**Advances in Environmental Biology**, 11(5) May 2017, Pages: 70-78

AENSI Journals

**Advances in Environmental Biology**

ISSN-1995-0756 EISSN-1998-1066

Journal home page: http://www.aensiweb.com/AEB/

# Species Richness and Floristic Variation of Tree Communities in Island Forests of Langkawi Archipelago, Peninsular Malaysia

**[1,2]Faezah, P., [1,3]Nizam, M.S. & [4]Rohaiza, D.**

*[1]School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
*[2]Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*
*[3]Institute of Climate Change, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia*
*[4]Centre for Pre-University Studies, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia*

**Address For Correspondence:**
Faezah, P., School of Environmental and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
E-mail: m.n.said@ukm.edu.my



Received 8 January 2017; Accepted 28 April 2017; Available online 24 May 2017

## ABSTRACT

Island forests are among forest habitats that are vulnerable to natural and anthropogenic disturbances, whereby the disturbances would influence the survival of biological species of the ecosystems. Langkawi Archipelago contains many small island forests and rapid development of tourism industry within this archipelago might contribute impacts to the tree flora of the forest communities on the small islands. Hence, this study tries to explore species richness, floristic variation of tree communities and relationship between species and island areas of four selected island forests in the Langkawi Archipelago, and data gathered are anticipated to be used for management of island forests at the Langkawi Archipelago. Tree surveys were carried out in study plots of 0.5 hectare each, at island forests of Gunung Raya Forest Reserve (GRFR), Pulau Tuba Forest Reserve (PTB), Pulau Timun Forest Reserve (PTM), and Pulau Singa Besar Forest Reserve (PSB). All trees with diameter at breast height (dbh) of 5.0 cm and above were enumerated and tree species were identified. Species data were analyzed for diversity and richness using the Shannon and Margalef indices; rarefaction analysis was used to compare richness between sites; whilst Detrended Correspondence Analysis (DCA) was used to determine floristic pattern. A total of 1916 trees were recorded from all study plots which comprised of 52 families, 159 genera and 293 tree species. The GRFR exhibited the highest species number of 135 tree species, followed by the PTB (106 tree species), the PSB (84 tree species) and the PTM (75 species). Tree density varied from 394 (PTM) to 584 (PTB) individuals per 0.5 hectare. Species accumulation curves showed that the curves were far from reaching the asymptote even when the whole dataset were combined. The results exhibit positive relationship between number of species and island size with $R^2$ value of 0.9053. The DCA ordination diagram clearly grouped the four study plots by their geological formation that indicated a gradient of species change from PTM to GRFR sites.

**KEYWORDS:** Langkawi Island, plant diversity, species-area relationship, Detrended Correspondence Analysis

## INTRODUCTION

Insular biology has always drawn the attention of ecologists [1] due to their ecosystems that are particularly vulnerable to biological invasions. Forest ecosystems of small islands are more sensitive compared to those forest ecosystems of large islands whereby on the small islands, the forest vegetation display special growth conditions such as slow-growth trees, having small tree diameter and small leaves for its adaptation to the extreme weather condition. Plant populations on islands and mainland often differ in their distribution because of physical environment factors. Island populations are usually more differentiated and contain less diversity than comparable mainland samples [2]. Island vegetation tend to have higher percentage of endemic species than other areas due to small geographical area available for each species [3], and have high percentage of endangered species because small islands are highly vulnerable to the impacts of climate change and sea-level rise [4]. Currently, majority of the island biota are severely threatened due to anthropogenic pressures [5]. Although conservation value for biodiversity of tropical forest has been demonstrated in continental regions, there has been little attention to tropical forests on oceanic island systems. It is particularly critical to understand the conservation implications of biological species on islands because of several unique conservation challenges of these biological communities. First, island systems frequently have unusually high endemism because of low species immigration, making them hotspots of biodiversity [6]. In addition, because island species evolved in isolation, they are particularly subject to the negative impacts of invasive species competition, novel pathogens, predation and herbivory [7].

This study aimed to determine the variation of tree species richness between four forest habitats within Langkawi Archipelago that include of Pulau Tuba (PTB), Pulau Timun (PTM), Pulau Singa Besar (PSB) and Gunung Raya Forest Reserve (GRFR) Langkawi, thus reveal differences in species composition between those islands. Furthermore, we also determined relationships between total species number and the size of the islands, and we hypothesize that large island are more likely to have higher species richness compared to small islands. This study is anticipated to contribute knowledge on patterns of tree species composition in island forests of Langkawi archipelago, which is essential for sustainable management of the forest ecosystems.

## MATERIAL AND METHODS

### *Study Area and Tree Sampling:*

The Langkawi Archipelago lies west of Peninsular Malaysia in the Andaman Sea near the Malaysian-Thai border. The archipelago consists of 99 islands at high tide and 104 islands at low tide [8]. Tree samplings were conducted at four island forests in Langkawi Archipelago which include Gunung Raya Forest Reserve of P. Langkawi (GRFR), Pulau Tuba (PTB), Pulau Singa Besar (PSB) and Pulau Timun (PTM) (Figure 1). Ten study plots of 25x20 m each (total area of 0.5 hectare) were established at each study area. In each plot, all trees with diameter at breast height (dbh) of 5 cm and above were tagged and measured its diameter. Leaves specimens of each measured tree were collected for preparation of voucher specimens and identification. Species identification was made possible up to species level by referring to the keys described in *Tree Flora of Malaya* [9][10][11][12].

### *Data Analysis:*

Data of all tree species were tabulated in Microsoft Excel according to its habitat and were summarized to describe species composition and abundance of the tree communities at each site. Several diversity and richness indices were calculated, amongst them were Shannon Diversity Index and Margalef's Richness Index (13). Comparison of species richness between forests was made using Paleontological Statistics (PAST) Version 2.17 [14] and EcoSim (Null Modelling Software for Ecologist) Version 1 [15]. Other analyses that were conducted include species richness estimations and rarefaction to examine species diversity and community structure. Floristic patterns were examined by subjecting the sample data to Detrended Correspondence Analysis (DCA), a method derived from reciprocal averaging [16], available in the CANOCO program version 4.0 [17].

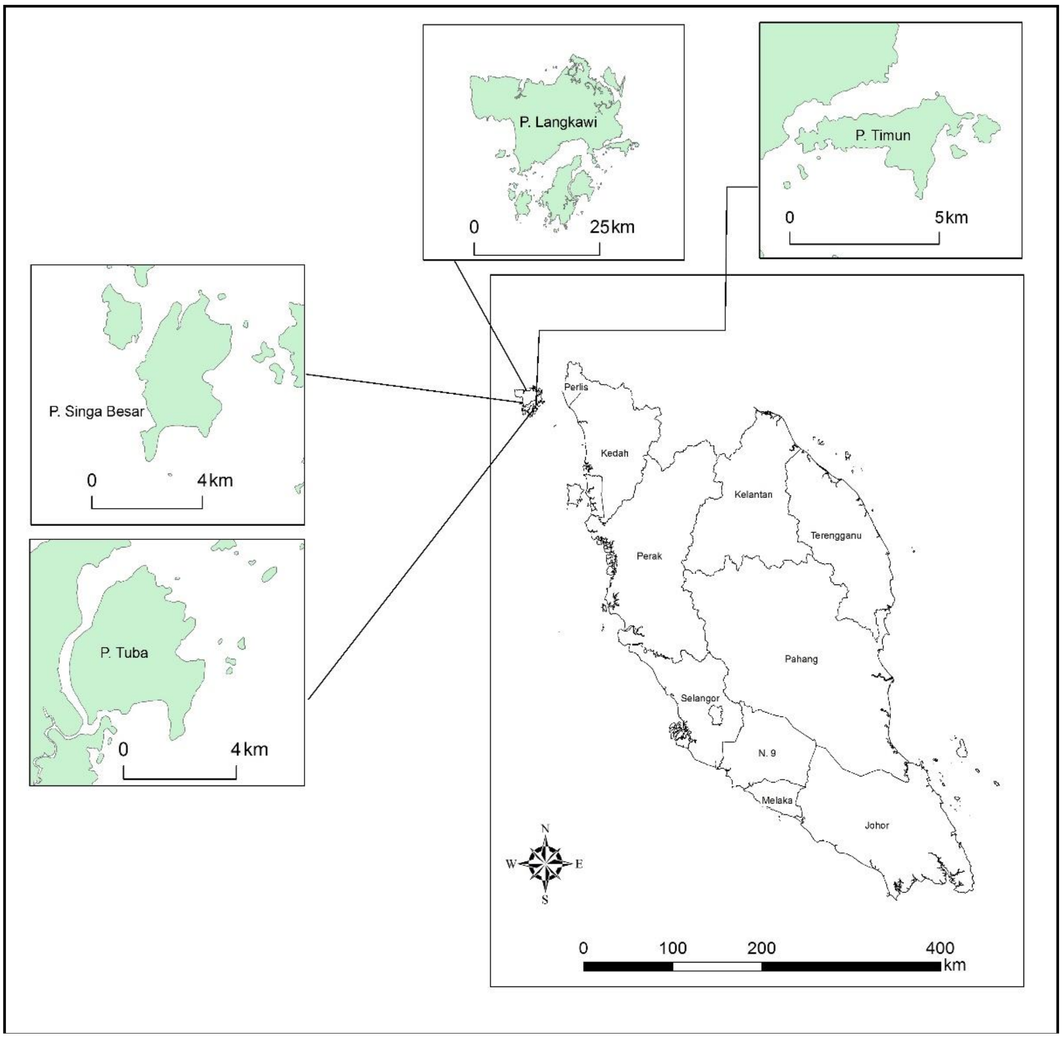


**Fig. 1:** Map of Peninsular Malaysia showing the location of four study sites in Langkawi Archipelago, Malaysia

## RESULTS AND DISCUSSION

*Floristic Composition:*

Table 1 shows summary of the tree floristic composition at the four study sites in Langkawi archpelago. A total of 52 families, 159 genera, 293 tree species from 1916 tree individuals were encountered at all sites. Out of these, 45 families comprised of 92 genera, 135 tree species and 478 individuals were recorded in GRFR; 36 families of 68 genera, 106 species and 584 individuals were enumerated in PTB; 26 families comprised of 63 genera, 84 species and 460 individuals were recorded in PSB; and 28 families consisted of 68 genera, 75 species and 394 individuals were recorded in PTM. Vegetation is often dependent on parents' material of the soil. GRFR is granitic and the soils derived from granite and shale is more nutrient-rich and heavily vegetated (135 species). In contrast, fewer plant species grows on the soil of Setul limestone of PTM (75 species) that contributed to different species richness between the two sites. Similar trend was reported at Mule Mountains, Cochise County, Arizona, USA that showed the result of strong associations of tree species with granite substrate [18]. Moreover, [19] also showed high tree species number in forest on granite substrate compared to limestone formation in the Perlis State Park, Malaysia. Association of soil characteristics and vegetation patterns have been described in many studies in various forest habitats [20][21][22].

**Advances in Environmental Biology**, 11(5) May 2017, Pages: 70-78

**Table 1:** Floristic composition of tree populations at four study plots in Langkawi Archipelago

| | GRFR | PTB | PSB | PTM |
|---|---|---|---|---|
| Family | 45 | 36 | 26 | 28 |
| Genus | 92 | 68 | 63 | 68 |
| Species | 135 | 106 | 84 | 75 |
| Individual | 478 | 584 | 460 | 394 |

*Species Richness:*

Table 2 shows the species diversity of tree communities in the four study locations. The trend of Shannon index (*H*) study can be depicted as GRFR > PTB > PSB > PTM. The highest value of *H* was recorded for GRFR (4.34) followed by PTB (4.08), PSB (3.91) and PTM (3.6). The Margalef's species richness index ranged from 12.38 for PTM to 21.72 for GRFR. High evenness is a sign of ecosystem stability, which reflected that no single species dominated the ecosystem and evenness is a subset of measures of equitability. The nonparametric species richness estimator, Chao 1 estimated the number of species based on number of observation ($S_{obs}$), which is the total number of species observed in a sample. Chao 1 estimated that 204 species can be expected from GRFR ($S_{obs}$ =135 species), 137 species for PTB ($S_{obs}$ =106 species), 106 species for PSB ($S_{obs}$ =84 species) and 100 species for PTM ($S_{obs}$ =75 species). All estimations were higher than the observed values, which is an acceptable estimation for a diverse ecosystem. According to [23], Chao 1 is one of the nonparametric estimators that are the least biased and most precise compared to other estimators (e.g. Chao 2, ACE, ICE, and Jackknife). It provides minimum estimates of richness and assumes homogeneity amongst samples.

**Table 2:** Diversity and richness indices of tree communites at four study sites in Langkawi Archipelago

| Index | Value | | | |
|---|---|---|---|---|
| | GRFR | PTB | PSB | PTM |
| No. Species ($S_{obs}$) | 135 | 106 | 84 | 75 |
| Shannon Index (*H*) | 4.343 | 4.08 | 3.908 | 3.6 |
| Evenness_e^H/S | 0.5702 | 0.5582 | 0.5926 | 0.488 |
| Margalef | 21.72 | 16.48 | 13.54 | 12.38 |
| Equiatability, J | 0.8855 | 0.875 | 0.8819 | 0.8338 |
| Chao-1 | 204.4 | 137 | 105.7 | 100.4 |

*Rarefaction Curve:*

Figure 3 shows the species number of each sampling area at 394 individuals cut-off point that revealed GRFR had the highest estimation of average species number with 124.2±7.6 species, followed by PTB (93.3±8.16 species), PSB (80.0±3.3 species) and PTM (75±0 species) (Table 3). Overall, the results showed that there were significant differences of species richness between the four sampling areas. The rarefaction curve for the PTB lies significantly below that of the GRFR. Thus, the higher species richness of GRFR was not simply an artifact of the greater number of individuals collected. For example, 350 individuals of 89 species were collected from PTB, whereas a random sample of 350 individuals from the GRFR would be expected to contain approximately 117 species (Figure 3).

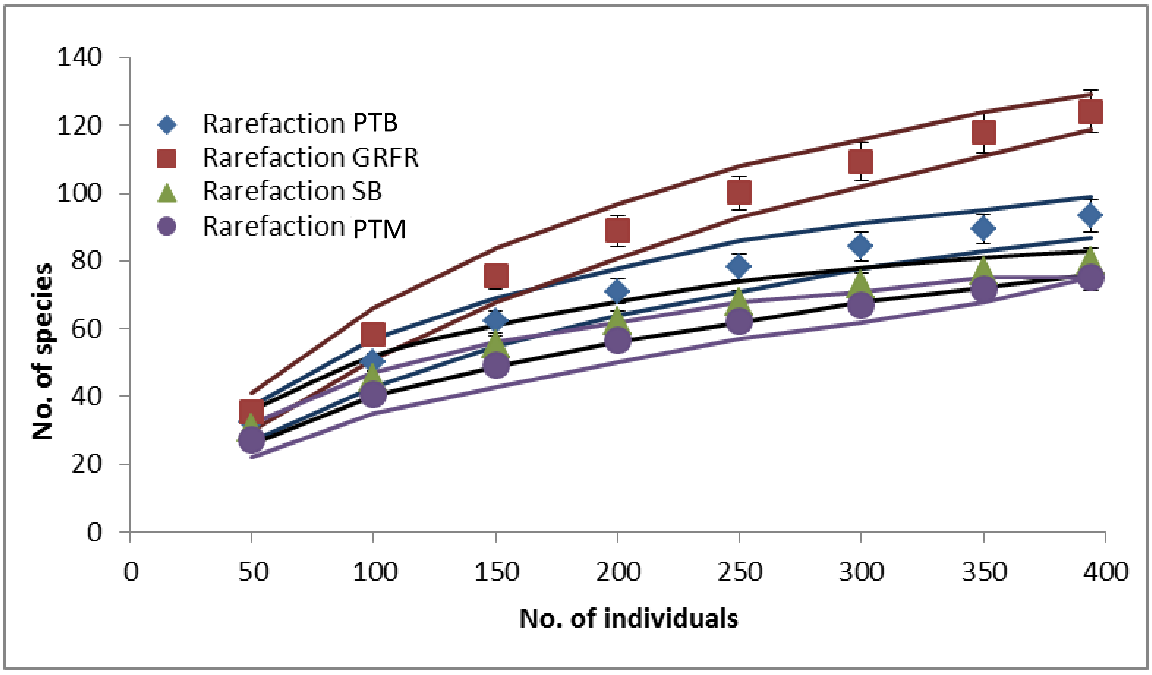


**Fig. 3:** Rarefaction curves at the cut-off point of 394 individuals for each study plot at Langkawi Archipelago, Malaysia. The solid line indicated the 95% confidence intervals (CI) for each curve. Comparison is considered significant when CI curves did not overlap between each other.

**Table 3:** Estimation of average species number for the four island forests in Langkawi Archipelago, Malaysia

| No. of individual | GRFR (species) | PTB (species) | PSB (species) | PTM (species) |
|---|---|---|---|---|
| 394 | 124.2 ± 7.6 | 93.3 ± 8.16 | 80.0 ± 3.3 | 75 ± 0 |

*Floristic Variation Pattern:*

Detrended Correspondence Analysis (DCA) ordination diagram illustrates the dispersion of sampling plots along environmental gradients. The graphic representation of the DCA (Figure 4) clearly grouped the four study plots by geological types. Four study areas were well separated along the DCA axis 1 in terms of species composition, of which the gradient length is 6.154 by the first DCA axis (Table 4). Gradient of species change from PTM (limestone) to GRFR (granite) sites, implied significant influence of environmental gradient on tree species composition. The DCA ordination illustrates the dispersion of sampling plots from the PSB site was relatively small, whereby the plots within the PSB were clumped together reflecting the plots are relatively similar floristically.

**Table 4:** Summary tables of DCA analyses of tree species data from four island forests in Langkawi Archipelago

| | Axis 1 | Axis 2 | Axis 3 | Axis 4 | Total inertia |
|---|---|---|---|---|---|
| Eigenvalues | 0.778 | 0.590 | 0.407 | 0.264 | 8.688 |
| Length of gradient | 6.154 | 5.258 | 3.241 | 2.896 | - |
| Cumulative percentage variance of species data | 9.0 | 15.7 | 20.4 | 23.5 | - |

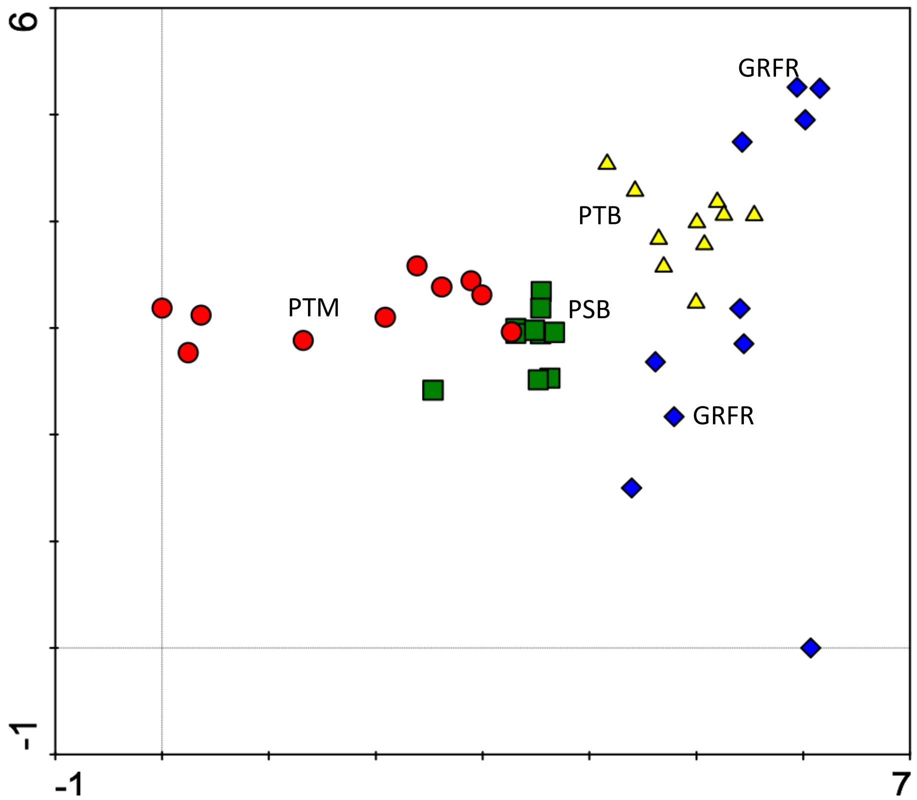


**Fig. 4:** DCA ordination diagram of 40 subplots based on tree species composition data (trees ≥ 5cm dbh) in four island forests of Langkawi Archipelago, Malaysia. Shape and colour of symbols represents: red circle = PTM; green square = PSB; yellow triangle = PTB; and blue diamond = GRFR.

It is apparent that sampling plots of PTM are located on the extreme left of DCA axis 1, whilst the plots of GRFR are located on the far right of the ordination, reflecting the long environmental gradient showed by the value of gradient length of axis 1 (6.154). The environmental gradient displayed by the ordination reflects different habitat characteristics that influence tree floristic composition of each island forest. Different habitat characteristics of islands in the Langkawi archipelago are mainly related to different geological and soil characteristics between islands of Langkawi Archipelago, which resulting different types of vegetation on the islands [24]. Possibly, differences in geological characteristics of PTM and PSB contributed to the obvious separation between the plots of the two sites, which indicated dissimilarity in terms of floristic composition. The PSB was made up from Singa formation whereas the PTM was made up from Setul Formation, of which the former is dominantly distributed by dark coloured shale and sandstone, while the latter is mainly made up of thin to thickly bedded dark grey limestone [24]. Meanwhile, GRFR which parent material is of granite, displayed plots that were separated at the right end of the diagram, inferring low similarity of species composition compared to those plots of PTM.

From the indirect gradient analysis of DCA, it is predicted that there are underlying factors that control the distribution pattern of vegetation communities. Environmental variables are obviously the factors that significantly influence the community patterns. This has been supported by many studies that look at relationships between floristic patterns and environmental gradients, and most of them stated that soil characteristics as one of the significant factors that control the vegetation pattern in a community [25] [26].

*Relationship between Island Area and Species Number:*

All four sites exhibit positive relationships between species richness and island size with $R^2$ value of 0.9053. (Figure 5). The island size ($km^2$) of this study in descending order was GRFR > PTB > PSB > PTM, of which the area of GRFR is 365 $km^2$, followed by PTB (17.45 $km^2$), PSB (11.38 $km^2$) and PTM (7.1 $km^2$). Similar trend for species number was observed whereby GRFR contained 135 species, followed by PTB (106 species), PSB (84 species) and PTM (75 species). Size of island is one of the primary determinants of insular species number [27], whether the islands are within climatically homogenous regions [28], or across climatic and biogeographic zones [29], and the findings of this study agree with another study that showed positive correlation between island area and species number [30]. Larger islands with many habitat types could support comparably higher species richness because they contain habitat types that are characteristically more species-rich than the habitat present in smaller islands [30]. Additionally, larger islands have a higher probability to receive diaspores than smaller ones and might provide a comparatively greater potential for *in situ* speciation because larger islands provide geographic features (such as mountain ranges or rivers) that are important for *in situ* speciation [31].

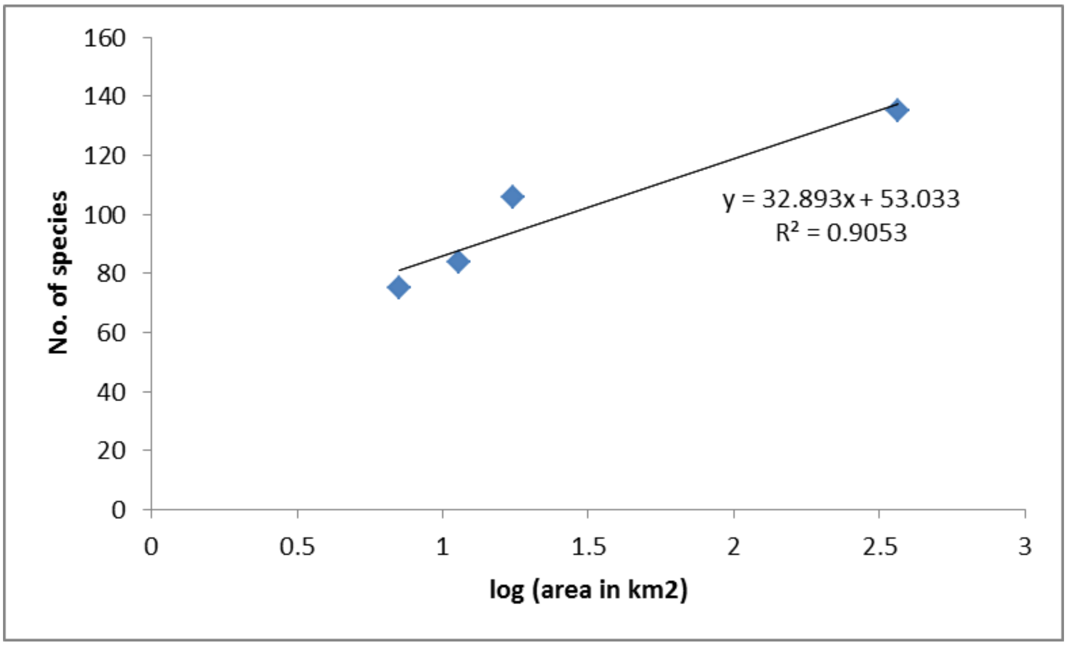


**Fig. 5:** Linear regression between number of species and log area at the four study sites in Langkawi, Malaysia

*Conclusion:*

The results showed that tree communities between four different island forests in Langkawi Archipelago displayed differences in terms of richness and diversity of tree species. The species richness of an island is the outcome of many processes affecting the colonization, evolution, and persistence of island populations. These processes may also vary in their outcome among island groups because of differences in the range of island area and habitat diversity. Although studies on the relationship between species richness and island area have been important to the development of many study areas of ecology, evolution, and conservation biology, understanding the species-area relationship generated from this study requires a closer look at its underlying processes. Floristic variation patterns between the distinct habitats of Langkawi suggested that there are environmental gradients that influenced the floristic patterns. Identifying the key underlying gradients, abiotic conditions and major soil influences on vegetation patterns is essential in formulating plans to protect and conserve island forest habitats of conservation interest.

## ACKNOWLEDGEMENTS

The authors would like to thank the Forestry Department of Kedah for access permission at the study sites and assistance on the ground. We are grateful to Ahmad Fitri Zohari for species identification, and the Universiti Kebangsaan Malaysia for financial support through Research University Grant GUP-2013-056.

## REFERENCES

[1] Balakrishnan, N.P. and M.K. Rao, 1983. The dwindling plant species of Andaman and Nicobar Islands, In: *An Assessment of Threatened Plants of India*, edited by S.K. Jain and R.R. Rao (Botanical Survey of India, Howrah) pp: 186-210.
[2] Spencer, C.H.B., 1996. The reproductive biology and genetics of island plants. *Phil. Trans. Bio. Sci.,* 351: 725-733.
[3] Rasingam, L. and N. Parathasarathy, 2009. Tree species diversity and population structure across major forest formations and disturbance categories in Little Andaman Island, India. Tropical Ecology, 50(1): 89-102.

[4] Mimura, N., L. Nurse and R.F. McLean, 2007. Small Islands p. 687-712 In M.L. Parry, O.F. Canziani, J.P. Palutikof *et al.* edited. *Climate change: impacts, adaptation and vulnerability. Contributions of working group II to the fourth assessment report of the IPCC*. Cambridge University Press, Cambridge.
[5] Bramwell, D., (ed.) 1979. *Plants and Islands.* Academic Press, London.
[6] Fa, J.E., R.W. Burn, P.M.R. Stanley and F.M. Underwood, 2004. Identifying important endemic areas using ecoregions: birds and mammals in the Indo-Pacific. *Oryx.* 38: 91-101.
[7] Vitousek, P.M., 2004. *Nutrient cycling and limitation: Hawaii as a model system*. Princeton University Press, Princeton.
[8] Jahal, K.C.A., H.N.N. Faizul, B.Y. Kamaruzzaman, S. Shahbudin, M.Z. Alam and J. Irwandi, 2009. Studies on physio-chemical characteristics and sediment environment along the coastal waters in Pulau Tuba, Langkawi, Malaysia. *Aquatic Ecosystem Health & Management* 12: 350-357.
[9] Ng, F.S.P. (ed.), 1978. *Tree Flora of Malaya. A manual for foresters*. vol. 3. Kuala Lumpur: Longman Malaysia Sdn. Bhd.
[10] Ng, F.S.P. (ed.), 1989. *Tree Flora of Malaya. A manual for foresters.* vol. 4. Kuala Lumpur: Longman Malaysia Sdn. Bhd.
[11] Whitmore, T.C. (ed.), 1972. *Tree Flora of Malaya: vol. 1, Forestry Department, Ministry of Agriculture and Lands, Malaysia.* Kuala Lumpur: Longman Malaysia Sdn. Bhd.
[12] Whitmore, T.C. (ed.), 1973. *Tree Flora of Malaya: vol. 2, Forestry Department, Ministry of Agriculture and Lands, Malaysia.* Kuala Lumpur: Longman Malaysia Sdn. Bhd.
[13] Magurran, A.E. and B.J. McGill, 2011. *Biological diversity: frontiers in measurement and assessment*. Oxford, Oxford University Press.
[14] Hammer, Ø. D.A.T. Harper and P.D. Ryan, 2001. PAST: Paleontological statistics software package for education and data analysis, *Palaeontologia Electronica,* vol. 4, 9pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm
[15] Gotelli, N.J. and G.L. Entsminger, 2000. EcoSim: Null models software for ecology. Version 5.0. Acquired Intelligence Inc. & Kesey-Bear. http://homepages.together.net/~ gentsmin/ecosim.htm.
[16] Hill, M.O. and H.G. Gauch, 1980. Detrended correspondence analysis, an improved ordination technique. *Vegetatio*. 42: 47-58.
[17] Ter Braak, C.J.F. and P. Šmilauer, 1998. *CANOCO Reference Manual and User's Guide to Canoco for Windows: 10 Software for Canonical Community Ordination (version 4).* Ithaca, NY: Microcomputer Power. pp: 352.
[18] Thomas, R.W., 1981. Vegetations on limestone and granite in the Mule Mountains, Arizona. *Ecology*. 62: 469-482.
[19] Zakaria, R., M.S. Nizam and I. Faridah-Hanum, 2015. Floristic, diversity and structure of tree communities in three distinct forest habitats of Perlis State Park, Perlis, Peninsular Malaysia. Journal of Science, 5(11): 1016-1023.
[20] Khairil, M., W.A. Wan Juliana and M.S. Nizam, 2014. Edaphic influences on tree species composition and community structure in a tropical watershed forest in Peninsular Malaysia. Journal of Tropical Forest Science, 26(2): 284-294.
[21] Nizam, M.S., A.R. Jeffri and A. Latiff, 2013. Structure of tree communities and their association with soil properties in two fan-palm dominated forests of east coast Peninsular Malaysia. Tropical Ecology, 54(2): 213-226.
[22] Nurfazliza, K., M.S. Nizam and M.N. Nur Supardi, 2012. Association of liana communities with their soil properties in a lowland forest of Negeri Sembilan, Peninsular Malaysia. *Sains Malaysiana*, 41(6): 679-690.
[23] Nizam, M.S., S. Rohani and Wan W.A. Juliana, 2012. Floristic variation of tree communities in two distinct habitats within a forest park in Pahang, Peninsular Malaysia
[24] Walther, B.A. and J.L. Martin, 2001. Species richness estimation of bird communities: how to control for sampling effort? *Ibis*. 143: 413-419.
[25] Leman, M.S., 2010. Geoheritage Conservation in Langkawi Geopark Malaysia. *Akademika.* 80: 19-30.
[26] Tuomisto, H., K. Ruokolainen, M. Aguilar and A. Sarmiento, 2003. Floristic patterns along a 43-km long transect in an Amazonian rain forest. Journal of Ecology, 91: 743-756.
[27] Newbery D McC and J. Proctor 1984. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak. IV. Associations between tree distribution and soil factors. Journal of Ecology, 72: 475-493.
[28] Whittaker, R.J., 2006. Island species-energy theory Journal of Biogeography, 33: 11-12.
[29] MacArthur, R.H. and E.O. Wilson, 1967. *The Theory of Island* Biogeography. Princeton University Press, Princeton.
[30] Kreft, H., W. Jetz, J. Mutke, G. Kier and W. Barthloott, 2008. Global diversity of island floras from a macroecological perspective. Ecology Letters. 11: 116-127.

**Advances in Environmental Biology**, 11(5) May 2017, Pages: 70-78

[31] Kohn, D.D. and D.M. Walsh, 1994. Plant species richness-The effect of island size and habitat diversity. Journal of Ecologyy, 82: 367-377.
[32] Lomolino, M.V., 2001. The species–area relationship: new challenges for an old pattern. Prog. Phys. Geogr, 25: 1-21.