Comparison of terrestrial vertebrates between natural and teak plantation forest in Peninsular Malaysia: A case study in Perlis State Park and Mata Ayer Field Center, FRIM

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Abstract. Species compositions are influenced by the habitat types and methods used in a study. The objectives of this study are to document species diversity in teak plantation in Mata Ayer Research Station, FRIM and to compare differences in species diversity and composition between plantation and natural forest of Perlis State Park. Different types of traps and methods were used to survey four targeted groups of vertebrates (small mammal, bird, reptile and amphibian), including mist net, harp trap, collapsible trap, and active search. A total of 252 individuals were captured, representing 117 species of 53 families of vertebrates. Alpha diversity analysis shows that natural forest has higher species diversity than a teak plantation. Shannon-Weiner Index show higher result in natural forest (3.768) than teak plantation (3.439) while evenness of species distribution is higher in teak plantation (0.8419) than the natural forest (0.4755). Sorenson dissimilarity index indicates that 90.4\% significant difference between sites thus; both sites have different species composition of vertebrates. Taxonomic distinctness however reflects different significant variation responses of both areas. Natural forest shows more species compared to plantation forest as it provides more food resources, suitable home and higher rate of reproduction while teak plantation shows a similar habitable environment with structural and conditions more similar to natural forest. So, both natural forest and plantation should be protected, manage and use suitable planning in order to sustain the biodiversity for future generation.

1. Introduction

Based on Convention on Biological Diversity (2001), a natural forest is defined as a forest composed of indigenous trees and not classified as forest plantation. In contrast, a forest plantation is an area consisting of introduced plants or seedlings for afforestation or reforestation purposes. Forest established by seedling or planting usually associated to pursue economic objectives such as timber or other wood products and carbon sequestration, water conservation and soil conservation. In early 1880,
there is a concern regarding the loss of desired species and initiated the forest plantation in Peninsular Malaysia. As forest plantation in the world increased in area, natural forest area had decreased by 14.6 million hectares per year while 1.5 million hectares of natural forest cover converted to plantation forest cover per year [9].

A natural forest ecosystem can support many different species, protect forest species and help to maintain biodiversity. As natural forests have the complexity of community, it helps enhance hydrological function and decrease soil nutrient depletion [12]. Natural forests also undoubtedly have much food resource availability for the animals and serve as their habitats and shelters. In a natural forest, dead trees at different stages of decay play critical ecological roles as valuable habitats. It gives food, shelter, and breeding conditions for many rare and threatened species, including bryophytes, insect, lichens, invertebrates, birds and mammals. Besides, deadwood found in the natural forest also involves forest nutrient cycle, carbon budgets, soil morphology and natural regeneration [23].

Plantation forestry areas increase by year as the global demand for timber increases. When non-native trees are used, plantation forests risk the global biodiversity as they contribute little to biodiversity [1,19]. Besides, single-species plantation requires a high nutrient demand and eventually leads to soil nutrient depletion [14]. Even though there are many proclaim that plantation forest has negative impacts on the biodiversity. Still, plantation forest is also an important source of industrial wood in terms of economic importance. It helps to reduce pressure on more significant areas of natural forests and generates positive environmental effects as they replace degraded marginal agricultural lands. It also serves to deflect logging away from native forests to renewable forest plantations. Although many were concerned with non-native species in plantation forest, it provides habitat for many native plants and animals [21]. Bremer & Farley [4] suggested through their study that plantation forest could contribute to biodiversity when plantation established on degraded lands rather than replacing natural ecosystems and plant with the indigenous tree. Stephens et al. [25] also highlighted that the biodiversity and plantation might not be necessarily exclusive as many have stipulated.

The study aims to document the vertebrate, namely small mammal, bird, amphibian, and reptiles that inhabit in two different habitat types, e.g. natural forest and teak plantation forest. Secondly, we are intended to investigate the differences in species richness, abundance and compositions on these vertebrates to illustrate the quality of biodiversity exits within two different habitats.

2. Methods and Materials

2.1 Study Sites

Natural Forest
Perlis State Park was selected as representative of natural forest. Mata Ayer Forest Reserve and Wang Mu Forest Reserve are located within Perlis State Park. This park has been classified as a forest sanctuary for wildlife (Ps. G.N. 17-2009), soil protection forest (Ps. G.N. 16-2009) and water catchment forest (Ps. G.N. 73-2008) [26]. The total area of the park is about 4,379.8ha and managed by Department of Forestry Peninsular Malaysia. The forests are located on limestone landscape and reported harboring vast diversity of flora and fauna.

Teak Plantation
Mata Ayer FRIM Field Center was established in 1974 under *Pinus caribaea* Seeds Improvement Program at Mata Ayer Forest Reserve and located in compartment 23 along Jalan Padang Besar, Perlis. The purposes of this field centre were to research teak species from different regions in the aspect of propagation, seed production and promote the high quality of the wood product. Before establishment, Mata Ayer Field Center was a secondary forest covered with native vegetation. The first nursery was built in the year 1960, and currently, the field covered 127.82ha of the teak plantation (Figure 1).
2.2 Vertebrates Sampling

Small Mammals
Fifty collapsible traps and 50 Sherman traps were deployed to capture non-volant mammal along a 500-meter line transect. All traps containing baits were placed 10 meters away from one another along the line transect. For Volant mammal, mist net and harp trap were used. All traps were left open and checked in the morning. The traps were checked daily, and any captured mammals were carefully removed into a cloth bath. All the captured mammals were examined, measured and photographed for identification.

Avifauna
A total of 10 mist nets were used to capture birds within each plot. All the mist net were placed in a suitable area randomly. All the nets were checked seven times daily. Cloth bags were used as a temporary placement for the captured bird. All captured birds were measured, identified and photographed for records.

Herpetofauna
Herpetofauna is a combination of taxa amphibians and reptiles. Active searches were carried out for herpetofauna in potential habitats such as river/tributary, water paddle, wetland, and swamps in both study sites. A group of four to five people using torchlight and snake tong searched for herpetofauna with a minimum time of two hours. Each study site comprised three sampling sessions. Every herpetofauna encountered were collected by hand or snake tong (especially for poisonous snake) and kept in cloth bag prior examination. Each individual captured were thoroughly examined, measured and photographed. Each species' representative individuals of each species were tissued for liver, preserved, and deposited into FRIM Zoological Collection, Kepong.

Alpha Diversity Analysis
We calculated species diversity for natural and plantation-based on several diversity indices provided by PAST (Citation). Firstly, we subjected several indices, namely species richness, Shannon-Wiener diversity, Evenness, Dominance and estimator Chao 1, to overall data (combination of small mammals,
avifauna and herpetofauna) in order to picture whole diversity between natural and plantation forest. We used Chao 1 estimator to evaluate the total species richness expected in an area which includes species that are not caught during the survey in each study site. We also conducted ANOVA analysis to illustrate the differences among three groups of vertebrates in both study sites. A sample-based rarefaction curve was plotted to illustrate the completeness of sampling efficiency (Gotelli and Colwell, 2001).

**Dissimilarity Index**

To show the dissimilarity among the assemblage investigated in this study, we conducted Sørenson Dissimilarity analysis based on following formula: \( S_{S} = \frac{2a}{2a + b + c} \), where Sørensen similarity coefficient, \( a = \) number of species common to both sites, \( b = \) number of species unique to the first site, and \( c = \) number of species unique to the second site. Sørensen similarity usually is multiplied by 100% (i.e., \( SS = 67\% \)), and may be represented in terms of dissimilarity (i.e., \( DS = 1.0 - SS \)).

**Taxonomic Diversity and Distinctness**

We selected classic taxonomic measures developed by Clarke and Warwick (1999), taxonomic diversity and taxonomic Distinctness, which measured merged information relative to taxonomy, number of species and evenness of the sample and these remained insensitive to the sampling efforts (Clarke and Warwick 1999). The analysis was subjected to each taxa level of vertebrates that we investigated in this study to show the differences in taxonomic terms.

### 3. Results

A total of 252 individuals of vertebrates were successfully captured during surveys conducted in Perlis State Park and Mata Ayer Field Center in Perlis. Natural forest harbours higher species richness (91 species) compared to plantation (37 species) based on alpha diversity indices. Shannon Wiener indicates that that natural forest scored the highest value of 3.768 while plantation valued at 3.439. However, species evenness of vertebrates examined was more uniformly distributed in plantation compared to the natural forest (Table 1). During these surveys, the efforts contributed only to record about 34% (in the natural forest) to 50% (in plantation forest) based on diversity estimation given by Chao 1 analysis. This result is supported by a sample-based rarefaction curve that shows the curves have not yet reached their asymptote (Figure 2).

| Table 1. Alpha Diversity Indices of vertebrates collected in natural and plantation forests in the state of Perlis. |
|---------------------------------------------------------------|
| **Alpha Diversity Index** | Plantation Forest | Natural Forest |
| Taxa (S) | 37 | 91 |
| No of Ind. | 59 | 193 |
| Dominance (D) | 0.0388 | 0.0689 |
| Shannon (H) | 3.439 | 3.768 |
| Evenness (e^H/S) | 0.8419 | 0.4755 |
| Chao-1 | 74.5 | 261.1 |
ANOVA analysis shows that the whole vertebrates assemblages in the natural forest were significantly different from plantation forest \((F=7.569, p\text{-value}=0.006405)\). Based on Sorenson Dissimilarity Index, the value of 90.4\% indicated significant differences in vertebrates' assemblage between natural and plantation forest.

**Table 2.** Taxonomic diversity and Distinctness based on three taxa of vertebrates investigated in natural and plantation forest in the state of Perlis.

| Taxa            | Taxonomic Diversity | Taxonomic Distinctness |
|-----------------|---------------------|------------------------|
|                 | Natural Forest | Plantation Forest | Natural Forest | Plantation Forest |
| Small Mammal    | 1.918±0.1825       | 3.105±0.676          | 2.905±0.1215   | 3.327±0.494       |
| Avifauna        | 3.368±0.095        | 3.1±0.288            | 3.448±0.086    | 3.356±0.265       |
| Herpetofauna    | 3.756±0.111        | 3.831±0.342          | 3.889±0.0905   | 4.07±0.3025       |

Although the diversity of small mammals in natural forests is higher (15 spp) than plantation (13 spp), there is no significant difference among the small mammal assemblage recorded. The taxonomic diversity of small mammal (Table 2) directly indicates that the richness in the taxonomic hierarchy in teak plantation is much higher in distance hierarchy than small mammals found in Perlis State Park. However, as in avifauna assemblage, there is a definite dissimilarity of birds between natural and plantation forest, as shown in Table 2. The taxonomic Distinctness for herpetofauna assemblage appears to be higher in plantation compared to natural forest.

**4. Discussion**

We managed to capture 252 individuals of vertebrates in both natural forest and teak plantations where 91 species were identified in the natural forest through this study. In contrast, 37 species were found in the teak plantation. This indicates that natural forest harbour higher richness than teak plantation. Like most studies, the finding is anticipated where species diversity is comparably higher in the natural forest than plantations. However, plantation forest harbours more diversity than any intensive land use [24]. The natural forest in Perlis State Park is a mixture of lowland and hill dipterocarp forest. Dipterocarp forest hold up more niches for the higher number of unique species compositions [11,5,15,18] and denser forest area provides higher structural diversity and higher food availability for
the animals [14]. In a natural forest, there are much deadwood or coarse woody debris than in teak plantation where many species of small mammals, avian and reptile use dead wood as breeding habitat, for cover, nesting, roosting, foraging, shelter or as a source of prey [2,6]. Although the natural forest has a more significant number of species presented, the species in the teak plantation are distributed more equitably among the species. There is because the natural forest homes to rarer and unique species, which influences the evenness of the natural forest.

We found the richness among small mammals and herpetofauna assemblages recorded in the natural forest were higher comparably, but taxonomic distinctness of both assemblages was higher in the teak plantation. Lower taxonomic Distinctness of small mammals and herpetofauna in the natural forest might show the possibility of forest fragmentation, as taxonomic Distinctness is quite sensitive for the discriminating species of the affected areas [22,8]. Diversity for avifauna shows the different result from the small mammal. There is dissimilarity of avifauna assemblage in term of taxonomic distinctness between natural and plantation forest. Some studies show plantation forest has impoverished biodiversity [10], marginally different [20] and unexpectedly high biodiversity [7]. According to Stephens et al. [24], diversity in plantations appears to be low at first glance and compared to other land uses. Yet, there is significant variation in responses depending on the bioindicator employed. Heterogeneity of habitat directly influences interpretation of avifauna species compared to small mammals in a plantation landscape.

Consequently, this explained the differences in the taxonomic Distinctness in bird assemblage in both sites. The diversity and composition of vertebrates are highly reliant on the age of the vegetation. The teak plantation establishment in Mata Ayer Field Center was nearly 60 years ago and might have reached ecosystem stability viable to a vast diversity of vertebrates. Native species plantation also shows similar to slightly lower biodiversity when compared with natural forest. Sometimes, it can provide a habitable environment with structural and conditions more similar to the natural forest [24].

Sampling done in both habitats only documented 30% to 50% of the estimated diversity of vertebrates. Sampling effort is one factor that influences the total diversity captured in a particular area or habitat. Many studies had indicated that a prolonged sampling period could increase the chances of documenting higher diversity coupled with diversification on methods deployed during the sampling period [16,17]. Basset [3] explained that a higher sampling effort accounting for the heterogeneity of the forest would have provided a more balanced view of differences in species richness between plantations and the forest. The diversity of vertebrates demonstrated in this study is far from complete. It is believed more vertebrates will be documented with a more systematic and much more extended period of sampling.

5. Conclusion
The study showed that the richness, abundance and compositions of vertebrates in the natural forest are higher than teak plantation forest. However, the diversity of vertebrates found in teak plantation pictures a unique vertebrate assemblage that required a neat tailored management to preserve the remaining diversity within the plantation landscape. The information obtained through this study could serve as baseline information to plantation and park managers to formulate holistic planning to conserve biodiversity.

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