Malays. Appl. Biol. (2015) 44(2): 107–117

SPATIAL AND TEMPORAL VARIATION OF AMPHIBIAN ASSEMBLAGE AT KUALA GANDAH, KRAU WILDLIFE RESERVE, PAHANG, PENINSULAR MALAYSIA

NURULHUDA, Z.[1,2], DAICUS, B.[3,5], SHUKOR, M.N.[1], FAKHRUL HATTA, M.[4] and NORHAYATI, A.[1*]

[1]School of Environment and Natural Resource Sciences, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia
[2]School of Marine and Environmental Sciences, Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu, Malaysia
[3]Universiti Kebangsaan Malaysia, Institute for Environment and Development (LESTARI), 43600 Bangi, Selangor, Malaysia
[4]Institute of Biodiversity, Bukit Rengit. Department of Wildlife and National Parks, 28500 Lanchang, Pahang, Malaysia
[5]University of Malaya, Faculty of Science, Institute of Biological Sciences, 50603 Kuala Lumpur, Malaysia
[*]E-mail: norhayatiahmad@ukm.edu.my

ABSTRACT

Recent global amphibian declines have emphasized the need for long-term, large scale monitoring programmes. Many factors have to be considered, including robust spatial sampling, duration and detectability when designing for such monitoring programmes. In this study, both active and passive sampling methods were used to increase detectability of animals. Habitat characteristics were also explored, which included disturbance history, vegetation type and microhabitat to explain species richness, relative abundance and community structure. The total species of anurans sampled from the pit-fall traps in this study was 17 species within five families, while the total of anuran species obtained from the active sampling along the rivers was 13 species from six families. The species richness could be explained significantly by two out of 10 environmental parameters measured; canopy cover and distance from forest trails, while the most abundant individuals sampled could only be explained significantly by the depth of leaf litter layer. From the cluster analysis, five main groups can be distinguished according to microhabitats, lifestyles and life cycles. Generally, disturbed habitats are characterised by widespread habitat-generalists and/or human commensal taxa, whereas the riparian habitat and forests tend to be characterised by habitat-specialist taxa. The results of this study may assist scientists to determine trends in the selection of microhabitat by amphibians.

Key words: frogs, microhabitat, monitoring, forest management

ABSTRAK

Kemerosotan global amfibia kebelakangan ini telah menekankan keperluan untuk program pemonitoran jangka masa panjang dan skala besar. Banyak faktor yang perlu dipertimbangkan, termasuk pensampelan reruang yang teguh, tempoh masa dan kebolehkesanan apabila merekabentuk program pemonitoran tersebut. Kajian ini menggunakan kaedah pensampelan aktif dan pasif untuk meningkatkan kebolehkesanan haiwan. Ciri-ciri habitat juga dikaji, termasuk sejarah gangguan, jenis tumbuh-tumbuhan dan mikrohabitat untuk menjelaskan kekayaan spesies, kelimpahan relatif dan struktur komuniti. Jumlah spesies yang disampel daripada perangkap lubang dalam kajian ini ialah 17 spesies dalam lima famili, manakala jumlah spesies Anura yang diperolehi daripada pensampelan aktif ialah 13 spesies daripada enam famili. Kekayaan spesies bolel diterangkan secara nyata oleh ketebalan lapisan serasah daun. Daripada analisis kelompok, lima kumpulan utama boleh dibezakan mengikut mikrohabitat, gaya hidup dan kitar hayat. Secara umumnya, habitat terganggu dicirikan oleh Anura yang umum mendiami habitat meluas dan/atau taksa komensal dengan manusia, manakala habitat riparian dan hutan menjurus kepada taksa yang khusus kepada habitat tersebut. Hasil kajian dapat membantu saintis untuk meramal tren pemilihan mikrohabitat oleh haiwan Amfibia.

Kata kunci: amfibia, mikrohabitat, pemonitoran, pengurusan hutan

* To whom correspondence should be addressed.

INTRODUCTION

Since the 1980s, emphasis has been given to the global decline of herpetofauna, especially amphibian species. The first systematic study of amphibian population declines was published by Barinaga, 1990 and since then, despite many studies done, there is still no simple answer to explain the cause of this declines (Kiesecker *et al.,* 2001; Voris & Inger 1995). Many factors have been attributed to this decline, such as habitat loss and fragmentation (Blaustein & Kiesecker, 2002), annihilation of native frogs by alien species (Kats & Ferrer 2003), and the global emergence and spread of the pathogenic fungus *Batrachochytrium dendrobatidis* (Skerratt *et al.,* 2007). The latter was also detected in Malaysia, but the prevalence was very low (Savage *et al.,* 2011).

Amphibian assemblages are influenced by factors, such as, local habitat, environmental parameters and characteristics of the landscape. Local habitat variations that may affect amphibian assemblage may include depth of litter layer, canopy cover, and soil humidity (deMaynadier and Hunter, 1995). Hecnar and M'Closkey (1998) have shown in southwestern Ontario ponds that the species richness of amphibians was positively correlated with vegetation cover, but was negatively correlated with depth of water column. According to a study on 120 locations worldwide, Carey *et al.* (2001) found out that temperature and presence of water were the two most important factors that determine species abundance of amphibians. At the landscape level, amphibians are dependent on the presence of wetlands that are linked or connected to upland habitats in the USA (Brown *et al.,* 2012). An extensive study looking at the abundance of frogs at Nanga Tekalit, Sarawak in 1962, 1970 and 1984 has revealed a more complex factor that influence the pattern of abundance, including intrinsic biological characteristics of the species, such as size at sexual maturity and length of reproductive life, while extrinsic factors included variation in rainfall (Voris and Inger 1995).

Monitoring spatial and temporal variations and identifying environmental and habitat parameters that influence those variations are essential in understanding the response of wildlife towards land or forest management. Since amphibians respond well to various environmental changes, any changes in the spatial and temporal distribution in their assemblage may indicate or provide an early warning to any threat in the immediate environment. Thus, the objectives of this study were to identify the spatial and temporal variation of amphibia assemblage and determine trends in the selection of microhabitat by amphibians at Kuala Gandah Station, within the Krau Wildlife Reserve, Pahang, Peninsular Malaysia.

MATERIALS AND METHODS

Study area

The Krau Wildlife Reserve (KWR) is predominantly covered with lowland dipterocarp forests at the east and highland forests at the west. The reserve is drained by three major river systems, namely Sg. Krau, Sg. Lompat, and Sg. Teris (Figure 1). The landscape ranges from flat lowlands to undulating hilly terrain; altitude ranges from 43 m to the highest peak of 2107 m, that is Gunung Benom. The reserve has was established in 1923, starting with a total area of 552 km^2. It was regazetted twice in 1965 and 1968 until it reached its present size of 624 km^2 (Perhilitan & DANCED, 2001). Geographically, KWR is positioned at the centre of Peninsular Malaysia (3°43'N, 102°10'E; Kuala Lompat Research Station) in one of the driest regions of the country. Rainfall in the reserve is relatively low; between 1980 mm and 1999 mm (Perhilitan & DANCED, 2001), the annual mean precipitation recorded from the nearest weather station at Temerloh was 1968 mm and the daily temperature fluctuated between a minimum of 23°C to a maximum of 33°C (Perhilitan & DANCED, 2001). There are usually only two seasons each year in Peninsular Malaysia: the dry season runs from June to September and two peaks of rainy seasons from October to January and from April to May each year. There are five posts within this reserve: Kuala Lompat Research Station (KL), Lubuk Baung (LB), Kuala Sungai Serloh (KS), Kuala Gandah (KG), and Jenderak Selatan (JS).

Study sites

The study focused on Kuala Gandah (3°36'N, 102°09'E), which is located at the south of KWR, where the National Elephant Conservation Centre is also located. There are several indigenous *Che Wong* villages in the area, with an estimated 40 households. They maintain many narrow motorbike trails in the reserve as their means of travelling in and out of the forest to the nearest town to get supplies. The topography of the area is fairly flat, with swamp patches throughout the existing 1 km x 1 km sampling grid established by previous researcher, and hills in the eastern side. Streams can only be found in the south part of the grid (Kingston *et al.,* 2003).

Sampling method

Standard methods were used to sample the herpetofauna within the study site, including fenced pitfall trapping, diurnal and nocturnal censuses, and opportunistic searches (Heyer *et al.,* 1994). A total of 14 transects (labelled A-N), consisting of drift fences and pitfall traps, was set up along an established transect in a grid of 400 x 400 m. The

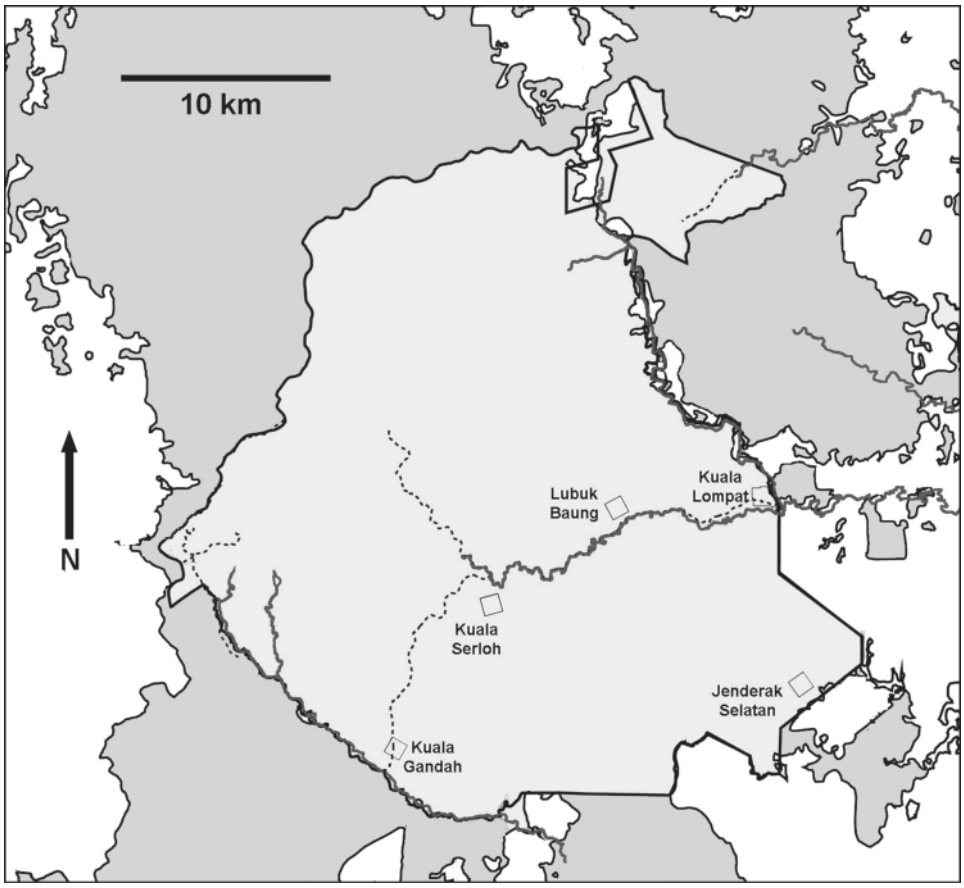

Fig. 1. Study area at Krau Wildlife Reserve and the study site at Kuala Gandah Station.

grid was further subdivided into 16, each measurng 100 x 100 m. A total of nine pitfall traps were set up per line in this subgrid, each trap was 5 m apart from the other. The total lines established in the grid was 14 and the total pitfall traps was 126. The 0.3-m tall drift fences of galvanised metal flashing were buried ~5 cm below soil surface to prevent animals from burrowing under them. The 18 L pitfall traps (plastic buckets), measuring 0.5 m deep and 0.2 m in diameter was buried along the drift fence. Drain holes were punched at 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 opened for seven continuous days per month for 12 continuous months and were examined once a day before noon (Table 1). Trapped animals were taken in for measurements using cotton bags or plastic bags.

The visual encounter survey procedure consists of active searching for animals using wide-beam headlights by walking at a steady pace within a constrained area at a specific time at night, usually within the first 2-4 h after dark fall. Surveys were conducted for 7 continuous days per month for 12 months (Table 1). Time spent surveying depended on the density of animals per unit area. Animals in their microhabitats, i.e. on rocks, riverbank, on vegetation, were caught by hand and brought back to the field lab for measurements.

Voucher museum specimens of most taxa were collected to aid the identification of unknown taxa and to collect tissue samples for taxonomic groups requiring further systematic studies. All specimens were deposited at the Institute of Biodiversity,

Table 1. Sampling schedule for both the pitfall trappings and the active sampling method

Month	Pitfall trappings	Active sampling
Aug 2009	19.08.09 – 25.08.09	25.08.09 – 31.08.09
Sept	11.09.09 – 17.09.09	05.09.09 – 11.09.09
Oct	15.10.09 – 21.10.09	22.10.09 – 28.10.09
Nov	02.11.09 – 08.11.09	15.11.09 – 21.11.09
Dec	16.12.09 – 22.12.09	09.12.09 – 15.12.09
Jan 2010	19.01.10 – 25.01.10	25.01.10 – 31.01.10
Feb	22.02.10 – 28.02.10	15.02.10 – 21.02.10
Mar	01.03.10 – 07.03.10	07.03.10 – 13.03.10
Apr	24.04.10 – 30.04.10	15.04.10 – 21.04.10
May	21.05.10 – 27.05.10	13.05.10 – 19.05.10
Jun	22. 06.10 – 28.06.10	15.06.10 – 21.06.10
Jul	17.07.10 – 23.07.10	22.07.10 – 28.07.10

Bukit Rengit, KWR. 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. Environmental parameters chosen comprise topography, structure and composition of vegetation, prasence of water bodies, and signs of human disturbances, such as trails (Heyer *et al.,* 1994).

Relative abundance

Relative abundance was calculated using Relative Interspecific Elevational Capture Index (RIEC) based on Bonvincino *et al.* (1997):

$$\text{RIEC} = \frac{\text{Number of individuals for each species x 100}}{\text{Total animals}}$$

Calculation of S_{obs} from individuals was performed using rarefaction in Ecosim vers. 7.0 (Gotelli & Entsminger 2001). By this method, a specified number of individuals are randomly drawn from the community sample, and the process repeated 1000 times to generate a mean and a variance of species richness across a range of sample sizes. The program calculates the species richness and constructs a sampling curve (or rarefaction curve) of species richness for each site. The mean sampling curves from the different sites were then plotted with 95% confidence intervals. Differences in species richness among sites are indicated if the boundary of the 95% confidence interval and the values were expressed as mean ± SE. If the confidence intervals of two curves do not overlap then the species richness is significantly different between the two samples. The results are presented as mean ± SE.

$$E(\hat{S}_n) = \sum_{i=1}^{s}\left[1 - \frac{\binom{N - N_i}{n}}{\binom{N}{n}}\right]$$

Where; $E(\hat{S}_n)$ = the expected number of species
S = total number of species in the entire collection
n = value of sample size (number of individual) chosen for standardization (n≤N)
N_i = total number of individuals in species-i
N = total number of individuals collected
$\binom{N}{n}$ = Number of combinations of n individuals that can be chosen from a set of N individuals

Cluster analysis

Data of microhabitat of each species of amphibians were recorded at the specific data sheet. A total of 35 variables were used in this study (Table 2). In order to identify the similarity composition in two different habitats, Jaccard Similarity index, *J* was used (Ludwig & Reynolds, 1988), using Multivariate Statistical Package (MVSP) software (Kovach, 1999).

Jaccard Similarity Coefficient, *J*:

$$J = \frac{c}{S1 + S2 - c}$$

Where,
J = number of resources states in common between two species.
a = number of resources state in species A.
b = number of resources state in species B.

RESULTS AND DISCUSSION

Species composition

Overall, amphibians were present at all transects, but the highest abundance was at transect J with a total of 169 individuals or 21.8% of the total, followed by line A (11.3%; n=88) and N (11.2%; n=87), while the lowest was from line H (1.8%; n=14) (Figure 2). Referring to Table 3, the transect line that recorded the highest species number was A (n=11), while the lowest were H and K (n=5 each). The species that occurred on all 14 transect lines were *Micryletta inornata* (n=413), *Ingerophrynus parvus* (n=147), and *Megophrys nasuta* (n=49), while species that were only represented by one individual were *Limnonectes paramacrodon* (line I), *L. blythii* (line J), *L. kuhlii* (line J), *Xenophrys aceras* (line L), and *Ingerana tenasserimensis* (line M).

Based on the One-way ANOVA, only *Fejervarya limnocharis*, *Micryletta inornata* and *Hylarana laterimaculata* showed significant difference in their abundance across all or most of the lines (Table 4). For *F. limnocharis*, line E recorded the most number, significantly different than those of lines B, C, G, H, J, K and N. Lines E, G and J were beside human trails, line B and C were in the forest, line H was in the swampy area, and line K was beside a creek. Based on these results, it can be deduced that *F. limnocharis* could be found in a variety of habitats, especially in disturbed areas, as suggested by Inger and Stuebing (1999) and Ibrahim *et al.* (2008). The abundance of *Micryletta inornata* on line J differed significantly with those on lines L, H, B, I, F, M, A, K, D and E. Lines J and E were both beside forest trails, but line J had a thicker canopy cover and litter layer. The rest of the lines were either in forest,

Table 2. Microhabitat parameters selected for this study

No.	Parameters	Note
1.	Vegetation type	Primary Dipterocarp forest (MDF)
2.		Peat forest
3.		Heath Forest
4.		Agriculture
5.		Edge of MDF
6.	Horizontal position	Permanent stream
7.		Intermittent stream
8.		Permanent pond
9.		Intermittent pond
10.		Swamp
11.	Distance from water body	≤ 1 m from water body
12.		> 1 m from water body
13.	Vertical Position	Under soil surface
14.		On top of or under leaf litter
15.		Under rock
16.		On rock
17.		Under log
18.		On log
19.		In log
20.		On exposed soil surface
21.		On leaf surface
22.		On seedling or herbaceous plant
23.		On shrub or treelet
24.		On tree or woody climber
25.		On tree stump
26.		On dead tree
27.		On leaf blade
28.		In grass
29.	Substrate	Leaf of tree
30.		On stem of herbaceous plant
31.		On branch of woody tree
32.		On stem of shrub
33.		On epiphyte
34.		Under log, fallen tree, fallen branch
35.		Muddy bank/ soil/ rock

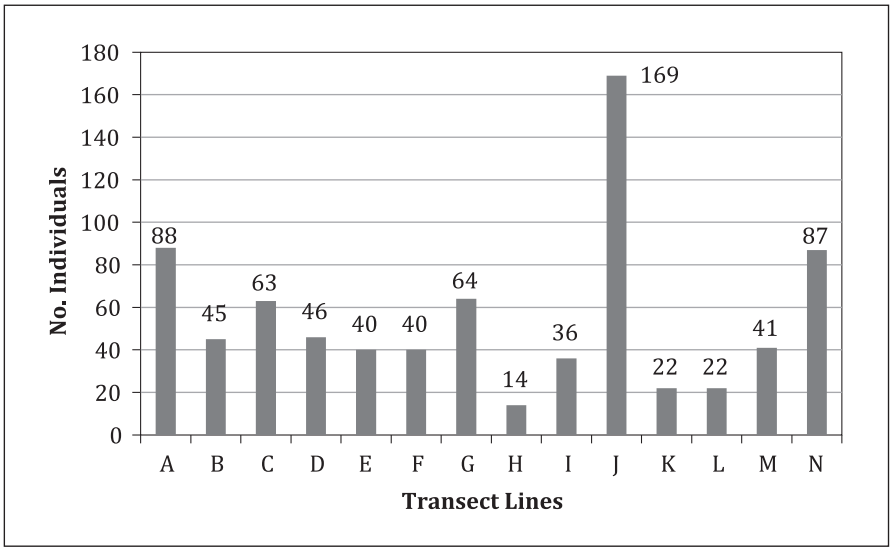

Fig. 2. Total number of individuals of amphibians sampled from each transect.

Table 3. Abundance, relative abundance (%) of amphibians according to species and transect lines

FAMILY/SPECIES/TRANSECTS	A	B	C	D	E	F	G	H	I	J	K	L	M	N	Total	% Total
BUFONIDAE																
Ingerophyrnus parvus	30	12	17	7	7	5	9	1	2	14	5	13	17	8	**147**	**18.9**
Ingerophyrnus quadriporcatus	5	7	9	1	2	1	2	0	6	1	0	1	5	3	**43**	**5.5**
DICROGLOSSIDAE																
Fejervarya limnocharis	1	0	0	2	5	1	0	0	3	0	0	2	1	0	**15**	**1.9**
Limnonectes blythii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**0.1**
Limnonectes kuhlii	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**	**0.1**
Limnonectes paramacrodon	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**	**0.1**
Limnonectes plicatellus	0	2	1	2	0	0	0	0	4	2	0	0	0	1	**12**	**1.5**
Occidozyga laevis	1	1	2	2	1	4	7	1	1	6	0	2	0	2	**30**	**3.9**
MEGOPHYRIDAE																
Megophrys nasuta	3	9	4	7	2	5	2	4	2	2	1	2	4	2	**49**	**6.3**
Xenophrys aceras	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**	**0.1**
MICROHYLIDAE																
Kaloula baleata	6	3	1	4	1	1	3	1	4	12	0	0	0	5	**41**	**5.3**
Kalophyrnus palmatissimus	2	0	0	1	1	0	0	0	0	0	0	0	0	0	**4**	**0.5**
Kalophyrnus pleurostigma	1	0	1	1	0	0	0	0	0	0	0	0	0	0	**3**	**0.4**
Micryletta inornata	37	11	28	19	20	23	41	7	12	125	13	1	12	64	**413**	**53.2**
RANIDAE																
Hylarana laterimaculata	1	0	0	0	0	0	0	0	1	5	1	0	0	2	**10**	**1.3**
Hylarana picturata	1	0	0	0	1	0	0	0	0	0	2	0	1	0	**5**	**0.6**
Ingerana tenasserimensis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**	**0.1**
No. Individuals (n)	88	45	63	46	40	40	64	14	36	169	22	22	41	87	**777**	**100**
No. species	11	7	8	10	9	7	6	5	10	10	5	7	7	8	**17**	
% Rel. abund.	11.3	5.8	8.1	6	5.1	5.1	8.3	1.8	4.6	21.8	2.8	2.8	5.3	11.2	**100**	

swamps and near riparian areas. This is consistent with a report by van Dijk *et al.* (2004), who recorded this species in forest edges and disturbed areas, but not as commensal species in agricultural or human settlement areas. Norhayati *et al.* (2005) found out that this species was often found with difficulty on the forest floor or on low vegetation in lowland forests, because of its cryptic body colour. Thus, pitfall traps are efficient in sampling this species. Similar with *M. inornata, Hylarana laterimaculata* was siginificantly more abundant on line J than lines B, C, D, E, F, G, H, L and M. According to Leong (2004), males of *H. laterimaculata* often call for their mates from the forest floor or from low vegetation of up to 1 m from the ground on forest trails or forest edges. Thus, the abundance of this species on line J might be influenced by vegetation and reproduction.

Species richness

Species richness was estimated based on rarefaction method. The highest averaged species richness was calculated for line I (6.94 ± 1.08), followed by line D (6.12 ± 1.14) and line L (5.58 ± 0.92). Table 5 shows that based on the non-overlapping confidence intervals between any two lines, there was no difference in the species richness values. The Shannon-Wiener indices also show insignificant difference between any two pairs of assemblages. The average H' values were in accordance with those obtained for the average species richness indices, with the highest value in line I (1.73 ± 0.197), followed by line D (1.55 ± 0.23).

Table 6 shows the microhabitat variables measured, while Table 7 shows the two-tailed Pearson Coefficient Correlation analysis to tie the relationship between species richness and microhabitat parameters, as well as between abundance and microhabitat parameters. The only significant positive correlation between species richness and microhabitat were shown by percentage of canopy cover (r=0.579, n=14, p<0.030) and distance with forest trails (r=0.598, n=14, p<0.024), and between amphibian abundance and microhabitat in the depth of litter layer category (r=0.846, n=14, p<0.000). Table 8 shows a more detailed correlation between abundance and depth of litter layer in five of the most frequently trapped species. Since amphibians do get out of their auatic habitat to forage for food on land in the forest (Semlitsch & Bodie 2003), these animals have to take care of the dehydration problem that they face in prolonged exposure to the sun in daylight because of their sensitive skin (Blaustein, 2003; Rothermel & Luhring 2005). An open canopy affects microhabitat of the forest floor through changing the humidity, temperature, vegetation cover and composition and

Table 4. One-way ANOVA analysis among lines and abundance of each species of amphibians

	Abundance																
Line	IP	IQ	FL	LB	LK	LP	LPL	OL	MN	XA	KB	KP	KPS	MI	HL	HP	IT
A	2.50±1.48^{a}	0.42±0.19^{a}	0.08±0.08^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.17±0.11^{a}	0.00±0.00^{a}	0.50±0.34^{a}	0.08±0.08^{a}	0.08±0.08^{a}	1.58±0.80^{a}	0.08±0.08^{ab}	0.08±0.08^{a}	0.00±0.00^{a}
B	1.00±0.30^{a}	0.58±0.34^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.17±0.17^{a}	0.08±0.08^{a}	0.75±0.35^{a}	0.00±0.00^{a}	0.25±0.18^{a}	0.00±0.00^{a}	0.00±0.00^{a}	1.00±0.44^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
C	1.42±0.83^{a}	0.75±0.51^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.17±0.11^{a}	0.42±0.19^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.08±0.08^{a}	0.08±0.08^{a}	2.08±1.62^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
D	0.58±0.26^{a}	0.08±0.08^{a}	0.17±0.11^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.17±0.11^{a}	0.17±0.11^{a}	0.42±0.15^{a}	0.00±0.00^{a}	0.33±0.33^{a}	0.00±0.00^{a}	0.08±0.08^{a}	1.75±0.79^{a}	0.00± 0.00^{a}	0.00±0.00^{a}	0.00±0.00 ^{a}
E	0.58±0.23^{a}	0.17±0.11^{a}	0.42±0.19^{b}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.17± 0.11^{a}	0.00±0.00^{a}	1.83±0.91^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.00±0.00^{a}
F	0.42±0.23^{a}	0.08±0.08^{a}	0.08±0.08^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.33±0.19^{a}	0.42±0.19^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.00±0.00^{a}	1.50±0.66^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
G	0.75±0.43^{a}	0.17±0.11^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.58±0.29^{a}	0.42±0.11^{a}	0.00±0.00^{a}	0.25±0.13^{a}	0.00±0.00^{a}	0.00±0.00^{a}	3.25±1.42^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
H	0.08±0.08^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.42±0.23^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.75±0.43^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
I	0.17±0.17^{a}	0.50±0.34^{a}	0.25±0.13^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.33±0.14^{a}	0.08±0.08^{a}	0.17±0.11^{a}	0.00±0.00^{a}	0.33±0.19^{a}	0.00±0.00^{a}	0.00±0.00^{a}	1.33±0.53^{a}	0.08±0.08^{ab}	0.00±0.00^{a}	0.00±0.00^{a}
J	1.17±0.35^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.17±0.11^{a}	0.50±0.23^{a}	0.17±0.11^{a}	0.00±0.00^{a}	1.00±0.49^{a}	0.00±0.00^{a}	0.00±0.00^{a}	10.1±4.76^{b}	0.42±0.26^{b}	0.00±0.00^{a}	0.00±0.00^{a}
K	1.17±0.29^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	1.67±0.71^{a}	0.08±0.08^{ab}	0.17±0.17^{a}	0.00±0.00^{a}
L	1.08±0.60^{a}	0.08±0.08^{a}	0.17±0.11^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.17±0.11^{a}	0.33±0.14^{a}	0.08±0.08^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.42±0.19^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}
M	1.42±0.61^{a}	0.42±0.19^{a}	0.08±0.08^{ab}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.33±0.23^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	1.50± 0.60^{a}	0.00± 0.00^{a}	0.08±0.08^{a}	0.08±0.08^{a}
N	0.67±0.31^{a}	0.25±0.18a	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.00±0.00^{a}	0.08±0.08^{a}	0.17±0.11^{a}	0.17± 0.11^{a}	0.00±0.00^{a}	0.42±0.23^{a}	0.00±0.00^{a}	0.00±0.00^{a}	5.58±3.01^{ab}	0.17±0.11^{ab}	0.00±0.00^{a}	0.00±0.00^{a}

n = 12 (number of samplings)
IP = *Ingerophrynus parvus*, IQ = *Ingerophrynus quadriporcatus*, FL = *Fejervarya limnocharis*, LB = *Limnonectes blythii*, LK = *Limnonectes kuhlii*, LP =*Limnonectes paramacrodon*, LPL = *Limnonectes plicatellus*, OL = *Occidozyga laevis*, MN = *Megophrys nasuta*, XA = *Xenophrys aceras*, KB = *Kaloula baleata*, KP = *Kalophrynus palmatissimus*, KPS = *Kalophrynus pleurostigma*, MI = *Micryletta inornata*, HL = *Hylarana laterimaculata*, HP = *Hylarana picturata*, IT = *Ingerana tenasserimensis*

Table 5. Average values of diversity indices based on rarefraction method on amphibian assemblage according to line transects

Transect line	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Sample size (n)	88	45	63	46	40	40	64	14	36	169	22	22	41	87
Rarefied sample size	14	14	14	14	14	14	14	14	14	14	14	14	14	14
No. species	11	7	8	10	9	7	6	5	10	10	5	7	7	8
Avg. Species richness	4.72	5.43	4.56	6.12	4.70	4.70	4.08	5.00	6.94	3.73	4.15	5.58	4.73	3.86
Variance	1.34	0.66	0.80	1.30	0.83	0.88	0.85	0.00	1.18	1.22	0.48	0.84	0.84	1.20
Std. Error	1.16	0.81	0.9	1.14	0.91	0.94	0.92	0	1.08	1.11	0.69	0.92	0.92	1.11
95% Conf. Interval (+)	7	7	6	8	6	6	6	5	9	6	5	7	7	6
95% Conf. Interval (-)	3	4	3	4	3	3	2	5	5	2	3	4	3	2
Avg. Shannon-Weiner Index, *H'*	1.26	1.55	1.27	1.55	1.36	1.17	0.99	1.27	1.73	0.8	1.08	1.27	1.31	0.83
Variance of *H'*	0.06	0.03	0.04	0.05	0.06	0.05	0.07	0	0.04	0.1	0.03	0.04	0.04	0.1
Std. Error	0.24	0.16	0.21	0.23	0.24	0.23	0.26	0	0.2	0.32	0.17	0.21	0.19	0.31
95% Conf. Interval (+)	1.73	1.84	1.67	1.97	1.77	1.58	1.44	1.27	2.07	1.43	1.38	1.67	1.67	1.43
95% Conf. Interval (-)	0.83	1.2	0.88	1.03	0.9	0.66	0.41	1.27	1.3	0.26	0.76	0.9	0.9	0.26
Evenness Index, *E*	0.64	0.88	0.71	0.79	0.72	0.69	0.65	0.79	0.86	0.45	0.71	0.71	0.76	0.5
Std. Error	0.05	0.04	0.07	0.05	0.08	0.02	0.07	0.06	0.08	0.1	0.07	0.07	0.08	0.03

Table 6. Microhabitat parameters and data at 14 transect lines in the study site

Line	Altitude (m)	% canopTaby cover	Depth of litter (cm)	Distance from water body (m)	Distance from human trail (m)	No. Fallen tree	No climbers	No. of herbaceous plants	No. ferns	No. palms
A	86	86.7	2.6	52	45	0	3	8	1	5
B	63	89.2	1.5	43	63	6	5	9	2	4
C	87	90.6	1.8	27	86	3	6	9	9	4
D	76	88.3	1.5	20	104	1	3	9	8	5
E	81	89.4	1.3	7	4	1	4	8	7	4
F	77	90.8	1.3	15	15	2	1	9	9	3
G	128	88.3	1.8	17	5	4	2	9	6	5
H	94	83.6	1.7	2	57	4	5	9	4	6
I	152	62.5	1.2	6	53	9	0	9	8	6
J	106	88.3	2.7	24	4	2	4	9	7	7
K	78	81.7	1.0	7	34	3	4	9	8	6
L	82	87.4	0.8	9	32	3	5	9	8	7
M	82	84.7	1.4	7	42	0	5	9	9	7
N	83	89.9	1.9	21	6	4	7	9	9	7

Table 7. A two-tailed Pearson Coefficient Corelation analysis between species richness and abundance with the 10 microhabitat variables

Microhabitat variables	r	N	P
(a) Species richness			
Altitude (m)	0.237	14	0.414
%canopy cover	*0.579	14	0.030
Depth of litter layer (cm)	0.268	14	0.354
Distance from water body (m)	-0.13	14	0.657
Distance from human trail (m)	*0.598	14	0.024
No. fallen trees	0.444	14	0.112
No. climbers	0.08	14	0.785
No. herbaceous plants	-0.096	14	0.744
No. ferns	-0.046	14	0.876
No. palms	-0.436	14	0.119
(b) Abundance			
Altitude (m)	0.162	14	0.581
%canopy cover	0.257	14	0.376
Depth of litter layer (cm)	**0.846	14	0.000
Distance from water body (m)	0.481	14	0.082
Distance from human trail (m)	-0.332	14	0.247
No. fallen trees	-0.203	14	0.487
No. climbers	-0.091	14	0.757
No. herbaceous plants	0.216	14	0.458
No. ferns	-0.077	14	0.793
No. palms	0.096	14	0.745

* a=0.05; **a=0.01

Table 8. A two-tailed Pearson Coefficient Corelation analysis between depth of litter layer and abundance of the five most frequently trapped species of amphibians

Species	r	N	P
Micryletta inornata	**0.773	14	0.001
Ingerophrynus parvus	*0.546	14	0.043
Megophrys nasuta	-0.029	14	0.923
Ingerophrynus quadriporcatus	0.150	14	0.609
Kaloula baleata	**0.802	14	0.001

* a=0.05; **a=0.01

depth of the litter layer (Orwig & Abrams 1995). Even in temperate forests, the thick canopy cover is identified as an important requirement for a healthy amphibian assemblages (Hecnar & M' Closkey 1998; Werner *et al.,* 2007).

There were four transects next to forest trails; Line E, G, J and N. These forest trails have been used regularly by the Che Wong tribesmen either on foot or on motorcycles, which left much of the surfaces with water-filled potholes, especially during the rainy season. Other studies have found that potholes are used by semi-aquatic amphibians species to lay their eggs (Kati, 2007; Forman & Alexander, 1998).

The five most abundant species of amphibians (*Micryletta inornata*, *Ingerophrynus parvus*, *Megophrys nasuta*, *Ingerophrynus quadriporcatus* and *Kaloula baleata*) show different patterns of correlation with depth of litter layer (Table 7). Positive correlations were found for *M. inornata* (r=0.773, n=14, p<0.001), *I. parvus* (r=0.546, n=14, p<0.043) and *K. baleata* (r=0.802, n=14, p<0.001). Leaf litter layer supports high abundance if various arthropods, which in turn, are a food source for amphibians (Fauth *et al.,* 1989). Van Sluys *et al.* (2007) also found out that land-dwelling frogs may sometimes depend on the high humidity that the leaf litter layer provides in order to lay eggs. The body pattern and colouration of these frogs are useful to blend in with their environment, which is the leaf litter layer, especially *M. nasuta*, *M. inornata*, and *I. quadriporcatus*.

Cluster analysis

The Cluster Analysis using the UPGMA of Jaccard Index of Similarity based on similarity of sampling lines produced five groups (Figure 3). Group 1 consisted of *Limnonectes blythii* only since this species is usually found in shallow rivers, especially on pebbly or sandy riverbank (Inger & Stuebing 1999). The rivers from where it is found may or may not be clear from sediment (pers. obs.). Group 2 comprised *Hylarana erythraea*, *H. labialis*, *Occidozyga laevis* and *Polypedates leucomystax*. Members of this group are usually associated with humans. In other words, these species are human commensals and/or generalist species or non-endemic taxa with wide distributions in Southeast Asia. *Hylarana erythraea,* however, is also commonly found at large open waterbodies, such as lakes (Norhayati *et al.,* 2009), and together with the others in the group, could also be found in gardens, plantations, primary and secondary forests (Norhayati *et al.,* 2005; Ibrahim *et al.,* 2008). The third group was made up of *Fejervarya limnocharis, Megophrys nasuta*, *Hylarana picturata* and *H. nicobariensis*. According to Inger and Stuebing (1999), *F. limnocharis* is usually found on grassy areas far from any waterbody, especially in the wet season. It seemed that this group could be found away from rivers or any water body, preferring to perch on low vegetation or on the ground. *Fejervarya limnocharis*, however, was the odd one in the group, since it could as well be in Group 1, being a human commensal too. Group 4 consisted of *Leptobrachium nigrops* dan *Calluella minuta*, both species were found mainly in swampy areas. Lastly, Group 5 was made up of *Ingerophrynus parvus* and *Kaloula pulchra,* both of which would usually congregate in big numbers and become sexually active right after a rain, near forest edge in disturbed and undisturbed forests (Norhayati *et al.,* 2005).

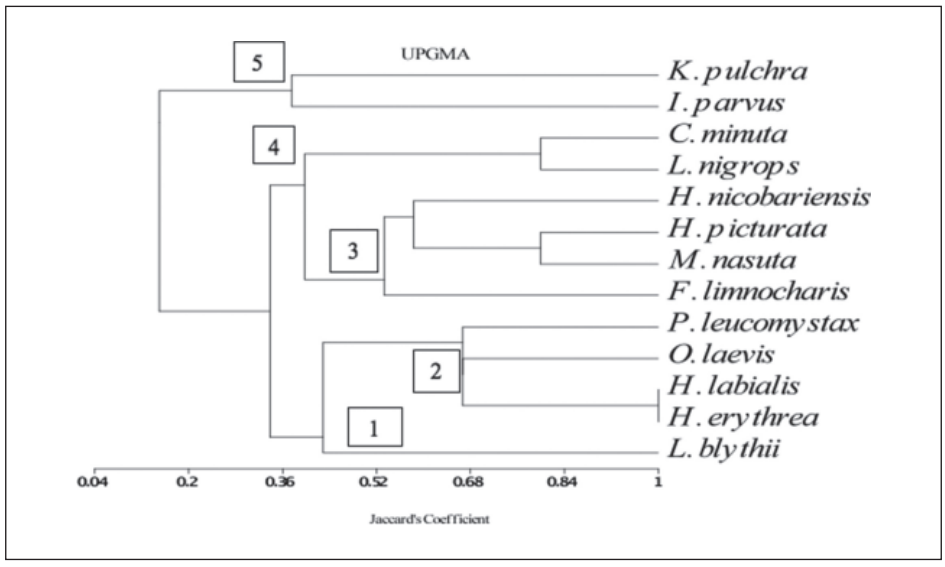

Fig. 3. Dendogram produced by Cluster Analysis of the 14 transects using the Jaccard Similarity Coefficient Index based on absence and presence data of amphibian species.

CONCLUSIONS

The total species of anurans sampled from the pit-fall traps in this study was 17 species within 5 families; Bufonidae: *Ingerophrynus parvus* and *Ingerophrynus quadriporcatus*; Dicroglossidae: *Fejervarya limnocharis*, *Limnonectes blythii*, *Limnonectes kuhlii*, *Limnonectes paramacrodon*, *Limnonectes plicatellus* and *Occidozyga laevis*; Megophyridae: *Megophrys nasuta* and *Xenophrys aceras*; Microhylidae: *Kaloula baleata*, *Kalophrynus palmatissimus*, *Kalophrynus pleurostigma* and *Micryletta inornata*; and Ranidae: *Hylarana laterimaculata*, *Hylarana picturata* and *Ingerana tenasserimensis*. The species richness at Kuala Gandah could be explained significantly by two out of 10 environmental parameters measured; canopy cover and distance from forest trails. The most abundant individuals sampled could only be explained significantly by the depth of leaf litter layer.

The total of anuran species obtained from the active sampling along the rivers was 13 species from 6 families: *Ingerophrynus parvus*; Dicroglossidae: *Fejervarya limnocharis*, *Limnonectes blythii* and *Occidozyga laevis*; Megophyridae: *Leptobrachium nigrops* and *Megophrys nasuta*; Microhylidae: *Calluella minuta* and *Kaloula pulchra*; Ranidae: *Hylarana erythraea*, *Hylarana nicobariensis*, *Hylarana labialis* and *Hylarana picturata*; and Rhacophoridae: *Polypedates leucomystax*. From the Cluster analysis, five main groups can be distinguished according to their microhabitats, lifestyles and life cycles. Generally, disturbed habitats were characterised by widespread habitat-generalists and/or human commensal taxa, whereas, the riverine habitat and forests tend to be characterised by habitat-specialist taxa. Although, this study managed to obtain many rare land-dwelling anurans, the limitation of the sampling method used did not quite capture the true representation of the anuran assemblage, for instance only one species of tree frog was sampled and that was the widespread *Polypedates leucomystax*. These rare and mostly endemic species are most likely to be displaced by human impacts. Additionally, these tree frogs are lacking in distribution and ecological information. It is important to include a suitable sampling technique to catch these shy taxa. Notwithstanding, the results have shown that a majority of taxa seemed persistent in existing in disturbed habitats. Thus, the importance of disturbed habitats in supporting these taxa cannot be underpinned and should be integrated in the future management and conservation plan.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the staff of the Department of Wildlife and National Parks (DWNP) for their assistance in the field, especially the rangers from the Institute of Biodiversity, Bukit Rengit and the staff of the Kuala Gandah Station. This research is supported by the Grant FRGS/1/2012/STWN10/UKM/02/4 and DPP-2013-082 of Universiti Kebangsaan Malaysia and the Universiti Terengganu Malaysia.

REFERENCES

Blaustein, A.R. 2003. Ultraviolet radiation, toxic chemicals and amphibian population declines. *Diversity and Distributions* **9**:123-140.

Bonvincino, C.R., Languth, A, Linderbergh, S.M. & De Paula, A.C. 1997. An elevational gradient study of small mammals at Capara'o National Park, Southeastern Brazil. *Mammalia* **61(4)**: 547-560.

Brown, D.J., Street, G.M., Nairn, R.W. & Forstner, M.R.J. 2012. A place to call home: amphibian use of created and restored wetlands. *International Journal of Ecology* 2012: 1-11. doi:10.1155/2012/989872.

Carey, C., Heyer, R.W., Wilkinson, J., Alford, R.A., Arntzen, J.W., Halliday, T., Hungerford, L., Lips, K.R., Middleton, E.M., Orchard, S.A. & Rand, A.S. 2001. Amphibian declines and envrionmental change: use of remote sensing data to identify environmental correlates. *Conservation Biology* **15**: 903-913.

deMaynadier, P.G. & Hunter, M.L. Jr. 1995. The relationship between forest management and mmphibian ecology: A review of the North American literature. *Environmental Reviews* **3**: 230-261.

Fauth, J.E., Crother, B.I. & Slovinsky, J.B. 1989. Elevational patterns of species richness, evenness and abundance of the Coata Rican leaf-litter herpetofauna. *Biotropica* **21**: 178-185.

Forman, R.T.T. & Alexander, L.E. 1998. Roads and their major ecological effects. *Annual Review of Ecology and Systematics* **29**: 207-231.

Gotelli, N.J. & Entsminger, G.L. 2001. EcoSim: Null models software for ecology. Vers. 7.0. Acquired Intelligence Inc. & Kesey-Bear. (Online). http://homepages.together.net/~gentsmin/ecosim.htm (19 June 2005).

Hecnar, S.J. & M'Closkey, R.T. 1998. Species richness patterns of amphibians in southwestern Ontario ponds. *Journal of Biogeography* **25**: 763-772.

Heyer, W.R., Donelly, M.A., McDiarmid, R.W., Hayek, L.C. & Foster, M.S. 1994. *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians*. Smithsonian Institution Press, Washington and London. pp. 364.

Ibrahim, J., Shahrul Anuar, M.S., Norhayati, A., Chan, K.O. & Mohd Abdul Muin, M.A. 2008. *The Common amphibians and Reptiles of Penang Island*. Penang: The State Forestry Department of Penang.

Inger, R.F. & Stuebing, R.B. 1999. *A Field Guide to the Snakes of Borneo*. Kota Kinabalu, Sabah: Natural History Publications (Borneo) Sdn. Bhd.

Kati, V. 2007. Diversity, ecological structure and conservation of herpetofauna in a Mediterranean area (Dadia National Park, Greece). *Amphibia-Reptilia* **28(4)**: 517-529.

Kats, L.B. & Ferrer, R.P. 2003. Alien predators and amphibian declines: review of two decades of science and the transition to conservation. *Diversity Distribution* **9**: 99-110.

Kiesecker, J.M., Blaustein, A.R. & Belden, L.K. 2001. Complex causes of amphibian population declines. *Nature* **410**: 681-684.

Kingston, T., Francis, C.M., Zubaid, A. & Kunz, T.H. 2003. Species richness in an insectivorous bat assemblage from Malaysia. *Journal of Tropical Ecology* **19**: 67-79.

Kovach, W.L. 1999. *MVSP – A Multivariate Statistical Package for Windows, Version 3.1*. Wales, UK: Kovach Computing Services.

Leong, T.M. 2004. *Hylarana laterimaculata*. Dlm: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. www.iucnredlist.org [21 September 2011].

Ludwig, J.A. & Reynolds, J.F. 1988. *Statistical Ecology: A Primer on Methods and Computing*. New York: John Wiley.

Norhayati, A., Juliana, S. & Lim, B.L. 2005. *Amphibians of Endau Rompin State Park, Pahang*. Kuala Lumpur: The Forestry Department of Peninsular Malaysia.

Norhayati, A., Juliana, S. & Shukor, M.N. 2009. A Survey of amphibian fauna. In. Mushrifah, I., Mohammad Shuhaimi, O., Sahibin, A.R., Khatijah, H. & Nur Amelia, A. (Eds.). *Sumber Asli Tasik Chini: Ekspedisi Saintifik,* pp.147-156. Bangi: Faculty of Science & Technology, Universiti Kebangsaan Malaysia.

Orwig, D.A. & Abrams, M.D. 1995. Dendro-ecological and ecophysiological analysis of gap environments in mixed-oak understoreys of northern Virginia. *Functional Ecology* **9***:* 799-806.

PERHILITAN/DANCED. 2001. *Management Plan for Krau Wildlife Reserve 2002-2006.* Kuala Lumpur: Jabatan Perlindungan Hidupan Liar dan Taman Negara.

Rothermel, B. & Luhring, T. 2005. Burrow availability and desiccation risk of mole salamanders (*Ambystoma talopoideum*) in harvested versus unharvested forest stands. *Journal of Herpetology*: **39**: 619-626.

Savage, A.E., Grismer, L.L., Anuar, S., Chan, K.O., Grismer, J.L., Quah, E., Muin, M.A., Ahmad, N., Lenker, M. & Zamudio, K.R. 2011. First record of Batrachochytrium dendrobatidis infecting four frog families from Peninsular Malaysia. *EcoHealth* DOI: 10.1007/s10393-011-0685-y.

Semlitsch, R.D. & Bodie, J.R. 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. *Conservation Biology* **17**: 1219.

Skerratt, L.F., Berger, L., Speare, R., Cashins, S., McDonald, K.R., Phillott, A.D., Hines, H.B. & Kenyon, N. 2007. Spread of Chytridiomycosis has caused the rapid global decline and extinction of frogs. *EcoHealth* **4(2)**: 125-134.

van Dijk, P.P., Inger, R.F. & Norsham, Y. 2004. *Leptobrachium nigrops*. Dlm: IUCN 2010 [21 September 2011].

Van Sluys, M., Vrcibradic, D., Alves, M.A.S., Bergallo, H.G. & Rocha, C.F.D. 2007. Ecological parameters of the leaf-litter frog community of an Atlantic rainforest area at Ilha Grande, Rio de Janeiro state, Brazil. *Australian Ecology* **32**: 254-260.

Voris, H.K. & Inger, R.F. 1995. Frog abundance along streams in Borneo. *Conservation Biology* **9(3)**: 679-683.

Werner, E.E., Skelly, D.K., Relyeaand, R.A. & Yurewicz, K.L. 2007. Amphibian species richness across environmental gradients. *Oikos* **116**: 1697-1712.