.7

Table 5 The tree species occurrences at the coastal and inland plot of Redang Island forest.

No.	**Family**	**Species**	**Coastal**	**Inland**
1	Lauraceae	*Actinodaphne* sp.	0	1
2	Euphorbiaceae	*Agrostistachys longifolia* (Wight) Benth.	2	0
3	Lauraceae	*Alseodaphne peduncularis* (Wall. ex Nees) Meisn	2	0
4	Lauraceae	*Alseodaphne* sp.	2	1
5	Euphorbiaceae	*Antidesma cuspidatum* Müll.Arg.	0	2
6	Moraceae	*Artocarpus nitidus* Trécul	1	0
7	Euphorbiaceae	*Baccaurea parviflora* (Müll.Arg.)	1	1
8	Euphorbiaceae	*Baccaurea racemosa* (Reinw.) Müll.Arg.	0	1
9	Lecythidaceae	*Barringtonia macrostachya* (Jack) Kurz	2	1
10	Anacardiaceae	*Bouea oppositifolia* (Roxb.) Meisn.	5	10
11	Anacardiaceae	*Buchanania arborescens* (Blume) Blume	0	2
12	Cluisaceae	*Calophyllum wallichianum* Planch. & Triana	8	9
13	Anacardiaceae	*Campylospermum serratum* (Gaertn.) Bittrich & M.C.E. Amaral	0	7
14	Fagaceae	*Castanopsis fulva* Gamble	1	0
15	Fagaceae	*Castanopsis* sp.	1	0
16	Opiliaceae	*Champereia manillana* (Blume) Merr.	7	11
17	Lauraceae	*Cinnamomum mollissimum* Hook.*f*.	1	0
18	Euphorbiaceae	*Croton laevifolius* Blume	0	7
19	Burseraceae	*Dacryodes costata* (Benn.) H.J. Lam,	0	2

20	Burseraceae	*Dacryodes longifolia* (King) H.J. Lam	1	0
21	Burseraceae	*Dacryodes rostrata* (Blume) H.J. Lam	9	5
22	Lauraceae	*Dehaasia cuneata* (Blume) Blume	0	2
23	Ebenaceae	*Diospyros pilosanthera* Blanco var. *oblonga* (Wall. ex G. Don) Ng	11	9
24	Rubiaceae	*Diplospora malaccensis* Hook. *f.*	0	2
25	Dipterocarpaceae	*Dipterocarpus costulatus* Slooten	0	10
26	Dracaenaceae	*Dracaena granulata* Hook.f.	3	7
27	Euphorbiaceae	*Drypetes longifolia* (Blume) Pax & K. Hoffm.	1	0
28	Euphorbiaceae	*Drypetes pendula* Ridl.	0	1
29	Euphorbiaceae	*Drypetes* sp.	1	0
30	Simaroubaceae	*Eurycoma longifolia* Jack	1	3
31	Cluisaceae	*Garcinia eugeniifolia* Wall. ex T. Anderson	0	2
32	Cluisaceae	*Garcinia nigrolineata* Planch. *ex* T. Anderson	3	18
33	Rubiaceae	*Gardenia tubifera* Wall. var. *tubifera*	5	0
34	Ulmaceae	*Gironniera parvifolia* Planch.	1	0
35	Sterculiaceae	*Heritiera javanica* (Blume) Kosterm.	0	1
36	Celastraceae	*Kokoona littoralis* Laws.	2	0
37	Fagaceae	*Lithocarpus* sp.	1	1
38	Chrysobalanaceae	*Maranthes corymbosa* Blume	1	0
39	Melastomataceae	*Memecylon floridum* Ridl., J. Straits Branch Roy	0	3
40	Melastomataceae	*Memecylon* sp.	4	0
41	Cluisaceae	*Mesua ferrea* L.	11	0
42	Cluisaceae	*Mesua kunstleri* (King) Kosterm.	0	2
43	Sapindaceae	*Mischocarpus sundaicus* Blume	1	0
44	Loganaceae	*Norrisia malaccensis* Gardner	0	1
45	Sapotaceae	*Palaquium obovatum* (Griff.) Engl.	3	7
46	Sapotaceae	*Palaquium rostratum* (Miq.) Burck	4	13
47	Sapotaceae	*Palaquium* sp.	2	2
48	Chrysobalanaceae	*Parinari costata* (Korth.) Blume ssp. *rubiginosa*	1	0
49	Euphorbiaceae	*Pimelodendron griffithianum* (Müll.Arg.) Benth.	1	0
50	Annonaceae	*Polyalthia* sp.	1	0
51	Rubiaceae	*Porterandia anisophyllea* (Jack *ex* Roxb.) Ridl.	0	1
52	Sapotaceae	*Pouteria malaccensis* (C.B. Clarke) Baehni	2	4
53	Rubiaceae	*Psydrax maingayi* (Hook.*f.*) Bridson	3	5
54	Myrtaceae	*Rhodamnia cinerea* Jack	2	1
55	Theaceae	*Schima wallichii* (DC.) Korth.	0	5
56	Santalaceae	*Scleropyrum pentandrum* (Dennst.) Mabb.	1	1
57	Dipterocarpaceae	*Shorea curtisii* Dyer *ex* King ssp. *curtisii*	0	4
58	Dipterocarpaceae	*Shorea glauca* King	11	0

59	Icacinaceae	*Stemonurus scorpioides* Becc.	0	1
60	Sterculiaceae	*Sterculia parviflora* Roxb. *ex* G. Don	0	1
61	Euphorbiaceae	*Suregada multiflora* (Juss.) Baill. var. *multiflora*	0	2
62	Anacardiaceae	*Swintonia schwenkii* (Teijsm. & Binn.) Teijsm. & Binn.	0	1
63	Symplocaceae	*Symplocos fasciculata* Zoll.	4	6
64	Myrtaceae	*Syzygium gratum* (Wight) S.N. Mitra	3	2
65	Myrtaceae	*Syzygium kunstleri* (King) Bahadur & R.C. Gaur	4	10
66	Myrtaceae	*Syzygium scortechinii* (King) P. Chantaranothai & J. Parn. var. *cuneatum*	1	4
67	Verbenaceae	*Teijsmanniodendron coriaceum* (C.B. Clarke) Kosterm	4	3
68	Dipterocarpaceae	*Vatica cinerea* King	24	22
69	Dipterocarpaceae	*Vatica lobata* Foxw.	3	0
70	Verbenaceae	*Vitex pinnata* L.	0	1
71	Polygalaceae	*Xanthophyllum eurhynchum* Miq.	3	2
72	Polygalaceae	*Xanthophyllum* sp.	1	0
		Total	167	220

Above ground biomass

The total above ground biomass of trees at DBH 5 cm and above in the coastal plot was estimated to be 491 t/ha whilst the inland plot value was estimated at 408 t/ha. Even though the coastal plot has fewer trees, they were relatively bigger trees, with a mean DBH of 12.78 ± 7.3 cm versus 11.19 ± 6.4 cm in the inland plot. These results were similar to Khairil *et al.* [15] who reported that the lake side and riverine forest had relatively higher above ground biomass and tree size compared to the inland forest at Chini watershed. Foo [13] and Norwahidah [14] also reported that the riverine forest had the higher value of above ground biomass compared to the inland forest. The factors such as tree size and forest gaps can influence the values of forest above ground biomass [15,16]. *Shorea glauca* had the highest tree biomass in the coastal forest with 130 t/ha while *Dipterocarpus costulatus* had the highest biomass in the inland forest with 98 t/ha. The Dipterocarpaceae was the family with the highest above ground biomass at both the coastal and inland plots with 146 t/ha and 102 t/ha, respectively (**Table 6**).

Table 6 The highest tree biomass (t/ha) of species and families at the two forest plots at Redang Island.

Plot	**Species**	**(t/ha)**	**Family**	**(t/ha)**
Coastal	*Shorea glauca*	130	Dipterocarpaceae	146
	Dacryodes rostrata	60	Burseraceae	61.4
	Vatica cinerea	13	Myrtaceae	60
Inland	*Dipterocarpus costulatus*	98	Dipterocarpaceae	102
	Palaquium rostratum	15	Anacardiaceae	25
	Vatica cinerea	3	Sapotaceae	24

Endemism and conservation status

A total of six species were identified as endemic species to Peninsular Malaysia which represents 8.3 % from the total 72 species in this study (**Table 7**). Ng *et al.* [17] stated that there are 2,830 tree species found in Peninsular Malaysia and the number of endemic tree species is 746, thus representing 26.4 % of the total number of species. Therefore, the endemic species number found in this study is low compared to the average in Peninsular Malaysia. It maybe because the study sites were small and the diversity of species in this island was lower compared to other areas in mainland Peninsular Malaysia.

Table 7 Endemic species in Peninsular Malaysia that were found at Redang Island, Terengganu.

Family	Species	Locations of endemism
Lauraceae	*Cinnamomum mollissimum* Hook.f.	Pn, Kl, Tg, Pk, Ph, Sl, NS, Ml, Jh
Burseraceae	*Dacryodes longifolia* (King) H.J. Lam	Kd, Kl, Tg, Pn, Pk, Ph, Sl, NS, Jh
Melastomataceae	*Memecylon floridum* Ridl.	Kl, Tg, Pk, Ph, Sl, NS, Sp
Rubiaceae	*Psydrax maingayi* (Hook.f.) Bridson	Ml and Ph northward
Cluisaceae	*Mesua kunstleri* (King) Kosterm. var. *kunstleri*	Tg, Ph, Pk, Sl, NS, Ml, Jh;
Dipterocarpaceae	*Vatica lobata* Foxw	Tg, Ph, Jh

Notes: Tg= Terengganu; Pn= Penang; Ml= Malacca; Pk= Perak; Ph= Pahang; Sl= Selangor; NS= Negeri Sembilan; Sp= Singapore; Jh= Johor; Kl= Kelantan.

Table 8 The conservation status of tree species in the 0.2 ha study area based on the 2011 IUCN Red List of Threatened Species [6].

Family	Species	Ind	Status list
Dipterocarpaceae	*Vatica cinerea* King	66	Endangered A1cd
Dipterocarpaceae	*Dipterocarpus costulatus* Slooten	10	Critically Endangered A1cd+2cd, B1+2c
Burseraceae	*Dacryodes rostrata* (Blume) H.J. Lam	14	Lower Risk/least concern
Dipterocarpaceae	*Shorea glauca* King	11	Endangered A1cd
Dipterocarpaceae	*Shorea curtisii* Dyer ex King ssp. *curtisii*	4	Lower Risk/least concern
Cluisaceae	*Mesua kunstleri* (King) Kosterm.	2	Lower Risk/least concern
Dipterocarpaceae	*Vatica lobata* Foxw.	3	Critically Endangered A1c, C2a
Chrysobalanceae	*Maranthes corymbosa* Blume	1	Lower Risk/least concern
Chrysobalanceae	*Parinari costata* (Korth.) Blume ssp. *rubiginosa*	1	Lower Risk/least concern
Sterculiaceae	*Sterculia parviflora* Roxb. ex G. Don	1	Lower Risk/least concern
Melastomataceae	*Memecylon floridum* Ridl., J. Straits Branch Roy	3	Vulnerable

A total of 11 species, representing 11.1 % of the 72 species recorded in the study area were found to be listed in the 2011 IUCN Red List Categories of WCMC 2011 [18]. These species were rated in four different threat categories: (1) low risk, (2) vulnerable, (3) endangered and (4) critically endangered. Based on **Table 8**, a total of six species were listed as lower risk, one species as vulnerable, two species as endangered and another two species as critically endangered. *Vatica cinerea* was listed as an endangered species but had the highest number with 66 individuals compared to other species. All the endangered and critically endangered species listed were from the family of Dipterocarpaceae.

Discussion

Taxonomic composition

The results showed that inland forest has the highest density of trees which is similar to Khairil *et al.* [15] who found that inland forest showed higher stem density compared to riverine and seasonal flood forest. The comparison of the taxonomic composition between this study and other studies in Peninsular Malaysia is shown in **Table 2**. Dipterocarpaceae had the highest density in both the coastal and inland forest with 380 ind/ha and 360 ind/ha, respectively. This result is different from that of Raffae [16] and Daud [19] at Langkawi Island, and Norwahidah [14] and Khairil *et al.* [15] at Chini watershed where Euphorbiaceae had the highest density in the inland forests. However, based on Whitmore [20], old growth forests in Malaysia are normally dominated by the Dipterocarpaceae. Therefore, this result indicates that Redang Island still has not been affected by large scale disturbances. The comparison of species composition at Redang Island, Terengganu and other studies in Peninsular Malaysia is shown in **Table 9**.

Forest structure

Shorea glauca (Dipterocarpaceae) was the most important species in the coastal forest with Species Importance Value Index (SIV_i) of 10.5 % and in the inland forest, *Dipterocarpus costulatus* (Dipterocarpaceae) was the most important species with a SIV_i of 13.8 %. Dipterocarpaceae was the most important family in the coastal forest with a FIV_i of 20.4 and also in the inland forest with a FIV_i of 21.5 %. These results are different from those of Raffae [16], Nurhashimah [21] and Khairil *et al.* [15] who reported that Euphorbiaceae was the most important family at their study sites. According to Curtis and Macintosh [22], species with an IV_i of more than 10 % and families with a FIV_i of more than 40 % can be considered dominant species or families in a particular community. Therefore, in this study, *Shorea glauca* and *Dipterocarpus costulatus* (Dipterocarpaceae) were clearly dominating the forests at the coastal and inland sites of Redang Island. However, no dominant family was identified in these two forest types.

Species diversity and community similarity

The Shannon-Weiner Diversity index (H') for the coastal forest was 3.4 (H'_{max} = 3.9) and in the inland forest was 3.5 (H'_{max} = 4.0). The observed values were lower compared to other studies such as Raffae [16] at Bukit Matchinchang, Langkawi Island with H' = 4.32, Rohaiza [19] at Pulau Timun and Pulau Singa Besar, Langkawi Island with H' values of 3.9 and 3.6. Ismail *et al.* [23] at compartment 156 Pekan Forest Reserve with H' = 4.12 and Khairil *et al.* [15] at Chini watershed with H' = 5.4. This may be because our study was carried out on a relatively small island compared to mainland sites where the diversity was relatively higher. Based on the Shannon Evenness Index (J'), the two forest types have similar values, i.e. 0.88 versus 0.89. Referring to Magurran [12], a J' value of 1.00 represents a situation in which all species are equally abundant. The comparison of SIV_i, above ground biomass and the species diversity between this study and other studies in Peninsular Malaysia is shown in **Table 10**.

Table 9 The comparison of species composition at the Redang Island, Terengganu with other studies at Peninsular Malaysia.

Study	Area	Families	Genera	Species	Ind.
This study	Redang Island (coastal forest 0.1 ha)	26	37	48	167
	Redang Island (inland forest 0.1 ha)	25	43	50	220
Khairil *et al*. [15]	Chini watershed inland forest (1.4 ha)	57	164	393	2061
	Chini watershed riverine (0.7 ha)	53	133	260	894
	Chini watershed seasonal flood (0.9 ha)	57	137	268	1019
Rohaiza Daud [19]	Pulau Singa Besar, Langkawi (0.5 ha)	26	63	84	460
	Pulau Timun, Langkawi (0.5 ha)	28	68	75	394
Ismail *et al.* [23]	Pekan Forest Reserve (1.0 ha)	26	49	68	557
Foo [13]	Rimba Kenong Park (riverine 0.2 ha)	40	69	98	215
	Rimba Kenong Park (inland 0.2 ha)	44	76	117	285
Raffae [16]	Bukit Matchincang Langkawi (2.0 ha)	49	76	117	3673

Table 10 The comparison of above ground biomass, SIV_i and the species diversity between this study with other studies in Peninsular Malaysia.

Study	Total above ground biomass (t/ha)	SIV_i	SH-W index
Redang Island (Coastal)	491	*Shorea glauca* (10.5 %)	3.4
Redang Island (Inland)	408	*Dipterocarpus costulatus* (13.5 %)	3.5
Khairil *et al.* [15]			
Inland	366	*Endospermum diadenum* (3.36 %)	5.1
Seasonal Flood	379	*Streblus elongatus* (4.43 %)	5.1
Riverine	401	*Aporusa arborea* (2.96 %)	5.4
Ismail *et al.* [23]	399	*Stemonurus secundiflorus* (7.22 %)	4.12
Rohaiza Daud [19]			
Pulau Singa Besar	874	*Callerya atropurpurea* (5.53 %)	3.91
Pulau Timun	575	*Streblus ilicifolius* (6.4 %)	3.6
Raffae [16] Bukit Matchinchang	527	*Swintonia floribunda* (10.84 %)	4.32
Foo [13]			
Riverine	284	*Streblus ilicifolius* (11.24 %)	4.13
Inland	205	*Pentace floribunda* (12.71 %)	4.23

Conclusions

The two types of forest showed different floristic patterns. Even though the study area was small, the results showed that Redang Island had a high diversity and density of tree species. As one of the main tourism sites in Malaysia, Redang Island faces habitat degradation due to development activities. Based on the number and individuals of endemic and threatened species, a proper management and conservation strategy for this area is important to make the tourism industry sustainable. The results from this study can be used as a basic guideline for other ecological studies on the island, especially the study of the Redang Island forests involving a larger landscape in the future.

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