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# Assessment of Riparian Ecosystem on Amphibians along a Green Corridor in Oil Palm Plantation, Pasoh, Negeri Sembilan, Peninsular Malaysia

(Penilaian Ekosistem Riparia terhadap Amfibia di sepanjang Koridor Hijau di Ladang Kelapa Sawit, Pasoh, Negeri Sembilan, Semenanjung Malaysia)

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ABSTRACT

*The large scale expansion of oil palm plantations nowadays bring huge negative impact on habitat destruction and loss of biodiversity, especially at Pasoh, Negeri Sembilan, Peninsular Malaysia. The monoculture system that was developed since the 1970s has suppressed biodiversity levels because of the lack of suitable microhabitats. In order to assess ecological remediation of plantation, a green corridor was established along Sg. Petekah at Felda Pasoh 2. The assessment was conducted from March to May 2012 at Sg. Petekah green corridor (SPGC) at Felda Pasoh 2 and Felda Pasoh 3 with no green corridor (FP3). Amphibians were sampled for species richness by using fenced pit fall traps and visual encounter surveys. Microhabitat selection of amphibians was identified to come up with recommendations for improvement. The low Shannon-Wiener diversity value, H' at SPGC (1.82 ± 0.126) was obtained indicating that the remediation is yet to be achieved, but the H' value was much lower at PF3 (0.62±0.2) indicating a positive projection of remediation. Microhabitat selection study indicated that each amphibian species tend to avoid overlapping of microhabitat based on specific guilds. Based on the results, the green corridor should be widened to allow space for foraging and territorial defence, planted not only with trees but also shrubs and herbs to improve the ground cover for the amphibians and also to include other animal groups, such as birds and mammals.*

*Keywords: Biodiversity; frog; microhabitat; REDD; species richness*

ABSTRAK

*Pembukaan ladang kelapa sawit secara besar-besaran telah mengakibatkan pelbagai kesan negatif seperti kemusnahan habitat dan kehilangan kepelbagaian biologi terutamanya di Pasoh, Negeri Sembilan, Semenanjung Malaysia. Sistem monokultur yang dibangunkan sejak tahun 1970-an telah menghalang peningkatan kepelbagaian biologi disebabkan oleh kekurangan mikrohabitat yang sesuai. Bagi menaksir pemulihan ekologi di ladang, satu koridor hijau telah dibina di Sg. Petekah, Felda Pasoh 2. Penilaian telah dilakukan dari Mac hingga Mei 2012 di koridor hijau Sg. Petekah, Felda Pasoh 2 (SPGC) dan di Felda Pasoh 3 tanpa koridor hijau (FP3). Haiwan amfibia disampel menggunakan perangkap lubang berpagar dan kaedah tinjauan visual. Pemilihan mikrohabitat amfibia dikenal pasti untuk mencadangkan penambahbaikan terhadap jalur hijau ini. Nilai Indeks Kepelbagaian Shannon-Wiener, H' yang rendah (1.82 ± 0.126) diperoleh menunjukkan bahawa status pemulihan ekologi kawasan tersebut masih belum dicapai, tetapi nilai H' di PF3 yang lebih rendah (0.62 ± 0.2) menunjukkan unjuran positif terhadap pemulihan di koridor tersebut. Penilaian mikrohabitat mendapati setiap spesies amfibia lebih cenderung mengelak pertindihan mikrohabitat dengan spesies yang lain serta cenderung memilih mikrohabitat yang sesuai dengan ciri morfologi. Berdasarkan hasil kajian ini, koridor hijau perlu dilebarkan untuk menambah ruang untuk mencari makanan dan mempertahankan kawasan, perlu ditanam dengan pokok renek dan tanaman herba untuk menutup tanah sebagai tempat perlindungan amfibia dan perlu mengkaji kumpulan haiwan lain seperti burung dan mamalia.*

*Kata kunci: Katak; kekayaan spesies; kepelbagaian biologi; mikrohabitat; REDD*

## INTRODUCTION

Tropical deforestation is caused by multiple drivers and pressures, such as conversion of natural forest areas to agricultural area (Fitzherbert et al. 2008), logging (Johns 1985) and infrastructure development (Geist & Lambin 2002). The Food and Agricultural Organization (FAO) definition for deforestation is the conversion of forest to another land use or long-term reduction of tree canopy cover below the minimum 10% threshold (FAO 2001). In relation to the present global warming issue, among other impacts, tropical deforestation is considered as the second largest source of anthropogenic greenhouse gas emissions (IPCC 2007). Tropical deforestation has a high socio-economic and environmental impact and a very complex issue to address (Rudel & Roper 1997), especially in developing nations, including Malaysia.

In Malaysia, agriculture is the most important economic activity that develops the nation. Agricultural commodity sector includes oil palm, rubber and coconut planting. Malaysia is among the largest palm oil producers in the world. The rapid growth of this industry increases the demand of land use changes for oil palm plantations. Okuda et al. (2003) reported that old growth primary forest decreased by 50%, while area of oil palm plantation increased threefold from 1971 to 1996 at Pasoh, Negeri Sembilan and its neighbouring area. The increase of plantation area resulted in a decrease in forest areas in this country.

In tropical region, forest degradation is progressing at an alarming rate that alters a vast area of forest landscape (Laurance 1999). The opening of the forest canopy, modification of vertical structure and other attributes causes the reduction of the quality and quantity of woody vegetation cover and alters the spatial structure of the landscape through the process of fragmentation (Fitzsimmons 2003). Fragmentation, on the other hand, may cause a decline of ranging space of a species (Saunders et al. 1991), limit resources of the organism (Rebecca et al. 2008) and increase the edge effect in the fragmented forest community (Eben et al. 2008). Habitat fragmentation by roads and other boundaries may reduce dispersion of animal among different habitats (Gibbs 1998). Thus, the development of agricultural area, which does not have a buffer zone to facilitate mobility of wild animals within agro-areas and natural areas, may increase the risk of predatory and mortality.

The concern on deforestation, forest degradation and green house gasses (GHG) emissions nowadays, has led the United Nation (UN), in collaboration with UNEP, UNDP and FAO, to start an initiative to mitigate the problems of climate change resulting in the establishment of the Reducing Emissions from Deforestation and Forest Degradation programme or REDD. This programme was launched in 2008 during the 13$^{th}$ Conference of Party (COP13) of United Nation Framework on Climate Change Convention (UNFCCC) at Bali, Indonesia. The programme is targeting the developing countries to reduce the rate of forest clearance activities in their countries. The funding, which is fully injected by developed countries, such as Japan and Denmark is used to develop and implement the REDD strategies in the national strategies and development. The development programme that consist of analysing historical land-use data, designing deforestation baseline and drafting the strategies was supported by 40 developing countries (Davis et al. 2010).

Claudia et al. (2009) however, found that REDD will bias conservation activities towards high-carbon landscapes, leaving other ecosystems open to development, thus, reducing biodiversity and other ecosystem services. Riparian buffer zones or stream corridors, for instance, are important for biological conservation because diversity of flora and fauna here is often disproportionately high. Many animals use stream corridors to travel, forage and seek refuge (Spackman & Hughes 1995). In a managed forest in Malaysia, riparian zones are protected to reduce the impact on hydrological, to reduce forestry-related biodiversity loss and to reduce logging impacts on soils through sedimentation and changes to microclimate (Chappell & Thang 2007). For example, in the Reduced Impact Logging (RIL), the buffer zone deemed protected from logging impact along a stream or river is 20 m wide on both sides, irrespective of the width of the stream/ river but it seem not efficient to reduce the impact of sedimentation (Takashi et al. 2006). To date, most studies in the tropics have focused on the importance of maintaining riparian zones in logged forests for birds and insects (Chan et al. 2008). Almost no studies have been done on the importance of riparian zones for amphibians along streams in plantations. In areas where development for agriculture has replaced the original forested area, stream corridors are especially important to maintain amphibians and other biodiversity.

In order to address this problem, Forest Research Institute of Malaysia (FRIM), together with the National Institute for Environmental Studies, Japan (NIES), Japan International Cooperating Agency (JICA) and the Federal Land Development Authority (FELDA) established a green corridor at Felda Pasoh Dua, Negeri Sembilan in 1994. Thus, the study on amphibians' species richness and assemblage composition was initiated to understand the role of the green corridor as a shelter and ecological remediation of that area. The specific objectives of this study were to identify species richness, diversity and microhabitat of amphibians along riparian forest corridor in an oil palm plantation compared with a nearby oil palm plantation without a green corridor. Finally, this paper discussed about the remediation status of established green corridor along the river in an oil palm plantation.

## Materials and Methods

### Study Area

Felda Pasoh Dua (FP2) is one of the villages or settlements, developed by Federal Land Development Authority (FELDA) that is located in the district of Simpang Pertang, Jelebu, Negeri Sembilan. Felda Pasoh 2 was established in two stages; the first stage was opened in 1970 to 1971 and the second stage was developed between 1985 and 1986. The total Felda settlers were 384 people, representing 384 families. The total settlement area was 127.91 ha and the size of the plantation area was 2181.73 ha. The settlement is provided with a complete basic facility, including schools, mosques, a community hall and a business centre to develop the social status of the villagers. Meanwhile, in order to increase the quality of life for FELDA settlers, the authority has decided to plant the palm oil as a commodity income for them. The large oil palm plantation area generated high income for settlers and increased their economic status.

STUDY SITE

The study was carried out along Sungai Petekah, FP2. A green corridor was established along Sg. Petekah under research project ‘A Community Project of Tree Planting’ designated and conducted by Forest Research Institute of Malaysia (FRIM) (Noor Azlin et al. 2005). The 1 km corridor was planted few years ago along the river. The objective of the establishment was to serve as shelter and habitat for animal species to inhabit and colonize that area. The research area was conducted within the green corridor along Sungai Petekah (Figure 1).

Ten traps were established within the Sg. Petekah green corridor (SPGC), represented by 10 sampling points from one end to the other of the green corridor, which was about 1 km long (Table 1). The distance between each trap was about 90 m. A control site was chosen at Felda Pasoh Tiga (FP3), which does not have a green corridor, located in the same plantation area as the treatment site and received the same water source from Pasoh Reserve Forest. The GPS readings of all sampling points are shown in Table 1. The distance between SPGC sampling site and FP3 sampling site is about 7 km. It was assumed that there

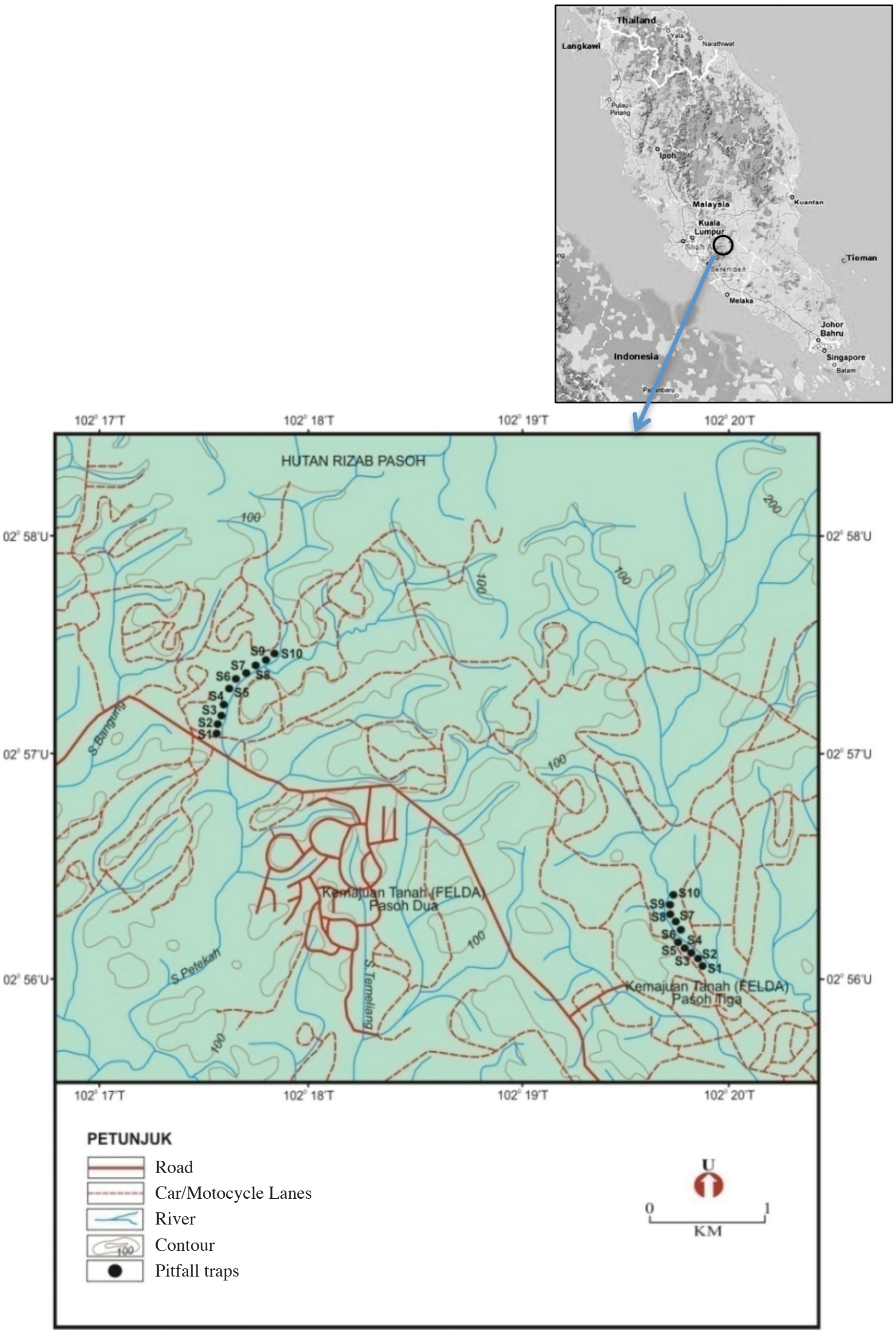


FIGURE 1. Black dots show the locations of the pitfall traps at Sungai Petekah, Felda Pasoh Dua and the control site at Felda Pasoh Tiga

TABLE 1. The GPS reading for all ten sampling point in two sampling location

| Points | Treatment site SPGC | Control site FP3 |
|---|---|---|
| 1 | 02° 57' 06 N, 102° 17' 30 E | 02° 56' 03 N, 102° 19' 46 E |
| 2 | 02° 57' 09 N, 102° 17' 29 E | 02° 56' 05 N, 102° 19' 46 E |
| 3 | 02° 57' 11 N, 102° 17' 31 E | 02° 56' 07 N, 102° 19' 46 E |
| 4 | 02° 57' 13 N, 102° 17' 34 E | 02° 56' 08 N, 102° 19' 45 E |
| 5 | 02° 57' 17 N, 102° 17' 37E | 02° 56' 08 N, 102° 19' 43 N |
| 6 | 02° 57' 21 N, 102° 17' 37 E | 02° 56' 10 N, 102° 19' 39 E |
| 7 | 02° 57' 22 N, 102° 17' 39 E | 02° 56' 11 N, 102° 19' 39 E |
| 8 | 02° 57' 23 N, 102° 17' 42 E | 02° 56' 14 N, 102° 19' 37 E |
| 9 | 02° 57' 23 N, 102° 17' 45 E | 02° 56' 15 N, 102° 19' 32 E |
| 10 | 02° 57' 24 N, 102° 17' 47 E | 02° 56' 17 N, 102° 56' 35 N |

was no population overlapping that could have caused biasness during trapping of animals.

## SAMPLING METHOD

Two sampling methods were used during this study; drift fenced-pitfalls and visual encounter survey. Drift fences in combination with pitfall traps are suitable and often used to determine the species richness of an area, to detect the presence of rare species, estimate relative abundances and to determine habitat use by individual species (Bury & Corn 1987). However, this method is not suitable to trap certain species of amphibians, such as tree frogs and burrowing frogs (Dodd 1991). Thus, the visual encounter survey was also conducted to supplement trapping effort. An array, consisting of drift fences and pitfall traps, was set up along a transect at Sg. Petekah (Figure 2) from 18th March to 5th May 2010. The array was positioned within the narrow green corridor, between the dirt road and Sg. Petekah. The array was spaced at 100 m intervals, making the transect about 1 km in total length. Each array consisted of 20 sections of drift fence measuring15 × 1 m of galvanized metal flashing, originating from a central pitfall trap and were arranged parallel to the river. Drift fences were buried ~5 cm below soil surface to prevent animals from burrowing under them. The 18.9-L pitfall trap (plastic bucket) was buried at the centre. Drain holes were punched in the bottom of each pitfall. Pitfall traps were buried flush with the ground surface and the drift fence overhung the lip of each pitfall trap. The traps were examined once a day before noon. Trapped animals were taken in for measurements using cotton bags or plastic bags.

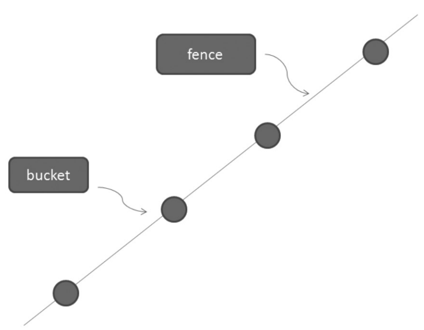


FIGURE 2. Schematic diagramme of four fenced-pitfall traps

The visual encounter survey procedure consists of active searching for animals using wide-beam headlights in a randomized walk at a steady pace within a constrained area at a specific time at night, usually within the first 2-4 h after dark fall from 20th April to 5th May 2010. Time spent surveying was short depending on the density of animals per unit area. Animals in their microhabitats, i.e. on rocks, riverbank and on vegetation were caught by hand and brought back for measurements.

The physical conditions of the amphibians, the weight (gm), length from snout to anus (mm) and tibia length (mm) parameters were recorded. Each length measurements were carried out by using Vernier calliper. Voucher specimens of most taxa were collected to aid the identification of unknown taxa and to collect tissue samples for taxonomic groups requiring further systematic resolution. The specimens were euthanized using tricaine (ethyl 3-aminobenzoate), a methanesulfonate salt, fixed in 10% formalin and kept in 70% ethyl alcohol at the Museum of Zoology, Universiti Kebangsaan Malaysia. Taxonomic nomenclature follows the Amphibian Species of the World 5.3 by the American Museum of Natural History (http://research.amnh.org/herpetology/amphibia/), last accessed on 5 June 2009. Taxonomy for *Hemidactylus* follows Carranza and Arnold (2006); *Draco* taxonomy follows Manthey (2008).

## DATA ANALYSIS

The data from the fieldwork was analyzed by using BioDap and MVSP software to estimate the species richness and diversity. Meanwhile, species accumulation curve was generated using Ecosim 700 software (Gotelli & Entsminger 2001). Shannon-Wiener Diversity Index (*H*') was used to assess species diversity on the area. The advantages of using this index are that this index includes the number of species and the equality of the species. The value of the index indicated the species diversity. The dominance of the species in certain community is determined by using Simpson Dominance Index (*D*). This index is very sensitive to the community which has large dominance species. The inversion of D value, 1/D also shows species diversity. Evenness Index was used to determine either one species dominate one community or not. The microhabitat data of each species of amphibians were recorded at the specific data sheet. A total of 35 variables were used in this study. In order to identify the similarity composition in two different habitats, Jaccard Similarity index, *J* was used (Ludwig & Reynolds 1988). The microhabitat of the amphibians species were recorded and identified. The similarity of the microhabitat was calculated and predicted by using principal component analysis using SPSS Version 18.0. The group of microhabitat were divided into Horizontal Position, Vertical Position and Substrate. The principal component analysis was done on 18 microhabitat variables occupied by amphibians using MVSP version 3.1. The dependent variables were the abundance of amphibian species considered. The independent variables were the three groups of microhabitat parameters (horizontal position, vertical position and substrate) that were assessed in identifying the tendency of species in selecting their own microhabitat. The mean number of species on transects between sampling sites by performing a Chi Square test to compare two sampling locations and factorial ANOVA on $\log_{10}$ transformed abundance data to compare the effects of guilds between sites and the interactions of these factors. Assumptions of all statistical models were tested and met in all analyses performed. Statistical tests were generated using SPSS for Windows v. 18.0 (SPSS 2012). We set a criterion level of $p = 0.05$ for all statistical tests.

### IDENTIFICATION OF REMEDIATION STATUS

The remediation status of this area was assessed by using data on amphibians. Four assumptions were used to assess the remediation status of the area:

High Shannon-Wiener Diversity Index value; low Simpson's Dominance Index; the presence of human-tolerate species (as key species) as an indicator of a static ecological remediation process and the presence of forest key species as an indicator of a positive projection of the remediation process.

## RESULTS AND DISCUSSION

Overall, nine frog species from five families were sampled; five non-stream-breeding terrestrial, two terrestrial-stream-breeding and two non-stream-breeding arboreal species (Table 2). All nine species were sampled at Sg. Petekah green corridor (SPGC) and four at Felda Pasoh Tiga (FP3). The most sampled species at SPGC were *Fejervarya limnocharis* (40% of the total) and *Duttaphrynus melanostictus* (16%), while those of FP3 were *D. melanostictus* (83%) followed by *F. limnocharis* (27.5%).

Pitfall traps and visual encounter surveys are useful for sampling other animal groups, such as reptiles and small mammals. Overall, six species of reptiles and four of mammals were sampled. A total of four mammal species and four reptile species were sampled at SPGC, while two mammal species and three reptile species at FP3 (Table 3). *Viverra tangalunga* or the Malay civet is quite a common visitor to oil palm plantations and so is *Manis javanica* or the Pangolin. *Naja sumatranus* is the Spitting cobra

TABLE 2. Species and relative abundance of amphibians sampled at the two sites. Numbers in brackets are in percentage (the species abbreviation are applied in Figures 4-6)

| Species and abbreviations | | SPGC | FP3 | Total | Guild |
|---|---|---|---|---|---|
| Bufonidae | | | | | |
| *Duttaphyrus melanostictus* | Dm | 7 (15.6) | **20 (83.3)** | **26 (39.1)** | Terrestrial |
| *Ingerophyrus parvus* | Ip | 3 (6.5) | 0 | 3 (4.4) | Terrestrial |
| *Phrynoidis aspera* | Pa | 2 (4.4) | 0 | 2 (2.9) | Stream |
| Dicroglossidae | | | | | |
| *Fejervarya limnocharis* | Fl | **18 (40.0)** | 1 (4.2) | 19 (27.5) | Terrestrial |
| *Limnonectes blythii* | Lb | 1 (2.2) | 2 (8.3) | 3 (4.4) | Stream |
| Microhylidae | | | | | |
| *Microhyla heymonsi* | Mh | 2 (4.4) | 0 | 2 (2.9) | Terrestrial |
| *Kaloula pulchra* | Kp | 2 (4.4) | 0 | 2 (2.9) | Arboreal |
| Ranidae | | | | | |
| *Hylarana erythraea* | He | 5 (11.1) | 0 | 5 (7.3) | Terrestrial |
| Rhacophoridae | | | | | |
| *Polypedates leucomystax* | Pl | 5 (11.1) | 1 (4.2) | 6 (8.7) | Arboreal |
| Total species | | 9 | 4 | 9 | |
| Total numbers | | 45 | 24 | 69 | |

SPGC=Sg. Petekah green corridor, FP3=Felda Pasoh Tiga

TABLE 3. Species and relative abundance of reptiles and mammals sampled at the two sites

| Species | SPGC | FP3 | Total | Method |
|---|---|---|---|---|
| REPTILIA | | | | |
| Elapidae | | | | |
| *Naja sumatranus* | 1 | | | v |
| Gekkonidae | | | | |
| *Hemidactylus frenatus* | 1 | | | v |
| Scincidae | | | | |
| *Eutropis multifasciata* | 3 | 1 | | p |
| *Lygosoma quadrupes* | | 1 | | p |
| Varanidae | | | | |
| *Varanus salvator* | 1 | 2 | | v |
| MAMMALIA | | | | |
| Muridae | | | | |
| *Rattus tiomanicus* | 1 | 5 | 6 | p |
| Soricidae | | | | |
| *Suncus murinus* | 2 | | 2 | p |
| Viverridae | | | | |
| *Viverra tangalunga* | 2 | | 2 | v |
| Manidae | | | | |
| *Manis javanica* | 1 | | 1 | v |
| Total species | 12 | 9 | 10 | |

Site: SPGC=Sg. Petekah green corridor, FP3=Felda Pasoh Tiga; Method: p=pitfall trap, v=visual encounter survey

commonly found in oil palm plantations (Wuster & Thorpe 1989). According to the manager of the Felda Pasoh Dua, the cobras are sometimes acquired and released into the plantation to curb rats from destroying oil palm fruits (Wan Deraman 2012). The rest of the reptiles are naturally found in forests, but have adapted to agricultural land, cities, gardens and scrubland (Michael et al. 2011). Both *Rattus tiomanicus* and *Suncus murinus* are forest and agricultural land dwellers (Advani & Rana 1981; Buckle et al. 1997), but their numbers in the pitfall traps were rather low. Other studies have found that pitfall traps are the most commonly used method to catch many shrews (Shipley & Reading 2006). Observations in the field include predation by large water monitors in the pitfall traps, thus, traps must be checked as early in the morning as possible. The mean numbers of amphibians between SPGC and PF3 was statistically different ($p$=0.00), but when comparing the effect of guild between sites, there was no significant difference obtained when factorial ANOVA was performed. The amphibian species accumulation curve shown in Figure 3 reflects the same scenario in most studies of vertebrate communities in which the curve rises steeply at first and levels off in later samples as increasingly rare taxa are added (Gotelli & Colwell 2001). Meanwhile the

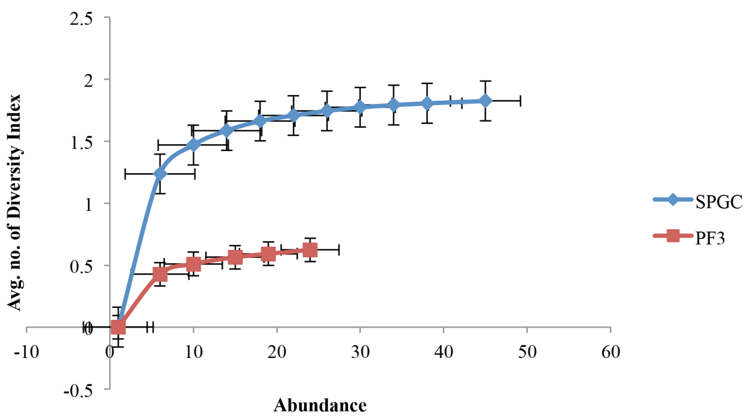


FIGURE 3. Species accumulation curves for amphibians generated from the pitfall trappings and visual survey of species richness estimates at both sampling sites

asymptote point shows the total species richness in the area of study (Heyer et al. 1994). The species accumulation curve suggests that most species likely to occur in the habitats sampled were detected.

Table 4 shows the value of Shannon-Wiener Diversity Index, *H*' at SPGC was higher (1.82 ± 0.13), compared to that of FP3 (0.62 ± 0.2). These values were supported by a higher Evenness index at SPGC (0.83) than that of FP3 (0.45). Referring to Table 2, there was no obvious dominant species at SPGC, which was reflected in the low Simpson's Dominance Index, *D*, at 0.20. In contrast, D at FP3 was high at 0.69 due to the presence of *D. melanostictus*, which accounted for about 83% of the total amphibians sampled. Comparison of the Shannon-Wiener diversity index between two sites using t-test indicate that there was significant difference $t_{cal}$=5.11> $t_{cri}$=1.68, df=42.21, $\alpha$=0.05). The null hypothesis that the two populations are the same is, thus, rejected.

In order to compare the assemblage of amphibian species between sites, the Jaccard similarity index, *J* was calculated (Ludwig & Reynolds 1988). The values of *J* were used as the basis for a cluster analysis according to Jaccard's Coefficient and Modified Morisita. UPGMA was used to test the degree (percentage) of similarity among the amphibian assemblages represented in each study site (Jongman et al. 1995). The value of *J* calculated was 0.44 or 44% overlap or similarity of the amphibian assemblages between sites.

An earlier study on amphibian diversity in an oil palm plantation at Pasoh was reported by Kiew et al. (1996a). The total frog species reported by them was 15 compared to 9 in this study (Table 5). Comparing to the amphibian species richness of a pristine lowland forest nearby, which is the Pasoh Forest Reserve (PFR), an updated checklist was published by Chan et al. (2009) based on their samplings and previous studies by Kiew et al. (1996b), Lim and Norsham (2003) and Norsham and Sukumaran (2006). The total number of amphibian species is 44, which is considerably high since PFR is considered almost fragmented by oil palm expansion on the west, north and south of its boundary (Adachi et al. 2006).

Graeme et al. (2012) considered species richness of frogs in five types of habitats in the Lower Kinabatangan River floodplain in eastern Sabah and found out that oil palm plantation had the least, with 12 species, almost half of what was recorded from a dry forest, wet forest and riparian forest, respectively. According to Graeme et al. (2012), amphibian assemblages of oil palm plantations were dominated by terrestrial, non-endemic, generalist species, adapted to human-made landscape. This study has shown that tree frogs were absent, except for the common tree frog *Polypedates leucomystax*, which is a non-stream breeding arboreal frog. All of the species recorded was typical of a non-forest habitat or human-modified landscapes.

While the effects of large-scale habitat loss on biodiversity are well known (Carlson 2000; Cushman 2006), the effects of microhabitat selection have received less attention. The group of microhabitat were divided into horizontal position, vertical position and substrate. Each species were analysed for every group and the microhabitat selection was identified by using NMDS in MVSP version 3.1. The dependent variables were the species abundance of the amphibian species considered. The independent variables were the three groups of microhabitat parameters (horizontal position, vertical position and substrate) that were assessed in identifying the tendency of species in selecting their own microhabitat. Ordination of the microhabitat data and species abundance was calculated using non-metric multidimensional scaling (NMDS) to determine the tendency of species on selecting microhabitat along the green corridor. Each species seemed to select different horizontal distance. *D. melanostictus* (Dm) and *H. erythraea* (He) tended to select distance between 0 and 1.0 m from water body, *I. parvus* (Ip) between 1.1 and 2.0 m, which overlaped with *P. leucomystax* (Pl), while *P. aspera* (Pa) and *K. pulchra* (Kp) between 2.1 and 3 m. *F. limnocharis* (Fl) chose their horizontal positioning between 3.1 and 4.0 m. *M. heymonsi* (Mh) and *L. blythii* (Lb) selected the farthest distance; >5.1 m from water body (Figure 4).

For vertical selection, Fl selected its vertical position in the grass, while Dm tended to select surface bare soil (Figure 5). He and Ip selected to localise themselves in the leaf litter, while Pl tended to stay in the trees. Mh and Kp were found under litter. Pa, Pl and Lb seemed to occur sympatrically with each other, usually on seedling, on shrub and on tree, most probably to camouflage themselves from the predators. The green body colour of Pa, Pl and Lb

TABLE 4. Diversity indices of amphibians according to the sampling sites

| Location | SPGC | FP3 |
|---|---|---|
| Shannon-Weiner Diversity Index, *H*' | 1.82 | 0.62 |
| Evenness Index, *E* | 0.83 | 0.45 |
| Variance, *H*' | 0.01585 | 0.04015 |
| Standard Error | 0.126 | 0.2 |
| Brillouin Index, *B* | 1.57 | 0.59 |
| Simpson Dominance Index, *D* | 0.202 | 0.692 |
| 1/D | 4.950 | 1.445 |

SPGC=Sg. Petekah green corridor, FP3=Felda Pasoh Tiga

TABLE 5. The comparison of amphibian complete checklist of PFR, Kiew et al. (1996a) and this study

| Taxa | PFR | Kiew et al. (1996a) | This Study |
|---|---|---|---|
| Bufonidae | | | |
| *Ingerophrynus parvus* | x | X | x |
| *Leptophryne borbonica* | x | | |
| *Duttaphrynus melanostictus* | x | X | x |
| *Phrynoidis aspera* | x | | x |
| Dicroglossidae | | | |
| *Fejervarya limnocharis* | x | X | x |
| *Limnonectes blythii* | x | X | x |
| *Limnonectes laticeps* | x | | |
| *Limnonectes malesianus* | x | X | |
| *Limnonectes paramacrodon* | x | | |
| *Limnonectes plicatellus* | x | | |
| *Occidozyga laevis* | x | X | |
| Megophryidae | | | |
| *Leptobrachium hendriksoni* | x | X | |
| *Leptobrachium nigrops* | x | | |
| *Megophrys nasuta* | x | | |
| Microhylidae | | | |
| *Chaperina fusca* | x | | |
| *Kalophrynus palmatissimus* | x | | |
| *Kalophrynus pleurostigma* | x | | |
| *Kaloula baleata* | x | | |
| *Kaloula pulchra* | x | X | x |
| *Microhyla berdmorei* | x | | |
| *Microhyla butleri* | x | X | |
| *Microhyla heymonsi* | x | X | x |
| *Microhyla mantheyi* | x | | |
| *Microhyla supercilliaris* | x | | |
| *Micryletta inornata* | x | | |
| Ranidae | | | |
| *Humerana miopus* | x | X | |
| *Hylarana baramica* | x | | |
| *Hylarana erythraea* | x | X | x |
| *Hylarana glandulosa* | x | X | |
| *Hylarana labialis* | x | | |
| *Hylarana laterimaculata* | x | | |
| *Hylarana luctuosa* | x | | |
| *Hylarana nicobariensis* | x | | |
| *Hylarana picturata* | x | X | |
| *Odorrana hosii* | x | | |
| Rhacophoridae | | | |
| *Nyctixalus pictus* | x | | |
| *Polypedates colletti* | x | | |
| *Polypedates leucomystax* | x | | x |
| *Polypedates macrotis* | x | x | |
| *Rhacophorus appendiculatus* | x | | |
| *Rhacophorus cyanopunctatus* | x | | |
| *Rhacophorus nigropalmatus* | x | | |
| *Rhacophorus pardalis* | x | | |
| *Rhacophorus prominanus* | x | | |
| Total species | 44 | 15 | 9 |

Complete PFR= Kiew et al. (1996b), Lim and Norsham (2003), Norsham and Sukumaran (2006), Chan et al. (2009)

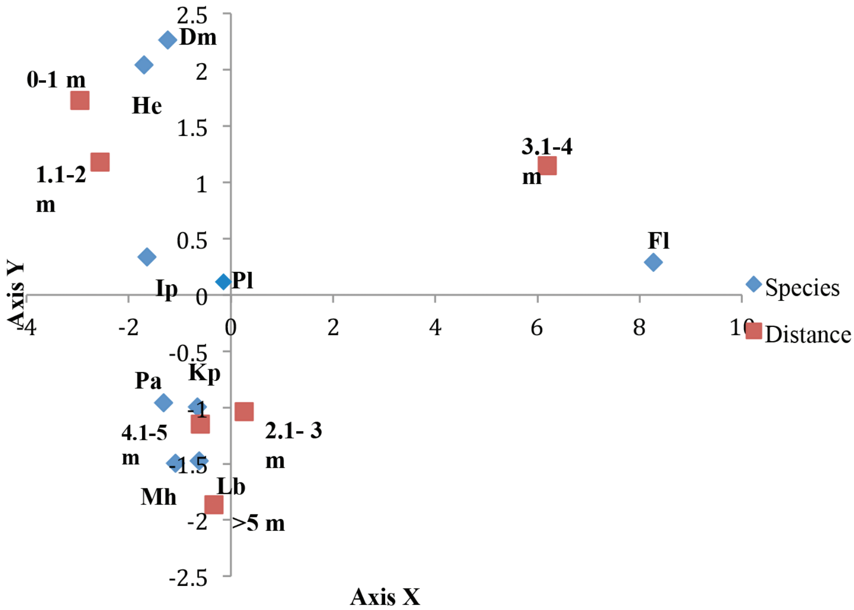


FIGURE 4. The tendency of amphibian species to select the distance from water body (species abbreviation in Table 2)

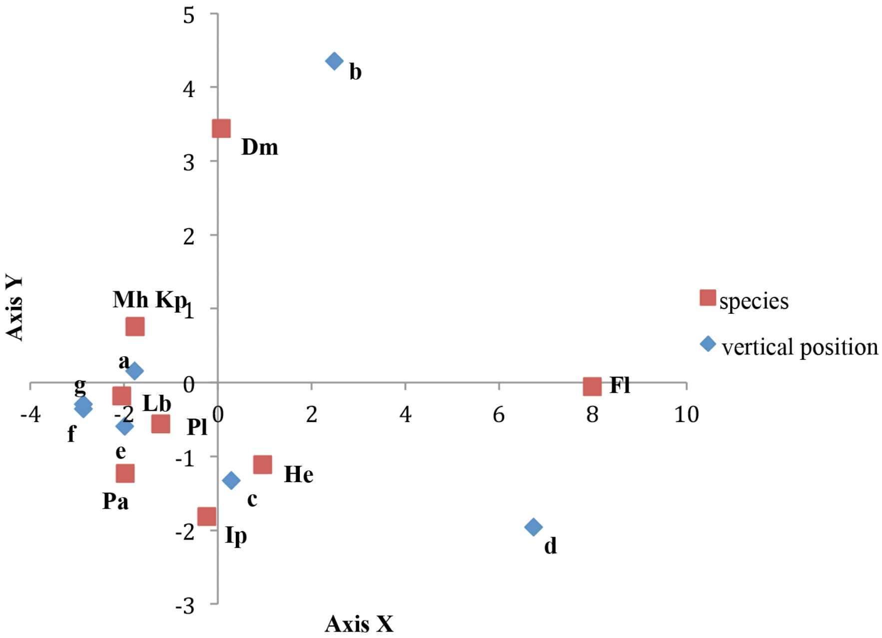


FIGURE 5. The pattern of tendency of amphibian on selecting their vertical position (species abbreviation in Table 2)

blends well with grassy areas. Ip, Mh and Kp have light brown body colour that also blends well with the litter.

In substrate selection only five substrates were selected by amphibian species at SPGC (Figure 6). Fl seemed to select bank of mud, of sand, of small gravel or of rock for its substrate. Meanwhile, Lb selected stem of branch of herbaceous plant and Pl chose leaf of plant for their substrate. The tendency of Fl to choose bank of mud, sand, small gravel or rock for its substrate is reflected by the toe morphology of these species, which characterises scansorial living. The substrates are classified as scansorial ecomoprh. The selection of leaf surface for Pl as substrate may be explained by the expanded toe discs that help this species to live an arboreal life.

Amphibians are the best biological indicator to assess the health of an ecosystem. The sensitivity of amphibians to environmental changes, such as chemical pollution (Harte & Hoffman 1989), habitat lost and degradation, disease and

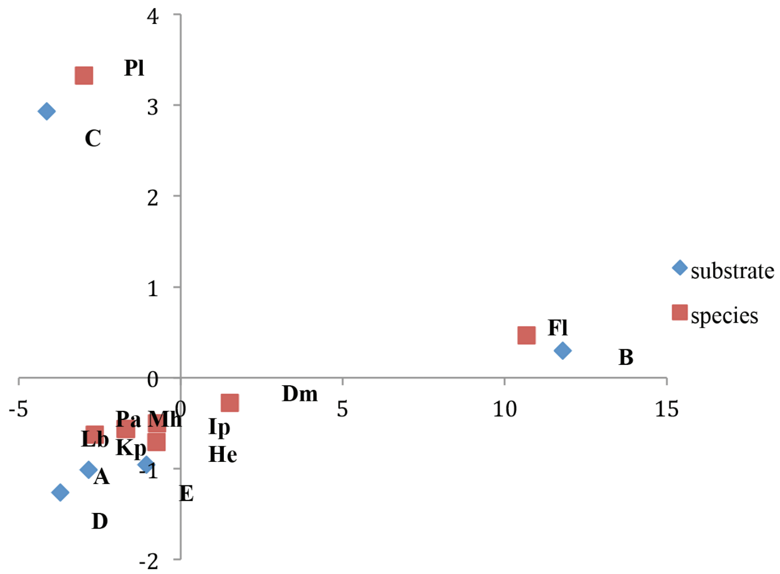


FIGURE 6. The pattern of tendency of amphibian on selecting their substrate (species abbreviation in Table 2)

climate change (Ryan et al. 2002) and habitat destruction (Blaustein et al. 1994) has long been demonstrated by many researchers.

The selection of the key species follows Kiew et al. (1996a) that listed key species for man-made habitat and forest habitat, which included *D. melanostictus, H. erythraea, F. limnocharis* and *M. butleri,* while *H. labialis* and *O. hosii* were listed as key species for forest habitat. The presence and absence of key species can provide important information to assess remediation status of an area. The value of Shannon-Wiener Diversity Index at SPGC was low at 1.82 ± 0.126, even though the Simpson's Dominance Index was low (0.21). The presence of *P. leucomystax, F. limnocharis* and *H. erythraea,* which are key species for man-made habitat at SPGC and the absence of forest key species (*H. labialis* and *O. hosii*) indicate that remediation status of the area has yet to be achieved. On the other hand, the diversity indices when compared to FP3 were significantly higher, indicating a positive projection towards achieving remediation process.

The conversion of forest land to oil palm plantation is a major problem of habitat loss for amphibian species in Malaysia. Additionally, the usage of fertilizer and pesticide exacerbate the situation because these chemicals may accumulate in tissues and organs of amphibians. Populations may occur in pockets due to fragmentation of natural forests. Species assemblage in plantation forest across the landscape may also change to include only generalist and commensal species. The management of agricultural areas in Malaysia has not emphasized on creating, maintaining buffer zones or river corridors to support biodiversity. This zone is very important to the remaining animals and plants to adapt to and sustain existence in an otherwise much deprived ecosystem off food source and functional service. Several important recommendations were made to improve the efficiency of the green corridor in plantations. There is substantial evidence shown in this study that green corridors support higher species richness of amphibians than in plantations without such corridors. This study, however, only demonstrates that the green corridor contain associated certain species and that by maintaining the green corridor, these certain species are likely to continue to exist. The full scale of the plantation landscape is yet to be tackled, instead of just a stretch of green corridor. The NMDS has shown that amphibians tended to concentrate within 0-5 m away from any water body. Few amphibian species were found at a distance of more than 5 m from water bodies. The width of the established green corridor, however, was only about 3 m, thus, limiting foraging and/or territorial space. Therefore, the width of the green corridor should be increased. Moreover, domestic cattles and buffaloes belonging to the FELDA settlers may also influence species richness and abundance of amphibians by overgrazing the grass along the green corridor, which would increase the risk of predation. Perhaps it would be better to not only plant woody trees, but also shrubs and herbs, to increase ground cover for the amphibians.

Another challenge is to look at how this highly transformed habitat influence development or containment of zoonoses and vector borne diseases. According to Lim (2008), in severely modified forest ecosystems due to logging and clearing for agriculture, there is a high risk of upsetting the balance of natural vectors, hosts, parasites, coupled with the invasions of commensals and close contacts with humans. The potential for zoonotic and vector borne diseases is much higher if agricultural land is not managed well. The real challenge is actually to improve the general biodiversity conservation value of an area that has been permanently transformed for a very long time. In such a highly transformed agricultural area, management interventions to enhance biodiversity will not be very effective since there is little available source habitat left, unless there were patches of semi-natural to natural habitats left to support more species. Tscharntke et al. (2008) have shown that not only tropical agricultural landscapes support fewer species of birds and insects than semi-natural habitats, but that functional diversity also differed between them. Such findings are also supported by this study, in which amphibians between the two sites did not differ significantly among guilds. Nonetheless, the green corridor should be promoted in order to enhance ecosystem services provided by biodiversity, such as biological control of pests, pollination and provision of host plants or habitats (Bianchi et al. 2006). In conclusion, the green corridor should be promoted in order to enhance ecosystem services provided by biodiversity, such as biological control of pests, pollination and provision of host plants or habitats. Realising the importance, this study must be extended to include other groups of animals, such as birds and insects. Finally, the real challenge is actually to improve the general biodiversity conservation value of an area that has been permanently transformed for a very long time. This would not only be a feat for all managers, but it would probably be beneficial in the long run, especially when trying to achieve the Forest Stewardship Certificate (FSC).

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