Diversity of freshwater fish in Forest Research Institute Malaysia (FRIM): A comparison of diversity between man-made and natural forest in Selangor, Malaysia

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Abstract. This present study aimed to investigate the diversity of freshwater fish in a planted forest within three tributaries, namely Sungai Kroh, Sungai Chemubong, and Sungai Cahaya, in the Forest Research Institute Malaysia (FRIM) campus. In this study, freshwater fish were sampled using a backpack electro-fisher and scoop nets along 100m transect lines for each sampling site (at upper, middle, and lower part) of the respective river. All individuals collected were examined and measured to identify at their species level. However, we found no fish presence in Sg. Cahaya across all sub-section of the tributary. Hence, the result of fish was based on two tributaries of Sg. Kroh and Sg. Chemubong. A total of 235 individual freshwater fish recorded in FRIM belong to 10 species comprising six families. The highest recorded family belongs to Cyprinidae (30%), followed by Channidae and Danionidae families with 20% respectively, whereas the other three family only represent 10% respectively. Shannon-Wiener indices showed that the highest diversity was recorded for Sg. Chemubong, \(H = 1.283\), while the lowest was recorded for Sg. Kroh, \(H = 1.097\). The highest Evenness index of fish species was detected for Sg. Chemubong, \(E = 0.5098\) and the lowest for Sg. Kroh, \(E = 0.2994\). We carried out a similarity analysis by comparing freshwater fish from adjacent natural forest reserves, namely Sungai Kanching Forest Reserve. Based on the presence-absence data, the species composition of the freshwater fish between the man-made forest (FRIM campus) and natural forest (Sungai Kanching Forest Reserve) was almost 82% similar based on the Sørensen similarity index. The discussion was made based on the available findings in this study to illustrate the freshwater ecosystem stability in a man-made tropical forest, for instance, in FRIM Campus.

1. Introduction

Freshwater environments are considered among the most vulnerable ecosystems on the planet, and one of the major threats to the environment is land-use change [1, 2]. In general, land modifications along riverine area will result in the loss of riparian vegetation, diminishing the diversity of aquatic vertebrates by changing water flow regimes, increasing sedimentation and nutrient loads [3, 4]. Malaysia is rich in biodiversity and recognized internationally as a ‘mega diversity country’ [5]. Malaysia's freshwater ecosystem, which includes both natural and man-made bodies of water, is a major source of aquatic resources [6]. Malaysia is home to 470 of the 1000 fish species found in
freshwater habitats of the South-East Asian Tropics [5, 7, 8]. The distribution of freshwater fish in Malaysia can be divided into two zoogeographic regions. The first region is Peninsular Malaysia, and the second region is West Malaysia, Sabah and Sarawak [5].

Forest is the crucial habitat as the majority of the biodiversity of Malaysia resides within the habitat. Reforestation and afforestation are typical strategies for rehabilitation and recovery programs to minimize erosion. These forestry activities may result in major landscape alterations and biodiversity shifts [9]. Planted or man-made forests had led to expansion and increasing proportion of the forested area, thus acting as a potential repository for Malaysia’s biodiversity [10]. It is also recognized to be partly compensated for the loss of natural forest in ecological function and home for biodiversity, including freshwater habitat [11].

One of the largest and oldest man-made tropical forests in Peninsular Malaysia is the Forest Research Institute Malaysia (FRIM) campus (3°14′06″N, 101°37′59″E), which is located about 16 km northwest of the metropolitan city of Kuala Lumpur, Malaysia [12]. FRIM campus covered 544.3 hectares and was previously known as a tin-mining wasteland and vegetable garden [13, 14]. It is now recognized as a National Heritage Site covered with a tall closed canopy of dipterocarp forest as a result of almost a 100-year-old experiment of reforestation since 1926 [14]. Urbanization and other development affecting Kuala Lumpur City led to FRIM being one of the remnant green open spaces near the federal capital city that provide a home to many vertebrates and invertebrates species [13, 15]. Studies of animals and insects have been well carried out since 1982 in the FRIM campus, and the results showed a healthy and balanced diversity. Recent studies on herpetofauna show new records of species being listed yearly, indicating the forest in FRIM harbours more vertebrates than anticipated [13].

Researchers of FRIM carried out many intensive studies and documentation on vertebrates, but study on freshwater fish within FRIM campus was introductory and required an exhaustive inventory. Therefore, the purpose of this study is; i) to document and produce a comprehensive checklist of fish found in all water bodies within the FRIM campus, ii) to investigate the diversity and composition of fish found in three naturally flowing tributaries in FRIM and lastly iii) to compare the quality of diversity of fish in the man-made forest (FRIM) with natural forest (Sungai Kanching of Templar Park and Kanching Forest Reserve).

2. Materials and Methods

2.1. Study Site
Within the FRIM compound, three major tributaries flowing across the campus are Sungai Kroh, Sungai Chemubong and Sungai Cahaya (Sungai= river or tributaries) (Figure 1). Fish study at Sungai Kanching and its tributaries was selected as a comparison site as it is located adjacent to the FRIM campus [16]. The rivers located in Kanching Eco Park and Templar Park, both forest complexes, were continuous with FRIM. Both parks encompass nearly 500 hectares in size, and are popular among locals for recreational activity.
2.1.1. Habitat Characteristics. The majority of the tributary substrates were sandy, covered with cobbles and only a small percentage filled with slits. Boulders only detected at upper reach in Sungai Kroh with a minute percentages. All the tributaries were classed as river level I and II based on water quality. Almost all the tributaries were shaded by forest canopy and the river bank was grown with riparian vegetation.

2.2. Fish Sampling
The fish sampling was executed using a Root-Smith LR 24 Backpack Electrofisher. Each tributary was divided into three sections: the upper reach, middle reach, and lower reach. A 100meter sampling line was established along each section for all three tributaries. One person conducted the electrofisher while three persons helped in netting the electrocuted fish. With a mesh size of 1cm, the scoop nets were used to capture the stunned fish. Electrofishing was done by wading and applying the same catching effort for each site, approximately two hours at each tributary (at each upper, middle and lower reaches). All the tributaries were sampled at least once during the study. Fish that could be confidently identified were enumerated and, if still alive, were released back to their natural environment. The ones that could not be identified were brought back to the Zoology Branch in FRIM for further examination. All the individuals were counted, and their species were identified with references based on [17, 18, 19, 20, 21]. Then, tissues were excised for molecular study purpose and deposited into Zoological Collection of FRIM.

2.2.1. Checklist of Fish
Apart from fish collected from the three tributaries, other fish in different habitats such as man-made lakes, ponds, swamps, and other water body presences within FRIM borders were included in the fish checklist. The originality of each species was identified by indicating as native or introduced species.

2.2.2. Statistical Analysis
Relative abundance for each species detected in each tributary was counted by dividing the total individual of species A with total individuals collected from the tributary. Alpha diversity indices such as species richness (S), Shannon-Wiener Index (H), Dominance Index, Evenness Index and Chao 1
species estimator were calculated using PAST software [22]. Chao 1 estimator was used to evaluate the total species richness expected in an area that includes species not caught during each tributary survey. A t-test was carried out to examine the differences in the abundance of species in the tributaries. Species composition found in FRIM campus was compared with fish diversity in Sg. Kanching based on Sorenson similarity Index with bootstraps valued at 10,000 and presented in unweighted pair group method with arithmetic mean (UPGMA) dendrogram.

3. Results

Three tributaries in FRIM campus were sampled for their fish diversity. However, we found no fish presence in Sg. Cahaya across all sub-section of the tributary. Hence, the result of the fish was based on two tributaries of Sg. Kroh and Sg. Chemubong. Two hundred thirty-eight individuals were captured in both tributaries, comprising 10 species of six families of primary freshwater fish. The t-test indicated that the abundance of species between both tributaries was insignificant ($t = 0.585, p$-value $> 0.05$) as the total individuals captured were 152 (Sg. Kroh) and 83 (Sg. Chemubong) were not much different. Cyprinidae was the dominant family in tributaries with three species followed by Channidae and Danionidae with two species respectively. In contrast, families of Synbranchidae, Clariidae and Osphronemidae were represented by a single species respectively (Figure 2). Apart from fish collected from the three tributaries, other fish in different habitats such as man-made lakes, ponds, swamps and other water body presences within FRIM borders were included in the checklist of freshwater fish as tabulated in Table 1.

![Figure 2. The species diversity of freshwater fish found in both Sg. Kroh and Sg. Chemubong of FRIM.](image)

Species compositions of freshwater fish in Sg. Kroh and Sg. Chemubong were dominated by species *Poropuntius normani* (45.4%) followed by *Rasbora vulgaris* (23.1%) and *Barbodes binotatus* (16.4%). Species ranking curve was illustrated in Figure 3(c). Alpha diversity indices for both tributaries were shown in Table 2. Shannon-Wiener and evenness indices indicated that Sg. Chemubong has more richness, abundance, and evenly distributed freshwater fish species than Sg. Kroh. However, Sg. Kroh was the highest in dominations of species diversity. Interestingly, sampling in both tributaries was managed to document 73% (Sg. Chemubong) and 97% (Sg. Kroh) of species diversity estimated by Chao 1 analysis. The finding was supported by sample-based rarefaction curves for both tributaries, with both curves almost reaching its asymptote (Figure 3a & 3b). Unweighted pair group method with arithmetic mean (UPGMA) dendrogram constructed based on Sorenson similarity
index clearly shows that the species composition of freshwater fish found in both tributaries of FRIM were almost 82% similar with species compositions found in natural habitat of Sg. Kanching and its tributaries (Figure 3d).

**Table 1.** Checklist of freshwater fish presences in FRIM campus.

| Family       | Scientific Name                   | Common Name  | Originality |
|--------------|-----------------------------------|--------------|-------------|
| Cyprinidae   | *Poropuntius normani*             | Tengas Daun  | Native      |
|              | *Barbodes binotatus*              | Tebal Sisik  | Native      |
|              | *Barbodes banksi*                 | Tebal Sisik  | Sarawak     |
|              | *Osteochilus vittatus*            | Ikan Terbol  | Native      |
|              | *Oxygaster anomalura*             | Ikan Lalong  | Native      |
|              | *Barbonymus schwanenfeldii*       | Lampam Sungai| Native      |
|              | *Carassius auratus auratus*       | Ikan Emas    | Introduce   |
|              | *Cyprinus carpio*                 | Ikan Lee Koh | Introduce   |
|              | *Neolissochilus sp.*              | Ikan Tengas  | Introduce   |
| Osphronemidae| *Trichopodus trichopterus*        | Sepat Ronggeng| Native    |
|              | *Trichopsis vittata*              | Ikan Karim   | Native      |
|              | *Osphronemus goramy*              | Ikan Kalui   | Native      |
|              | *Betta pugnax*                    | Ikan Pelaga  | Native      |
| Channidae    | *Channa lucius*                   | Bujuk        | Native      |
|              | *Channa striata*                  | Haruan       | Native      |
|              | *Channa micropeltes*              | Ikan Toman   | Native      |
|              | *Channa limbata*                  | Kedak        | Native      |
| Clariidae    | *Clarias nieuhofii*               | Keli Limbat  | Native      |
|              | *Clarias leiacantus*              | Keli Hutan   | Native      |
|              | *Clarias gariepinus*              | Keli Afrika  | Introduce   |
| Danionidae   | *Danio albolineatus*              | Bada Jalur   | Native      |
|              | *Rasbora vulgaris*                | Seluang      | Native      |
| Anguillidae  | *Anguilla marmorata*              | Belut Sinsilog| Native  |
| Osteoglossidae| *Scleropages formosus*           | Ikan Kelisa  | Native      |
| Pangasiidae  | *Pangasius pangasius*             | Ikan Patin   | Native      |
| Synbranchidae| *Monoperus albus*                 | Belut Paya   | Native      |
| Arapaimidae  | *Arapaima gigas*                  | Arapaima     | Introduce   |
| Cichlidae    | *Oreochromis sp.*                 | Tilapia      | Introduce   |
| Poeciliidae  | *Poecilia reticulata*             | Ikan Gupi    | Introduce   |
| Serrasalmidae| *Colossoma sp.*                   | Ikan Pacu    | Introduce   |
Figure 3. Sample-based rarefaction curve for Sg Kroh (a) and Sg. Chemubong (b). Species ranking based on abundance (c) and UPGMA dendrogram of Sorenson similarity index between tributaries in FRIM and Sg. Kanching and its tributaries (d).

Table 2. Alpha diversity of freshwater fish in Sg. Kroh and Sg. Chemubong of FRIM campus.

| Sites         | Richness (S) | Shannon Index (H) | Dominance (D) | Evenness | Chao I |
|---------------|--------------|-------------------|---------------|----------|--------|
| Sg Kroh       | 10           | 1.097             | 0.5267        | 0.2994   | 10.25  |
| Sg Chemubong  | 8            | 1.283             | 0.3161        | 0.5098   | 11     |

4. Discussion
Among the three tributaries in FRIM campus sampled, no fish were found in Sg. Cahaya across all sub-sections of the tributary. Sg. Cahaya is characterized by narrow and shallow channels, with higher elevation gradients compared to both Sg. Kroh and Sg. Chemubong. Despite the lack of investigations on freshwater fish assemblages along tributary elevational gradients, a couple of published data show a linear reduction in species richness and diversity with increasing elevation [23, 24]. These findings also indicate that the fish community at high elevation may be numerically dominated by a few specialized species [7, 23, 24]. The hydraulic of habitats in high gradient tributaries are also subjected to natural episodic and sporadic climate forcing, which affects the water physico-chemical quality to decline, particularly after heavy rain and storms [25, 26]. In addition, shallow water areas could be considered less suitable for fish habitat [27]. More intensive samplings may increase the chances of discovery for freshwater fish in Sg. Cahaya [7]. Furthermore, sampling at the mouth of a Sg. Cahaya...
tributary may increase the likelihood of obtaining freshwater fish as diversity rises spatially from upstream to downstream [7, 24].

The t-test result showed that the abundance of species between two tributaries was insignificant, as the total individuals captured were 152 (Sg. Kroh) and 83 (Sg. Chemubong) were not much different. This could be attributed to the physical characteristics of the tributary's habitats, where the substrates of both Sg. Kroh and Sg. Chemubong were sandy with cobbles and only a small portion filled with slits [28]. In addition, both tributaries were shaded by forest canopy and the river bank was grown with riparian vegetation. Furthermore, water quality showed that both tributaries were classified as river level I and II, with clear water bodies. In order to improve the understanding of the relationship between river physico-chemical characteristics and the abundance of fish species, further study is essential to be carried out.

Among the families, Cyprinidae is the most dominant fish family in Sg. Kroh and Sg. Chemubong with approximately 30% of total species recorded. The finding represents similarities with most freshwater fish studies conducted in which family Cyprinidae recorded the highest percentage of richness and abundance [29, 30, 31]. Cyprinidae is almost an exclusively freshwater fish family globally, with 210 genera and about 2010 species [27, 32]. The same goes in Malaysia, where Cyprinidae is considered the largest freshwater fish family in terms of the number of genera and species and its abundance in Malaysia freshwater habitats except for brackish water, where representatives are rarely available [27, 33].

The dominance of Cyprinidae could be probably due to the high adaptive variability and availability of extensive heterogeneous habitat structure in Malaysia freshwater habitats [28]. Based on the species ranking curve, species compositions of freshwater fish in Sg. Kroh and Sg. Chemubong were dominated by species Poropuntius normani (45.4%) followed by Rasbora vulgaris (23.1%) and Barbodes binotatus (16.4%). These three species are classified as common and widely distributed in freshwater streams in Malaysia [34, 35, 36].

In terms of species richness, Sg. Kroh can be considered richer in species composition compared to Sg. Chemubong, as ten species were obtained in Sg. Kroh where only eight species were found in Sg. Chemubong. Based on the Chao I estimator, the sampling effort managed to document 73% and 97% of estimated diversity for Sg. Chemubong and Sg. Kroh respectively. This indicates that sampling effort in Sg. Kroh is sufficient to completely survey the fish diversity compared to fish in Sg. Chemubong. Despite that, the result showed that Sg. Chemubong encompasses higher diversity compared to Sg. Kroh as denoted in Shannon-Wiener Diversity Index (H), where the species diversity for Sg. Chemubong is H = 1.283, while Sg. Kroh is H = 1.097. Such higher values in the Shannon-Wiener Diversity Index in Sg. Chemubong might be influenced by the evenness and dominance of species [37]. The species in Sg. Chemubong were more evenly distributed among different species unlike in Sg. Kroh is dominated by certain species and supported with higher Dominance Index value as shown in Table 2. Sg Chemubong is considerably much wider and has a deeper water body compared to Sg. Kroh. River with wider, deeper and longer channel or tributary may provide more heterogeneous living spaces, which could support a large number of freshwater fish species through the habitat segregation [38]. Furthermore, environmental factors, such as the physico-chemical of the water quality, hydrological, and habitat characteristics, could play major roles in species richness, diversity, and species survival in freshwater habitats [7, 25, 38].

Similarity coefficients based on Sorensen model were used to measure species similarity between man-made forest of FRIM campus and natural forests in Templer Park and Kanching Forest Reserve. This coefficient is designed equal to 100% in cases of complete similarity. In this study, unweighted pair method with arithmetic mean (UPGMA) dendrogram constructed shows the species composition of freshwater fish found in both tributaries (Sg. Kroh and Sg. Chemubong) of FRIM were almost 82% similar to species compositions found in the natural habitat of Sg. Kanching and its tributaries. Even though FRIM is noticeably a reforested habitat, the ecosystems established within the campus are equivalent to a natural forest as in Templer Park and Kanching Forest Reserve. A period of
nearly 100 years of reforestation effort within the FRIM campus had fruitfully restored the ecological functions and stability which finally made it able to harbour vast ranging species diversity.

5. Conclusion
The checklist presented herein is the first insight into the comprehensive freshwater fish diversity within the FRIM campus. Majority of freshwater fish recorded were originally native to FRIM ecosystem, with some non-local species being introduced into man-made lakes and ponds mainly for fishing recreation and attraction. However, such actions should be administered strictly to prevent invasive alien species within FRIM campus, especially on freshwater fish. The diversity of freshwater fish in tributaries in FRIM show a healthy and stable diversity comparatively to natural forest as in Templer Park and Sg. Kanching Forest Reserve. Despite being a reforested habitat, FRIM could serve as a repository for flora and fauna especially in highly developed environments and protection of the campus will ensure the continuity of harbouring vast biodiversity.

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