OPTIMAL SAMPLE AREA ESTIMATION FOR MEDICINAL PLANT BIODIVERSITY ASSESSMENT OF A LOGGED OVER HILL FOREST IN JERANTUT, MALAYSIA

NORHAJAR ESWANI BINTI MOHAMAD EHSAN

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NORHAJAR ESWANI BINTI MOHAMAD

EHSAN

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NORHAJAR ESWANI BINTI MOHAMAD EHSAN

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NORHAJAR ESWANI BINTI MOHAMAD EHSAN

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Chairman: Kamziah Abd Kudus, PhD

Faculty : Forestry

In plant inventory, sampling technique was less being considered by botanists. Sometimes the sampling is not enough and sometimes it is more than enough. Thus, it is wasting cost and time consuming. This study attempted to determine an optimal sample area required for medicinal plant biodiversity assessment, identify the traded medicinal plant resources available in forest, and examine the relationship between true size and quadrat size on medicinal plant diversity parameters such as species richness, species evenness and species accumulation. This study was conducted in Tekai Tembeling Forest Reserve (TTFR), Jerantut, Pahang. Four 1-ha plots (Plot1, Plot2, Plot3 and Plot4) were established within the forest area at the elevation range 300 a.s.l – 550 a.s.l. Each plot was divided into 100 quadrats of size 10x10m. Dbh, height, species name and number of trees by species were recorded. Species richness, diversity and evenness were estimated using Ecological Methodology Software. IVI was also computed to study the dominance vegetation of forest. Optimal sample area obtained from species area curve or species accumulation curve. Species area curves were constructed from species richness and selection quadrats were based on systematic and random approaches. There are four ways to determine species richness; number of species

observed, extrapolation of species area curve, log-normal distribution and nonparametric estimator. Nonparametric estimators included Chao1, Chao2, Jack1, Jack2, ACE, ICE and Bootsrap. The entire estimator evaluated based on the Mean Square Deviation (MSD). The smallest MSD is the best estimator. Quadrat selection method has two techniques; systematic and random. Systematic has four approaches while random has two approaches. Species area curve was constructed from each approaches. There were 236 species, 179 genera and 87 families of medicinal plants found. The most abundant family, genera and species were Euphorbiaceae, *Macaranga* and *Lygodium circinnatum* respectively. Most of the medicinal plants having dbh below than 5cm and only 33 individuals out of 674 having dbh greater than 50cm. *Cinnamomum porrectum* is the most dominant species according to IVI. Uses of each medicinal plant were also explained briefly. Species diversity showed Plot2 is the most diverse based on Shannon diversity index and Plot3 is the most even area because possessed highest evenness index. EstimateS program estimated 227 species in 4-ha but the true species observed is 236. Extrapolation of species area curve indicates the graph did not approach an asymptote but increase more rapidly. The log-normal distribution showed the $Ln\hat{S} = -0.47833 + (0.577954 * Ln(A))$ is the estimate regression equation generated for the species accumulation pattern of TTFR. Nonparametric estimator showed ACE is the best estimator. Even though the species observed showed the accurate result but, in term of nonparametric estimator ACE is the best. For quadrat selection method, species area curve for even quadrat, odd quadrat, row plot and 75% randomly chosen quadrat showed the graph attain an asymptote or optimal point. Thus, the inventory of medicinal plants did not require to carry out through

all plots or quadrats since the sampling technique mentioned before enough to cover the species richness.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai keperluan untuk ijazah Master Sains.

PENGANGGARAN KAWASAN SAMPEL YANG OPTIMUM UNTUK MENILAI KEPELBAGAIAN POKOK UBATAN DI HUTAN BUKIT YANG TELAH DIBALAK DI JERANTUT, MALAYSIA

Oleh

NORHAJAR ESWANI BINTI MOHAMAD EHSAN

Ogos 2011

Pengerusi: Kamziah Abd Kudus, PhD

Fakulti : Perhutanan

Dalam inventori tumbuhan, teknik penyampelan kurang mendapat perhatian daripada ahli botani. Kadang kala, penyampelan tidak mencukupi dan kadang kala ia melebihi daripada yang diperlukan. Oleh yang demikian ia membazirkan kos dan masa yang digunakan. Kajian ini dilaksanakan untuk mendapatkan kawasan penyampelan yang optimum untuk penilaian kepelbagaian biologi pokok ubatan, mengenalpasti sumber pokok ubatan yang boleh dijual di dalam hutan ini dan mengenalpasti hubungan antara saiz sebenar dan saiz quadrat untuk parameter kepelbagaian pokok ubatan seperti kekayaan spesies, keseragaman spesies dan taburan spesies. Kajian ini telah dijalankan di Hutan Simpan Tekai Tembeling (TTFR), Jerantut, Pahang. Empat plot telah dibina di sekitar kawasan hutan (Plot1, Plot2, Plot3 dan Plot4) pada julat ketinggian 300 a.s.l.- 550 a.s.l. dan setiap plot bersaiz satu hektar. Plot dibahagikan kepada bahagian yang lebih kecil, iaitu kuadrat yang bersaiz 10x10m. Dbh, tinggi, nama spesies dan bilangan spesies direkodkan. Indeks kekayaan spesies, kepelbagaian dan keseragaman dianggarkan dengan menggunakan program *Ecological Methodology*. IVI juga dikira untuk mengkaji vegetasi hutan. Penyampelan kawasan yang optimum diperolehi

daripada lengkuk kawasan spesies. Lengkuk kawasan spesies dibina daripada kekayaan spesies dan pemilihan kuadrat berdasarkan pendekatan sistematik dan rawak. Terdapat empat cara untuk mendapatkan kekayaan spesies iaitu; bilangan spesies yang diperhatikan, ekstrapolasi lengkuk kawasan spesies, taburan log-normal dan penganggar nonparametrik. Penganggar nonparametrik termasuk *Chao1*, *Chao2*, *Jack1*, *Jack2*, *ACE*, *ICE* dan *Bootstrap*. Semua penganggar dinilai berdasarkan *Mean Square Deviation* (MSD) dan nilai yang terkecil adalah yang terbaik. Kaedah pemilihan kuadrat mempunyai dua teknik iaitu sistematik dan rawak. Kaedah sistematik mempunyai empat pendekatan manakala kaedah rawak mempunyai dua pendekatan. Lengkuk kawasan spesies dibina berdasarkan setiap pendekatan. Terdapat 236 spesies, 179 genus dan 87 famili pokok ubatan. Famili, genus dan spesies yang paling banyak, masing-masing ialah Euphorbiaceae, *Macaranga* dan *Lygodium circinnatum.* Kebanyakan pokok ubatan mempunyai dbh kurang daripada 5cm dan hanya 33 individu pokok daripada 674 pokok yang mempunyai dbh lebih daripada 50cm. *Cinnamomum porrectum* adalah spesies yang paling dominan berdasarkan kepada nilai IVI. Kegunaan setiap pokok ubatan juga turut dijelaskan dengan terperinci. Plot2 menunjukkan kepelbagaian spesies yang paling tinggi berdasarkan indeks kepelbagaian Shannon dan Plot3 merupakan plot yang paling seragam vegetasinya kerana mempunyai indeks keseragaman yang tertinggi. Program estimateS menganggarkan terdapat 227 spesies dalam empat hektar tetapi bilangan spesies sebenar yang diperolehi ialah 236. Ekstrapolasi lengkuk kawasan spesies menunjukkan graf tidak mencapai asimptot tetapi terus menunjukkan peningkatan bilangan spesies. Taburan log-normal pula menunjukkan $Ln\hat{S} = -0.47833 + (0.577954 * Ln(A))$ ialah persamaan penganggaran regresi yang dijana untuk paten taburan spesies di TTFR.

Penganggar nonparametrik menunjukkan ACE ialah penganggar terbaik. Walaupun spesies diperolehi menunjukkan keputusan yang lebih tepat, namun daripada segi penganggar nonparametrik, ACE adalah yang terbaik. Untuk kaedah pemilihan kuadrat, lengkuk kawasan spesies untuk kuadrat genap, kuadrat ganjil, baris plot and pemilihan rawak 75% kuadrat menunjukkan graf mencapai asimptot atau titik optimum. Oleh yang demikian, inventori untuk pokok-pokok ubatan tidak perlu dilaksanakan untuk semua plot dan kuadrat memandangkan teknik penyampelan yang dijelaskan sebelum ini cukup untuk melitupi kekayaan spesies.

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LIST OF ABBREVIATIONS

(1-D)	Simpson's diversity index
<	smaller than
≥	greater than or equal to
A	area
ACE	Abundance-based Coverage Estimator of species richness
BA	basal area
BIOTROP	Southeast Asian Regional Centre for Tropical Biology
Chao1	An Abundance-based estimator of species richness
Chao2	An incidence-based estimator of species richness
cm	centimeter
dbh	diameter at breast height
E1/D	Simpson's evenness index
FRIM	Forest Research Institute Malaysia
H'	Shannon diversity index
Ha	hectare
HSTT	Hutan Simpan Tekai Tembeling
ICE	Incidence-based Coverage Estimator of species richness
IVI	importance value index
Jack1	First-order jackknife estimator of species richness (incidence based)
Jack2	Second-order jackknife estimator of species richness (incidence-based)
LN	linear regression estimate
m	meter
MD	mean deviation

MSD	mean square deviation
MSPD	mean square proportional deviation
NFI 4	Fourth National Forest Inventory
r^2	correlation coefficient
S	number of species
Σ'	Camargo evenness index
SAC	species area curve
SEAMEO	Southeast Asian Ministers of Education Organizaton
SO	species observed
TTFR	Tekai Tembeling Forest Reserve
VJRs	Virgin Jungle Reserves
XLSTAT	Statistical Program in Microsoft Excel

CHAPTER 1

INTRODUCTION

1.1 General

Optimal sample area estimation is a way to determine the optimum number of quadrats needed to be sampled which can represent the number of species in the study area. The optimal sampling estimates can reduce the possibilities of undersampling and oversampling. At the same time, it also can reduce cost and time. There are no specific methods on how to determine the optimum sampling. However, in this study, optimal sampling is investigated in relation to species richness and species area curve. Species area curve is plotted from species richness by using several methods and then the optimal sample size is observed based on the graph obtained, as the graph plotted showed stable condition, or asymptote level. The estimators of species richness are divided into four different methods such as number of observed species, extrapolation of species area curves, log-normal distribution and nonparametric estimator.

The increment rates on number of species varied for different forest types where certain species area curve could approach an asymptote level but other could not (Ney-Nifle & Mangle, 2000). Forest area with a few number of species usually reach an asymptote level much earlier. Study by Gadow and Ying (2007) to determine the minimum area required to capture species richness in the forest of Africa, Asia, South America and Europe found that the slope for species area curves were different amongst regions but the minimum area could be established

by estimating the maximum number of species in a specific forest community. Despite that, many assessment works on biological diversity in the forest is carried out without considering different sampling sizes and the size of study plot in Malaysian forests may range from one hectare to many hectares with various quadrat sizes depending on the type of forest. For instance, Sharma et al. (1996) conducted a study of flora and fauna which covered a study area of up to 3176 ha in Mata Ayer Forest Reserve and up to 2768 ha in Bukit Wang Mu Forest Reserve. Faridah Hanum et al. (2008) suggested, a minimum of 5-ha contiguous area was needed to capture species diversity in a tropical logged-over forest. Study conducted at Ayer Hitam Forest Reserve which has been logged over between 1936-1966 reported that it needed at least 5-ha plot to capture greater species diversity. However, TTFR had just being logged-over for approximately five years ago therefore, there might be a possibility that study area with 5-ha plot was apparently not enough to capture the actual species diversity or richness. However, question remains on the ideal size of plot area for logged-over forest particularly in regeneration processes where many new species emerged within gap areas and the addition of pioneer vegetation. Due to that, there are risks for both undersampling and oversampling if the size of sample areas are not determine adequately for regenerating logged-over forest. When undersampling occurred, it may result to bias inferences meanwhile, when oversampling occurred, the valuable resources such as cost and time consuming will be wasted.

Species richness in particular could not be observed from the data if the sampling size is inadequate to represent the whole population sample of study. Study by Kumar et al. (2006) in primary and secondary forests of Garo Hills found that

sampling in primary forest was adequate with the sample size of 1-ha where the species area curve has reached an asymptote level. However, they found that secondary forest species area curve does not approach asymptote level with just one hectare plot. This also means that for logged-over forest, species richness could not be determined by using one hectare plot of study sample. Species richness is usually measured as the observed number of species in a given area. As the size of area increased, species richness also increased and once the species richness has reached a stable condition, optimal sample area is considered has been attained. However, it is extremely difficult to obtain a complete inventory of the fauna or flora at a certain study plot and biodiversity data commonly suffer from heterogeneity in sampling strategies and/or sample size, as well as from survey unevenness. Because of this, sampling success is not always the same in all the surveyed areas, leading to potential important biases in the proportion of the total number of species that are inventoried in each place. The way species richness is measured might affect species-area curve, due to sampling effects and survey unevenness.

The variety of plant diversity gives various benefits to human being but many species were not recorded up to this date. One of the richest places for biodiversity is in the forest of Asian region where 45% of the total land area is covered by forest. Much research have and still being conducted on the flora and fauna within the region. In Malaysia, there have been numerous studies conducted on biological diversity to assess species richness and diversity in various forest ecosystems conducted (Faridah Hanum et al. 2001a & 2001b). In these studies, the diversity and density of medicinal plant in forest were also measured.

The subject of medicinal plants research in Malaysia covers many topics and for medicinal plants in natural forest, the topics were mostly about the diversity, conservation, economic value and ethnobotany. For example, a study by Tuan Marina et al. (2007) who surveyed the occurrence and economic values of medicinal trees in Tranum forest, while Jeremy et al. (2006) conducted inventory of wild medicinal plant population in Sri Lanka. Other studies such as by Eunice et al. (2007), collected all plants including medicinal plants trees in Mount Marsabit Forest and Khamis et al. (2005) recorded the use of plants among local community in Sungai Bebar, Pahang. However, there are no study has been done to estimate the optimal sampling for medicinal plant diversity in the forest as yet. This study is the first attempt to estimate the optimal sample area for medicinal plant biodiversity assessment specifically in hill forest of Jerantut, Pahang.

1.2 Problem Statement

There were many inventories and plot studies for medicinal plants in the forest that have been established in the past. This include study by Condit *et al.* (1996) who compared the three 50-ha plots for species-area and species-individual relationship for tropical trees at Pasoh. Andy et al. (2010) studied on common medicinal plants species found at burned and unburned areas of Klias peat swamp forest, Beaufort, Sabah and, Paul and John (2007) focus on medicinal plant diversity and uses in the Sango Bay Area, Southern Uganda. Both of the research carried out a study concerning diversity of medicinal plants. Rajastri et al. (2005) studied the conservation and documentation of the medicinal plant resources of India while Rainer and Tuan-Marina et al. (2007) focused on the economic value of medicinal

plants in Pahang. Faridah-Hanum et al. (2008) had argued that the optimal size to study the tree diversity in a logged over forests would be 5-ha but there had been no studies to estimate the optimal sample size to capture the optimal number of medicinal plant species. Determination of sampling size is a necessity to obtain the most precise diversity and richness of medicinal plants. From conservation point of view, if the optimal sample area could be estimated, the sufficient area to represent the whole study population could be determined and conservation work could be done easily. Hence, this study estimate the optimal sample area to study the medicinal plant diversity.

1.3 Research Objectives

The objectives of this study are:

- To identify and document the diversity of medicinal plants in logged-over hill forest of Tekai Tembeling Forest Reserve (TTFR), Jerantut, Pahang.
- To determine the optimal sample area richness for medicinal plant diversity assessment in logged over hill forest of Tekai Tembeling Forest Reserve (TTFR), Jerantut, Pahang.
- To examine the relationship between true size and quadrat selection on medicinal plant diversity parameters (species richness, species similarity and species accumulation).

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