Introduction of Biological Parameters for Environmentally Sensitive Area (ESA) Classification for Permanent Forest Reserve: A Case Study Based on Small Vertebrates’ Assessments in Selangor

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Abstract. Environmentally sensitive areas (ESAs) is vital for seeking the balance between biodiversity conservation and land use planning based on the concept of sustainable development. However, the classification of ESA in Malaysia grounded on physical attributes and the biological elements neglected. Therefore, the aim of the study is to propose a new approach of ESA for permanent forest reserve classification by integrating biological parameters based on small vertebrates with the existing physical attribute of ESA classification. Three forest reserves in northern Selangor selected and four taxa of small vertebrate e.g. small mammals, birds, amphibians and reptiles assessed to develop the biological parameters. Forty potential biological parameters were listed which were thoroughly screened and examined before final ten parameters were finalised. These parameters were composed of four categories including species diversity, trophic composition, origin of species and conservation status. An initial threshold values for each biological parameter were determined. The finding indicates the parameters are promising and the research need to further fine-tuned by conducting verification tests in various landscapes or regions before being integrated with physical attributes to enhance the existing classification of ESA in Malaysia.

1. Introduction
Malaysia has adopted two approaches to conserve biodiversity, namely via species and habitat protection. Numerous initiatives have been proposed and enforced for species protection, especially to the threatened species such as tiger (Panthera tigris) and elephant (Elephas maximus). Action plans like National Tiger Conservation Action Plan (NTCAP) and National Elephant Conservation Action Plan (NECAP) are documents that focus on conserving and protecting these species before extinct. On the other hand, another approach is via habitat protection. Gazettement, a particular area as a Protected Area based on specific laws and regulations, is one of the main initiatives. However, Environmentally Sensitive Areas (ESAs) is another critical approach that needs to be strengthening and implemented thoroughly.
Among the earlier concept of ESAs, it was introduced in the United Kingdom through the Agriculture Act 1986, where specific environments of national interest were included such as conservation of areas that important for environmental well-being and environmentally threatened by changing farming practices [1]. However, in the United States, ESAs defined as a land set-aside to protect particular natural environments including recreational areas, wilderness areas, wildlife refuge and historic sites [2].

In Malaysia, there are several definitions of ESAs. The earlier concept of ESA was focusing on the need to protect an area or fragile ecosystem that human may be affecting with the disturbances and produce negative impacts from the development [3]. The introduction of ESA in Malaysia backed in the 1990s as “Critical Areas” which provides a framework and guideline for the conservation of natural resources and the environment throughout the planning and implementation process [4]. The areas identified were undisturbed habitats such as catchment areas, biological diversity and research, natural habitats that support human activities and environmental functions, areas with steep slopes, historical sites and archaeological or geological value. On the other hand, the Department of Environment (DOE) defines ESAs, as areas require special attention before the approval of development in a particular place and its adjacent [5]. As for the Town and Country Planning Department of Peninsular Malaysia (PLANMalaysia), ESAs is an approach through the land use planning perspective. In 1998, a consensus regarding the scope of ESAs was done at the national level that defines as 10 categories such as biological diversity, highlands and steep slopes, catchment areas and wildlife protections [6]. Since then, the department has prepared a series of generic guidelines for the management of sectoral ESAs [7].

According to the 2nd National Physical Plan (NPP2), ESAs are ranked based on several physical criteria such as altitudes and slopes. Table 1 details the definition for each rank.

| Rank            | Description                                                                 |
|-----------------|-----------------------------------------------------------------------------|
| ESA Rank 1      | No development, agriculture or logging shall be permitted except for low-impact nature tourism, research and education. |
| ESA Rank 2      | No development or agriculture. Sustainable logging and low impact nature tourism may be permitted subject to local constraints. |
| ESA Rank 3      | Controlled development whereby the type and intensity of the development shall be strictly controlled depending on the nature of the constraints. |

Source: 2nd National Physical Plan (2011-2015)

ESAs are vital for seeking the balance between biodiversity conservation and land use planning based on the concept of sustainable development. According to these ranks, understanding the trade-offs between land development, environmental protection, and societal well-being must be integrated. Currently, the classification of ESAs by PLANMalaysia is mostly focusing on physical orientated attributes such as degree of slopes, high altitudes, and degree of risks and biological elements of an environment might be neglected. Decisions based only on physical attributes did not reflect the actual sensitivity of an environment.

Therefore, this study aims to propose biological parameters based on small vertebrates as an additional component into the ESAs classification in Malaysia. Mainstreaming and integration of both physical and biological attributes in the classification of ESA will establish inclusive protection to the environment.

2. Materials and Methods

2.1 Reference sites
Selangor has been the wealthiest state in Malaysia for the last four decades based on real GDP and per capita real GDP from 1970 until 2010 [8]. Despite having fast development and extensive land-use change, Selangor is committed to protecting and maintaining their 30% total forest reserves in the state based on Selangor State Structural Plan 2035 (Policy MP16 and Policy MP17).
The study focused on one of 11 ESA landscapes identified in Malaysia: Permanent Forest Reserves (PFR) [9]. Three PFR were selected as an experimental site to determine, examine and verify appropriate biology parameters to classify ESAs in Malaysia. They are Gading Forest Reserve, Bukit Kutu Forest Reserve and Bukit Tarek Forest Reserve (Extension).

Gading FR is one of the most extensive forests in northern Selangor with a total area of 18,828 ha (Fig. 1). Bukit Kutu FR covered a total area of 11,700 ha and considered a wildlife sanctuary. Both Gading FR and Bukit Kutu FR are located approximately 20 km apart. Bukit Tarek FR (E) is additional forestland to the existing Bukit Tarek FR. It is located south to Gading FR and west to Bukit Kutu FR with a total area of 3,560 ha of forested land. Bukit Tarek FR (E) is located about 10 km from Gading FR and 15 km from Bukit Kutu FR.

All study sites are classified as ESA Rank II, according to PLANMalaysia [9]. All selected areas were undergone a certain level of logging, and most of them were almost 30 years since the last of harvesting processes. Since then, no timber harvesting activities and any significant development prohibited. Therefore, these sites are best to reflect the conditions of ESA Rank 2 and elected as reference sites to develop and test biological parameters for ESA classification.

![Figure 1. The locations of three permanent forest reserve located at northern of Selangor State](image)

2.2 Vertebrates Assessment

The sampling was carried out monthly at each site from January 2017 until September 2019. At each station samples of vertebrates were collected along standardised plots using various types of traps to capture four selected taxa of vertebrates including small mammals (volant and non-volant mammals), avifauna, amphibians and reptiles.

Five line transects with 200m length were established in each forest reserves and built alternatively to each other transects. A total of 100 collapsible cage traps and three harp traps were deployed to trap non-volant small mammals such as rodents, shrews and squirrels; and volant small mammals (bats). A
minimum of 10 mist net and at least two series of direct observations to document species of birds, especially understory birds in each study site. At the same time, 25 unit of 18-litters sized buckets buried to the ground was used as a pitfall to trap terrestrial vertebrates especially amphibians and reptiles. The active search was conducted at least for two consecutive nights during respective sampling to search for nocturnal vertebrates particularly amphibians and reptiles at potential areas such as along riverbanks, water puddle, and other water bodies identified.

The sampling session conducted for five consecutive days, with a minimum of four trapping night effort, respectively. Traps checked based on standardised periods; collapsible cage traps, harp traps and pitfall traps checked once in every morning; while mist nest was checked at every two to three hours in morning and night. Any trapped animals were carefully removed and placed into cloth bag temporarily before the examination. All captured animals examined and measured. Specimens were identified to the species level using various references available. Only three representative individuals of each species found at each study site were collected and stored in 70% ethanol as voucher specimens. Liver tissues excised and stored in a vial containing absolute ethanol for further DNA analysis. Then, the specimens deposited in the Zoological Collection of Forest Research Institute Malaysia (FRIM).

2.3 Development of Biological Parameters
The data collected in three sites of ESA Rank 2 used to develop the biological parameters. Firstly, all the species divided into respective taxa and further classified to their family level. Then, the conservation and protection status for each species obtained through screening the current IUCN status and protection status highlighted by relevant acts and regulations on respective taxon.

In the present study, biological parameters were calculated using biological information of four taxa vertebrate species either with the help of the literature and personal experiences. Forty parameters relevant to the classification of ESA calculated based on structure, composition and assemblage pattern of four selected taxa of vertebrates. Biological parameters were categorised into four main groups, viz. species diversity, origin, trophic composition and conservation status.

Species diversity parameters calculated to express the species richness, which includes the number of species, the total number of family and the total number of individuals of each species for the respective taxon. Parameters based on the number of species and origin of species have been used as an indicator of environmental changes to reflects any form of stress on vertebrates by different authors. Sometimes long-term exposure to environmental changes such as forest structure due to development may cause complete elimination of certain vertebrates such as closed-canopy related birds from the particular forest. Matrix of a total number of individuals of a species in the site indicates the level of species richness and its ecological conditions.

The trophic composition parameters were based on the feeding patterns of each species found in three study sites. This parameter reflects trophic dynamics and used to assess the changes in ecological processes in a forest reserve of selected vertebrates. Percentage individuals as omnivores, carnivores, and herbivores are used to evaluate the status of the trophic structure and food base.

In this study, the International Union for Conservation of Nature’s Red List were used to access the conservation status for each species recorded within these study sites. Here, the total numbers of the least threatened species were also taking into account.

2.4 Determination of Threshold Value for ESAS Classification
The potential biological parameters that listed screened thoroughly based on the primary data collected from the field and published information to determine the best biological parameter to reflect the level of sensitivity of a permanent forest reserve. Each species classified into respective categories, and value for the individual parameter was calculated.

Redundancy analysis performed using the Spearman correlation test with pairs of parameters of all four categories regarded as sensitive. The purpose of doing so is to simplify the parameters, reduce the cost of analysis and avoid redundant information. A parameter is considered redundancy when being
positively correlated when the value of Spearman is significant ($r \geq 0.75$, $p \leq 0.05$), and only one was chosen to represent that particular information of the parameter represents.

The finalised parameters for ESA classification are taken further into consideration where the value for the respective parameter was converted to be used for scoring in ESA classification. The parameters values were trisected where the value of upper quartile 25% reflects a score of five, and the value of lower quartile 25% reflects a score of 1. As for the Median, the value given is three, which represent by the reference sites. The final score for a given forest reserve was obtained by simply adding all score for all parameters. Finally, the rating for classifying environmental sensitive area level developed for three levels of ESAs by dividing the total parameter score into three groups, e.g. ESA Rank 1, ESA Rank 2 and ESA Rank 3.

3. Results and Discussions

3.1 Vertebrates Assessments

A total of 144 species of small vertebrates were documented consisting of 47 species of mammals, 74 species of birds and 43 species of herpetofauna listed at the reference sites. A total of 10 families of mammals, 25 families of birds and 10 families under taxa herpetofauna were recorded. Amongst mammal families, Vespertilionidae was the most diverse with 12 species, followed by Muridae with nine species. Only one species has been recorded under the Erinaceidae, Tupaiidae and Nycteridae families. The results also showed that Gading FR was the richest in mammal species (33 spp) compared to Bukit Kutu FR (28 spp) and Bukit Tarek FR (E) (24 spp). As for bird diversity, the family Pycnonotidae was the most diverse with 14 spp, followed by Muscicapidae (9 spp). Under group herpetofauna, the family Dicroglossidae comprised of eight species and the second-highest abundant family were Bufonidae and Ranidae with four species, respectively.

Small mammals showed a negative response toward forest fragmentation in term of species [10,11] and individuals [12]. A similar response was shown in bird, amphibian and reptile species richness and abundance towards forest changes [13,14]. Consequently, vertebrates are sensitive to forest changes and are the best biological indicators to determine the sensitivity of environmental in this case in the permanent forest reserve.

3.2 Biological Parameters for ESA Classification

A total of 40 biological parameters were listed based on the vertebrates documented in three references sites. Off the forty parameters, most of them were positively associated with each other with Spearman $r$' value $\geq 0.75$. Therefore, only one or two-parameter in each category was selected to develop the ESA biological parameters. The general biological parameters were chosen, as it is easier for anyone to carry out the assessment, especially stakeholders of management.

**Table 2.** Scoring Criteria for the ten biological parameters to classify Environmental Sensitive Area (ESA) based on vertebrates found in three reference sites

| No  | Categories                  | Parameter                                                                 | SCORING | 1  | 3       | 5  |
|-----|-----------------------------|---------------------------------------------------------------------------|---------|----|---------|----|
| 1   | Species diversity           | Total no species (mammal, bird & herpetofauna)                            | < 83    | 84 | 91      | > 92 |
|     |                             | Total no of individual (mammal, bird & herpetofauna)                      | < 280   | 281| 401     | > 402|
| 2   | Trophic composition         | Total no of herbivores (mammal, bird & herpetofauna)                     | < 19    | 20 | 27      | > 28 |
|     |                             | Total no of carnivores (mammal, bird & herpetofauna)                     | < 43    | 44 | 55      | > 56 |
Out of 40 parameters listed, 10 parameters were shortlisted, which were comprised of four categories (Table 2). Under species diversity category, total numbers of species and the total number of individuals of all species were selected which reflect the species richness and ecological condition of a forest reserve. These parameters could be assessed merely based on documentation of vertebrate species found in a particular area of the forest reserve. A similar decision made in selecting parameters for trophic composition. Combination of trophic composition parameters chosen as it reflects the condition of feeding composition of vertebrates that found within sites of references than divided into a different group of the taxon. Different level of dynamic of trophic composition indicates that a particular forest area reached a maturity condition in sustaining a vast range of vertebrate species. As for conservation status category, all level of threatened categories, including critical endangered (CR), Endangered (EN) and Vulnerable (VU) combined and listed as threatened vertebrates. Presence of threatened species in a forest reserve imitates the importance of a particular forest reserve to be conserved as a natural habitat for the species. As for lower risk species, it is a combination of species classified as Near Threatened (NT) and Least Concerned (LC) based on IUNC Red List.

### 3.3 Threshold Values for ESA Classification

As the outcome, 10 biological parameters were shortlisted to be integrated into ESA classification. Values of each parameter converted into unitless biological parameters scores as in Table 2. Finally, the ratings of ESA classification and their score were classed into three levels as Rank I, Rank II, and Rank III as given in Table 3. The values presented in this study need to be incorporated with physical attributes or values before the final classification of ESA is determined.

| Biological Parameter scoring | Classification |
|------------------------------|----------------|
| 50-44                        | Rank 1         |
| 27-43                        | Rank 2         |
| 10-26                        | Rank 3         |

### 4. Conclusion

In conclusion, the biological parameters based on small vertebrates that developed through this study are promising as the parameters were comprehensive and holistic. However, the research needs to be tested out to see the sensitivity of the parameters in different landscape or region before intergraded with physical attributes to refine the ESA classification in Malaysia. Other biological elements such as plants should be included as other elements to enhance the classification of ESA for permanent forest reserve. This finding indicates that the integration of biological components in land use planning could be valuable, as it will reinforce the future sustainable development in the country.
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