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Species Richness and Distributional Pattern of Amphibians along an Elevational Gradient at Gunung Raya, Pulau Langkawi, Kedah, Malaysia

(Kekayaan Spesies dan Corak Taburan Amfibia Sepanjang Kecerunan di Gunung Raya, Pulau Langkawi, Kedah, Malaysia)

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ABSTRACT

A study on amphibian community at Gunung Raya, Pulau Langkawi was conducted in order to identify amphibian species richness and species distribution pattern along an elevation gradient. Species richness and distribution pattern of amphibians along an elevational gradient could explain factors that determine ecological processes in a particular highland. Passive sampling method by using two types of traps namely Drift- fenced pitfall trap and PVC *pipe trap were used from February 2014 until January 2015. 100 individual comprise of 10 species amphibian were recorded.* Leptobrachium smithii *were the most abundant (*n*=37) followed by* Megophrys aceras *(*n*=28). Rank abundance curve for amphibian community show a Broken Stick pattern (χ2=12.67,* p*=0.12). Species accumulation curve does not level off to an asymptote, indicating insufficient sample size despite intensive sampling effort. Estimation analysis by using Chao 1 predictor produces 12 amphibian species based on 100 pooled individuals. A weak positive exponential function fits the distribution pattern of amphibian abundance (y=0.0028x+13.39), reflecting species domination towards the peak. A negative exponential function fits distribution pattern of amphibian species number across the elevation gradient (y=-0.0091x+7.247), due to the lack of permanent water resource at the upper elevation. These results indicated that by understanding the upland ecology of amphibians, important decisions may be critical for designing conservation efforts and planning land use.*

Keywords: Altitude; diversity; Herpetofauna

ABSTRAK

Suatu kajian telah dijalankan ke atas komuniti amfibia di Gunung Raya, Pulau Langkawi bertujuan untuk mengenal pasti kekayaan spesies dan corak taburan spesies amfibia sepanjang kecerunan ketinggian. Kekayaan spesies dan corak taburan Amfibia sepanjang kecerunan ketinggian dapat menjelaskan faktor yang menentukan proses ekologi di dataran tinggi tertentu. Kaedah persampelan pasif menggunakan dua jenis perangkap, iaitu perangkap lubang berpagar dan perangkap paip PVC *dari Februari 2014 hingga Januari 2015. Sebanyak 100 individu amfibia yang terdiri daripada 10 spesies telah direkodkan.* Leptobrachium smithii *adalah spesies yang paling melimpah (*n*=37) diikuti* Megophrys aceras *(*n*=28). Lengkuk kelimpahan berpangkat bagi komuniti amfibia menunjukkan corak 'broken stick' (χ2=12.67,* p*=0.12). Lengkuk akumulasi spesies pula tidak mencapai asimptot, menunjukkan bahawa saiz sampel tidak mencukupi, walaupun usaha persampelan adalah intensif. Analisis penganggaran menggunakan Chao1 menghasilkan sebanyak 12 spesies amfibia berdasarkan 100 individu terkumpul. Fungsi eksponen positif yang lemah dipadankan dengan pola taburan kelimpahan Amfibia (y=0.0028x + 13.39), mencerminkan penguasaan beberapa spesies ke arah puncak. Fungsi eksponen negatif pula dipadankan dengan corak taburan bilangan spesies Amfibia di sepanjang kecerunan ketinggian (y = -0.0091x + 7.247) disebabkan oleh kekurangan sumber air kekal di paras atas. Keputusan kajian ini menunjukkan bahawa memahami ekologi Amfibia di kawasan tanah tinggi adalah penting untuk mereka bentuk usaha pemuliharaan dan merancang penggunaan tanah.*

Kata kunci: Altitud; Herpetofauna; kepelbagaian

INTRODUCTION

Terrestrial habitats are exposed to both temporal and spatial changes, which affect animals that live in them. Add on stochastic variations and population fluctuations, the dynamics of species assemblages are difficult to understand, if not, impossible to predict (Cornell & Lawton 1992; Porembski et al. 2000). Understanding patterns of species richness and biodiversity across these many factors, however, is essential to the proper conservation efforts designed to manage them, especially when facing unknown impacts of climate change that have been the plight of many herpetofaunal species worldwide. Most ecological studies use both temporal and spatial changes to assess species diversity. The factors that contribute to the shaping of species composition and richness are elevation (Owen 1989;

Qian et al. 2007), temperature (Wilgers & Horne 2006) and rainfall (Qian et al. 2007).

Körner (2007) suggested that elevational gradients are among the most powerful 'natural experiments' for testing ecological and evolutionary responses. Thus, elevation has a huge impact to the environment by causing changes to surrounding physical and biological structures, such as vegetation and soil. The changes in elevation may also alter habitat complexity, create ecotones, affect resource productivity and bear on species diversity and other ecological elements (Haeney 2001; Lomolino 2001; Rosenzweig 1995). Elevational gradients on mountains can show particularly large changes over a relatively small distance. However, patterns of species richness along elevational gradients vary considerably across regions (Naniwadekar & Vasudevan 2007), as well as the processes that govern these changes (Rahbek 2005, 1997, 1995). Nevertheless, elevational gradient effects on certain residential species groups can be used to determine the suitability of that habitat and compared to similar habitats in other locations.

The three most common patterns of elevational gradients of species distribution proposed are unimodal, monotonic decline and asymptotic (Rahbek 2005). There are many factors that contribute to the formation of these species distribution patterns. Naniwadekar and Vasudevan (2007) suggested that the formation of distribution patterns is influenced by two spatial levels: Alpha (local) and gamma (landscape). In alpha level, the formation of distribution factors is affected by competition, local climate, habitat structure and heterogeneity (Lomolino 2001). In the gamma level, distribution patterns are influenced by area, isolation and climatic gradients (Lomolino 2001), as well as mass effect, which is colonisation of species from nearby areas (Rahbek 1997).

The Gunung Raya Forest Reserve is the largest forested area in Pulau Langkawi, covering about 5,184 ha (Forestry Department of Kedah). This area was gazetted as a permanent forest reserve, by the Forestry Department in 1976. The reserve is located at the central part of Pulau Langkawi, with the peak at 881 m a.s.l. Geologically, Gunung Raya is part of the two large igneous stocks together with the adjacent Bukit Sawar, namely Gunung Raya Granite, dated as Late Triassic (Bignell & Snelling 1977). The Gunung Raya Forest Reserve serves as a large natural habitat for wildlife, including amphibians and reptiles. The species richness of the herpetofauna at this area, however, still remains unknown due to a lack of study. Study of the herpetofauna at Pulau Langkawi have been conducted by many researchers, such as Daicus et al. (2006), Grismer and Chan (2010), Grismer and Norhayati (2010), Grismer et al. (2008, 2006), Ibrahim et al. (2006) and Lim et al. (2010), with little information on species richness and distribution patterns. Thus, this study was conducted to identify species richness and distribution patterns of amphibians along an elevational gradient on Gunung Raya.

Materials and Methods

Study Site

Seven trails (labelled T1-T7) perpendicular to the main road were chosen systematically at different altitudes along the northwest face of Gunung Raya. Here are the descriptions of the sampling sites.

T1: Location: 006° 21.979' N, 099° 47.463' E; altitude: 68 m above sea level (a.s.l). The ground is a gentle slope of dry and hard soil. There are no large rocky areas and no steep cliffs. The nearest water body is about 50 m from a small stream. There is a small intermittent creek with flowing water only during the rainy season, which occurs from November to March. Hardwood trees dominate the area, with sparse palm trees. The area is particularly dry during the dry season, with hardly any moss cover. Canopy gaps are filled with palm trees, seedlings and climbers.

T2: Location: 006° 22.982' N, 099°47.187' E; altitude: 103 m a.s.l. The trail runs across water run-off area, with large blocks of granite boulders. The terrain is steep and there is no water source nearby during the dry season. The forest edge is predominantly overgrown by *Ficus* spp., pioneer trees, seedlings and rattans. The interior forest comprises of hardwood trees, such as Rengas (*Gluta* spp.) and Meranti (*Shorea* spp.). There are few mosses, ferns and palms found, while canopy gaps are covered with tree saplings.

T3: Location: 006° 23.628' N, 099°47.698' E; altitude: 237 m a.s.l. The steepness of the area is slight (10°) to moderate (60°). Due to surface runoff during the rainy season, there are large granite boulders, with coarse sandy soil substrate. The nearest water source is a small creek, approximately 10 m from the trap array. The vegetation is diverse, dominated by woody plants with sparse ferns and herbaceous plants, while canopy gaps are dominated by rattans and palms. The small creek is dominated on both banks by herbs, such as gingers and taro (Araceae).

T4: Location: 006° 23.739' N, 099°47.791'E; altitude: 307 m a.s.l. The steep terrain here ranges from 60° to 10° towards the end of the trail. There is no water body found near the area. Hardwood trees that line the ridge include figs (*Ficus* spp.), Meranti (*Shore* spp.) and Kayu Arang (*Diospyros* sp.). Canopy gaps are overgrown by rattans and palms.

T5: Location: 006° 23.198' N, 099°47.811'E; altitude: 408 m a.s.l. The trail runs along steep terrain of about 10°. The area is strewn with large granite boulders. There is a small, intermittent creek, but there is no permanent water source here. There are various herbaceous plants and shrubs, such as Tongkat Ali (*Eurycoma longifolia*) and Sandalwood (*Aquilaria* sp.), as well as rattans, palms and climbers.

T6: Location: 006° 22.905' N, 099° 48.030' E; altitude: 503 m a.s.l. The slope of this area is moderate, approximately 10°. The forest floor is covered with thick leaf litters. There is no water source nearby. Hardwood trees that are found here are mostly Meranti (*Shorea spp*.), Kayu Arang (*Diospyros* sp.), and Rengas (*Gluta* sp.). Canopy gaps are dominated by rattan and palm trees. Climbers are also found in the forest.

T7: Location: 006° 22.665' N, 099°49.278'E; altitude: 657 m a.s.l. This area is a water runoff during the rainy season. The terrain is a gentle slope of about 10° and the soil is mainly gravel. There is no permanent water source at the area. There is no water body found at the surrounding area. Apart from the usual hardwood trees and rattans, there are many climbers compared to the other trails. Most of the forest floor is strewn with granite boulders covered with mosses, ferns and herbaceous plants. Many of the tree trunks are covered with damp mosses.

SAMPLING METHODS

Sampling was conducted for 10 days every month for 12 months from February 2014-January 2015. Samplings were done by using drift-fenced pitfall traps (Figure 1) and PVC pipe traps (Figure 2). An array of drift-fenced pitfall traps consists of four 20 L plastic buckets was arranged in a 'Y' shape, with the arms or fence consisting of nursery nets with height between 50-70 cm and 10 m in length. Drift fences were buried ~5 cm below soil surface to prevent animals from burrowing under them. A 20 L pitfall trap (plastic bucket) was buried at the center, with three others at the end of each fence. Drain holes were punched in the bottom of each bucket. Pitfall traps were buried flush with the ground surface and the drift fence overhung the lip of each pitfall trap. Five sets or arrays of the traps were installed along each transect line (altitude) at least 50 m apart from one another. The traps were examined once a day before noon. The second method of trapping was with PVC pipes. A PVC pipe trap used in this study was 1 m long × 2.5 inch in diameter. At one end of the pipe, a cap was glued on in order to hold water in the pipe, while the other end was fixed with a T-shaped PVC connector to act as a cover for any animal seeking refuge in the pipe. The traps were filled with water to the brim and tied to suitable trees approximately 50 m apart along the transect line. A total of 20 sets of PVC pipe traps were installed along each sampling trail.

PREPARATION OF SPECIMENS

At least two voucher specimens were fixed for each species in 10% formalin and subsequently transferred into 70% alcohol for storage. All specimens were deposited in Langkawi Research Centre (LRC), Langkawi. Species identification as follows: Berry (1975), Grismer (2011) and Malkmus et al. (2002).

DATA ANALYSIS

A rank abundance plot was generated to gather information about a community in an area. MacArthur (1957) and Whittaker (1960) suggested that the plot is a visual approach to understanding the species abundance. Species are ranked in descending order from the highest number to the lowest and then the species are plotted in sequence numbering from the highest to the lowest along the x-axis. The logged transformed number of individual by using log10 format is plotted at the y- axis. The curve formed in the plot will follow either four main patterns of rank-abundance curve: log-normal, log-series, broken stick and geometric series. Each of the patterns has its own interpretation that reflects the community. For instance, the Broken stick pattern, reflects species that colonise the community simultaneously, and resource partitioning in the community occurs randomly (Gotelli & Graves 1996).

FIGURE 1. The drift-fenced pitfall trap installed in sampling location

FIGURE 2. PVC pipe trap tied up on the tree trunk

The use of estimators is important to obtain the actual estimation number of species in a certain area by extrapolating the existing data. Four estimators were used (Chao1, ACE, Jacknife1 and Jacknife2), because these estimators are suitable for discrete data with 1000 iterations. The estimators were generated by Estimates Win version 8.20.

Rarefaction method in Ecosim700 software programme was used to analyse species richness among species when all collections are scaled down to the same number of individuals (Hsieh & Li 1998). This method is important because none of the number of individuals collected in all sampling sites were the same. This statistical method is used to estimate the number of species expected to be present in a random sample of individuals taken from any given collection. The rarefaction method not only estimates the parameter of species richness, but also the confidence limit for this parameter (Soetaert & Heip 1990).

Results and Discussion

SPECIES COMPOSITION

A total of 100 individuals of amphibians from two orders, five families and 10 species were recorded (Table 1). The order Gymnophiona was represented by a single family, Ichthyopiidae, while the order Anura comprised four families, namely Bufonidae, Dicroglossidae, Megophyridae and Rhacophoridae. The highest number of species was from the family Dicroglossidae with four species, followed by Bufonidae and Megophryidae with two species each. The most abundant family was Megophyridae with 65 individuals or 65% of the total, compared to that of Dicroglossidae, with 24 individuals (24%). *Leptobrachium smithii* was the most abundant species with 37 individuals, followed by *Megophrys aceras* with 28 individuals and *Limnonectes macrognathus,* with 12 individuals.

None of the species recorded were categorised under threatened categories (Near Threatened, Threatened, Vulnerable, Endangered, Critically Endangered, Extinct in Wild and Extinct) endorsed by the International Union of Conservation and Nature Reserve (IUCN) (Table 1). Most of the species were categorised under the Least Concern (LC) category. Only one species, *L. macrognathus* was categorised under Data Deficient (DD), due to lack of information for assessment. From the total number of amphibians recorded, all of the species were trapped in the drift-fenced pitfall traps (DPT), except *Polypedates leucomystax*, which was trapped in the PVC traps.

RANK ABUNDANCE CURVE

Figure 3 shows the rank abundance curve of amphibian in Gunung Raya. The rank abundance pattern shown the broken stick pattern ($\chi2= 12.67$, $p= 0.12$). The presence of dominant species was detected in this curve, with many rare species represented by singletons (single individual) and doubletons (two individuals). *Fejervarya limnocharis, Ichthyophis* sp. and *Ingerophrynus parvus* were the singletons and *Phrynoidis asper* was the only doubleton recorded.

SPECIES ACCUMULATION CURVE AND SPECIES ESTIMATORS

The individual-based species accumulation curve of observed amphibian species at Gunung Raya in Figure 4 indicates that the sampling effort was incomplete, with the curve tending to increase instead of stabilizing.

In Figure 5, species' accumulation curves for the data set of amphibian species (100 individuals from 10 species) at Gunung Raya showed considerable variability in shape, but did not follow the asymptotic pattern. The number of species observed (Sobs) was 10. None of the estimator used in EstimateS performed well for these data, except Chao 1, which closely fits the Sobs curve.

TABLE 1. The composition of amphibian species at Gunung Raya, Pulau Langkawi

No.	Species	DFPT	PVCT	IUCN Status	Altitude (m)							
					68	103	237	307	408	503	657	Total
	AMPHIBIAN GYMNOPHIONA											
	Ichthyopiidae											
1	*Icthyophis* sp. Fitzinger, 1826	x		NA	0	0	1	0	0	0	0	1
	ANURA											
	Bufonidae											
2	*Ingerophrynus parvus* Boulenger, 1887	x		LC	1	0	0	0	0	0	0	1
3	*Phrynoides asper* Gravernhorst, 1829	x		LC	1	1	0	0	0	0	0	2
	Dicroglossidae											
4	*Fejervarya limnocharis* Gravernhorst, 1829	x		LC	0	1	0	0	0	0	0	1
5	*Limnonectes macrognathus* Boulenger, 1917	x		DD	2	3	7	0	0	0	0	12
6	*Occidozyga laevis* Günther, 1858	x		LC	2	0	2	0	0	1	0	5
7	*Limnonectes hascheanus* Stoliczka, 1870	x		LC	4	0	1	1	0	0	0	6
	Megophryidae											
8	*Leptobrachium smithii* Matsui et al. 1999	x		LC	2	6	7	0	7	7	8	**37**
9	*Megophrys aceras* Boulenger, 1903	x		LC	0	1	1	8	1	6	11	**28**
	Rhacophoridae											
	Polypedates leucomystax Gravernhorst, 1829		x	LC	2	1	3	1	0	0	0	7
	Total Number of Individual				14	13	22	10	8	14	19	100
	Total Number of Species				7	6	7	3	2	3	2	10
	Total Number of family				4	4	4	3	1	2	1	5

IUCN status: LC= Least Concern, DD= Data Deficient, NA= Not Available; DFPT=Drift-fenced pitfall traps, PVCT=PVC traps

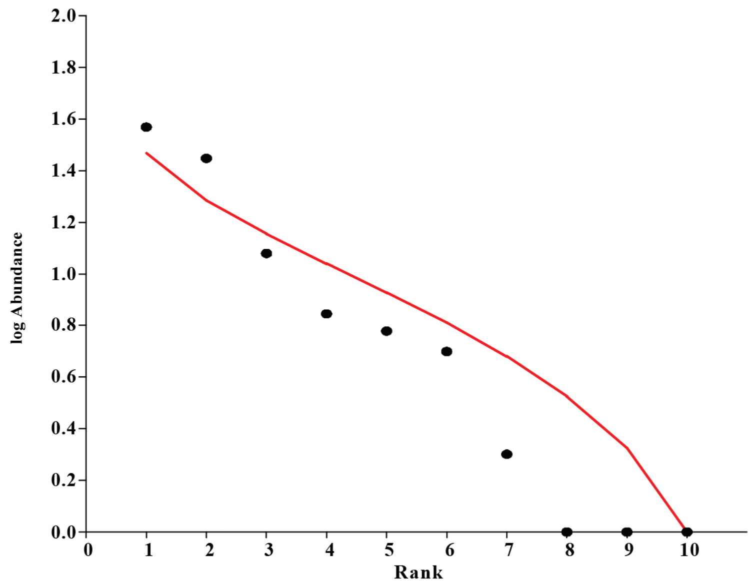

FIGURE 3. The rank abundance curve of amphibians at Gunung Raya, Pulau Langkawi. ($\chi 2$=12.67 p = 0.12)

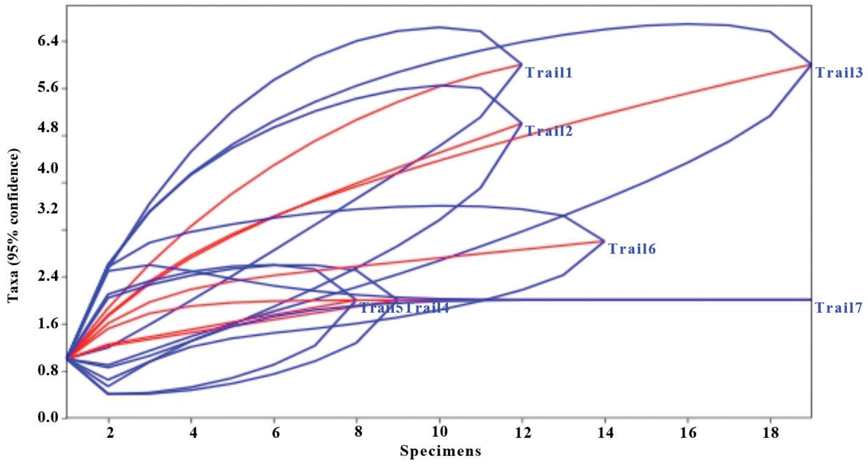

FIGURE 4. Individual-based rarefaction curve of amphibians at Gunung Raya, Pulau Langkawi based on an estimated 100 randomizations in the order of the sample

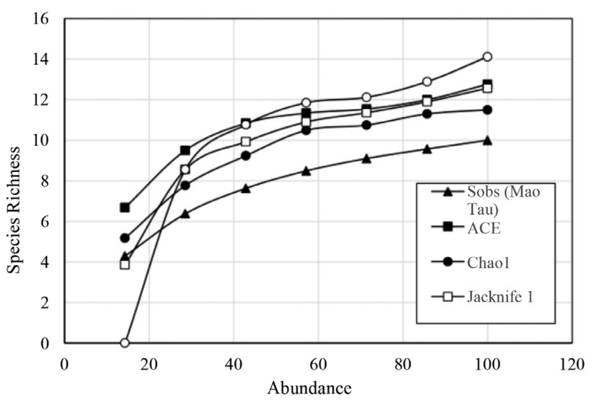

FIGURE 5. The accumulation curve of observed amphibians at Gunung Raya, Pulau Langkawi with species richness estimators of ACE, Chao1, Jacknife 1 and Jacknife 2

The data were simply insufficient to produce a better fit for the estimators. The best-fitted Chao 1 curve predicted 11.5 (≈12) species, based on 100 pooled individuals.

PATTERNS OF DISTRIBUTION

An incline trend in amphibian abundance with elevation was detected, but with a low value of regression (r2= 0.014). Linear regression showed that overall abundance inclined with elevation, but not significantly (r2= 0.014, F= 0.07, df= 6, p= 0.796) (Figure 6). The linear regression model of this trend on amphibian abundance is y= 0.0028x + 13.39. Meanwhile, a decline trend in amphibian species richness with elevation was detected (r2= 0.71) (Figure 7). Analysis of variance showed that the amphibian species richness and elevation

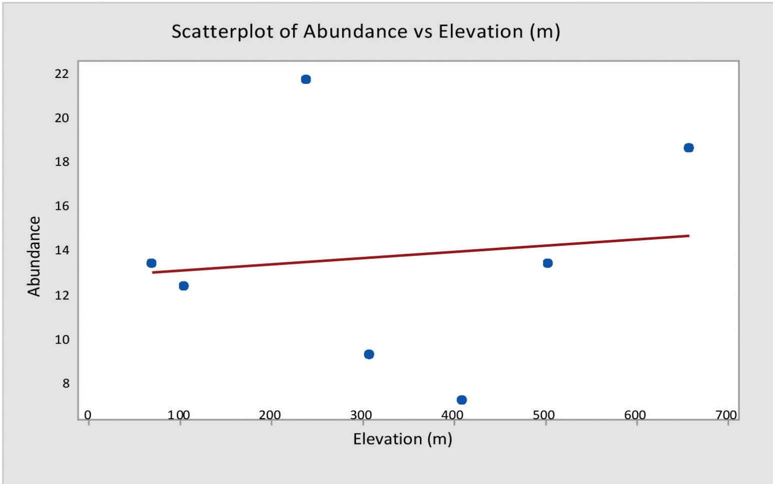

FIGURE 6. Linear regression model showing the effect of altitude to the amphibian abundance (y= 0.0028x + 13.39, r2= 0.014) at Gunung Raya (Anova= *p*= 0.796, F= 0.07)

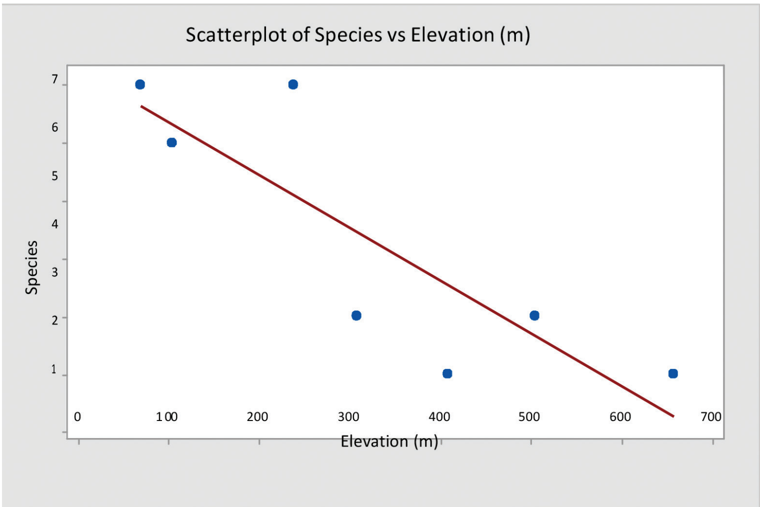

FIGURE 7. Linear regression model showing the effect of altitude to the amphibian abundance (y= -0.00908x + 7.247, r2= 0.71) at Gunung Raya (Anova, p= 0.017, F= 12.48)

distribution pattern was significant (F=12.48, df= 6, $p<0.05$). The linear regression showing the decreasing pattern of amphibian species richness with elevation is y= -0.00908x + 7.247.

SPECIES COMPOSITION ALONG AN ELEVATION GRADIENT

This study was carried out in a pristine mixed dipterocarp rainforest that covers the highest mountain in Langkawi, Gunung Raya (881 m). Access from the foothills to the upper elevations until the peak was through a well-maintained road. The disturbance level to the wildlife fauna on this mountain was minimal, with only a resort at the peak (D'coconut Hill Resort) and a golf resort at the foothills (Gunung Raya Golf Resort), which has been open since 1998. Gunung Raya had high herpetofaunal diversity, as reported from studies that covered the mountain, as well as other areas of the archipelago (Chan & Norhayati 2010; Daicus et al. 2006; Grismer et al. 2006; Ibrahim et al. 2006; Lim et al. 2010). The current study is a valuable addition to the literature, which provides a more comprehensive picture of the species richness and composition.

Despite the long duration of sampling (12 months), the sampling effort was incomplete, as the species accumulation curve did not plateau off. This study showed a total of 10 species of amphibians, all of them were accounted for from previous studies, except *Ingerophrynus parvus*, which was trapped at 68 m a.s.l. in a drift-fenced pitfall trap. *Leptobrachium smithii* was the most abundant species, followed by *Megophrys aceras*. The total number of amphibian species at Gunung Raya represents 38.5% of the total number in Langkawi Archipelago. Most of the amphibian species recorded in this study are common species or species that are Least Concern in the IUCN Red List, except for *Limnonectes macrognathus,* which is classified as Data Defficient (DD) and *Ichthyophis* sp., which is not identified to the species level yet.

RANK ABUNDANCE PLOT

According to Guo and Rundel (1997), the most appropriate approach for measuring diversity must be capable of detecting subtle differences between sites. In this regard, the rank-abundance curves are useful tools to investigate the richness and composition-based diversity of a site, since they straightforwardly account for both richness, measured as the number of ranks, i.e. by the length of the x-axis and equitability, derived from the slope of the rank-abundance curves, i.e. the higher the slope, the lower the equitability of the assemblage. In other words, the strength of the rank- abundance curve is that it allows all the data to be maintained relative to the distribution of the values being considered (i.e. species data) without any loss of detail since every single abundance is clearly shown (McGill et al. 2007).

The rank abundance curve (Figure 1) shows a Broken Stick pattern, which was proposed by MacArthur (1957). This pattern described an assemblage of amphibians with overlapping niches with low resource partitioning. Gotelli and Graves (1996) described the broken stick as a model of sequential colonization, with each species randomly invading some proportion of the niches of established species. The overall rank abundance was shown by *Leptobrachium smithii* (n=37), which proved that the use of drift-fenced pitfall traps were suitable for sampling litter frogs (Corn 1994). The tails (left and right) of a rank-abundance curve represent dominant and rare species (Murray & Westoby 2000). Rare species are indicated by the singletons, namely *Ichthyophis* sp., *Ingerophrynus parvus* and *Fejervarya limnocharis;* and a doubleton, *Phrynoidis asper* (Figure 1, Table 1). Grismer et al. (2006) reported an adult *Ichthyophis* sp. from loose soil beneath a fallen log at 250 m elevation. This species is adaptive to fossorial mud and leaf litter tunnels, which is why it is difficult to trap or search actively. This species was also found at Gunung Machinchang, Telaga Tujuh and Durian Perangin Waterfall. *Fejervarya limnocharis,* however, is a species known to prefer grassy areas, forest edges and disturbed lowland areas, such as paddy fields. Although this species was rare on Gunung Raya, elsewhere on Langkawi, it was very common. Specimens had been found at Pantai Kok and the paddy field along Jalan Padang Matsirat (Ibrahim et al. 2006); in the drainage ditch alongside the road at the base of Gunung Raya, at Wat Wanaram near Kuah and the Oriental Village (Grismer et al. 2006). Likewise, *Phrynoidis asper* is also a common riparian toad species occurring along rocky streams of Pulau Langkawi, but uncommon on Gunung Raya. The species was reported at Lubuk Semilang, Telaga Tujuh, 400 m elevation on Gunung Machinchang, Gunung Raya and Wat Tham Kisap near Kuah (Grismer et al. 2006), while Ibrahim et al. (2006) reported it from Sungai Korok and Sungai Perangin.

SPECIES ACCUMULATION CURVE AND SPECIES RICHNESS ESTIMATOR

None of the species accumulation curves levelled off to a plateau, indicating incomplete sampling, even though the duration was 12 months (Figure 4). According to Inger (2003), to estimate species richness of any tropical region of any size, it is necessary to extend the sampling period to cover interspecific variation in activity patterns and seasonal patterns in weather. In this case, although the sampling period was 12 months, there were only five pit fall traps set up at each altitude (trail). Species accumulation curves must have established an obvious plateau to provide reasonable estimates of species richness. Small samples, even when collected over a limited number of trapping periods or limited number of traps might invariably provide species richness estimates based on species accumulation curves that are under-represented. From Figure 5, the fitted Chao 1 curve predicted a 11.5 (≈12) species, based on 100 pooled individuals, which was the best fitted estimator to the observed 10 species of (Sobs) amphibians at Gunung Raya compared to those of other estimators.

DISTRIBUTION PATTERN ALONG ELEVATION GRADIENT

There was not enough evidence to indicate an incline trend of amphibian abundance with increasing elevation (r2= 0.41, p=0.119). The total sum of individuals was mostly contributed by *Leptobrachium smithii* (n=37), but this species was distributed fairly equally along all elevations, except at mid elevation (307 m a.s.l., Table 1). *Megophrys aceras* was abundant at elevation 307, 503 and 657 m a.s.l. (Table 1), but was also present at the rest of the elevations, except at the lowest. Incidentally, only these two species were trapped at the highest elevation. Due to low temperatures and high humidity, the amount of leaf litter was distinctively high, indicating low levels of decomposition. Litter frog species are actually well-suited in this kind of habitat, favouring high density of leaf litter (Stuart et al. 2006; Vonesh 2001).

The declining trend of amphibian species along elevational gradient on Gunung Raya was expected due to the lack of water bodies (Figure 7). Other studies have also reported the same patterns (Das et al. 2007; Inger & Stuebing 1992; Khatiwada 2012; Naniwadekar & Vasudevan 2007). Das et al. (2007) showed a decline pattern of amphibian species from 200 to 800 m a.s.l. at Matang Range, Sarawak. The limiting factor was the lack of water at the upper elevation. High species richness at the lower altitudes is primarily due to favourable climatic conditions, such as warm temperature, high productivity, precipitation, and humidity (Navas 2002), as well as water, which is important for breeding (Buckley & Jetz 2007).

CONCLUSION

In summary, 10 amphibian species were recorded from five families, none of which was categorized as threatened species by the IUCN. The rank abundance curve showed the broken stick pattern, indicating that the amphibian assemblage shared the same niche and resources. The fitted Chao 1 curve predicted a total of 11.5 (≈12) species, based on 100 pooled individuals, which was the best fitted estimator to the observed 10 species of (Sobs) amphibians at Gunung Raya compared to those of other estimators. The species accumulation curve did not reach asymptote indicating incomplete sampling effort. While the low number of amphibian species across the elevation was likely caused by the changes of microhabitat, such as decreasing number of permanent stream and ditches across the increasing elevation. Thus, spatial study need to be conducted in order to seek actual causes of species richness and distribution pattern of amphibian in this area.

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REFERENCES

Berry, P.Y. 1975. *The Amphibian Fauna of Peninsular Malaysia*. Kuala Lumpur: Tropical Press.

Bignell, J.D. & Snelling, N.J. 1977. Geochronology of Malayan granites. *Overseas Geology and Mineral Resources* 47: 1-72.

Buckley, L.B. & Jetz, W. 2007. Environmental and historical constraints on global patterns of amphibian richness. *Proceedings of the Royal Society B: Biological Sciences* 274: 1167-1173.

Chan, K.O. & Norhayati, A. 2010. Distribution and natural history notes on some poorly known frogs and snakes from Peninsular Malaysia. *Herpetological Review* 40(3): 294-301.

Corn, P.S. 1994. Straight-line drift fences and pitfall traps. In *Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians,* edited by Heyer, W.R., Donnell, R.W., Mcdiarmid, L.A.C., Hayek & Foster, M.S. Washington DC: Smithsonian Institution Press. p. 64.

Cornell, H.V. & Lawton, J.H. 1992. Species interactions, local and regional processes, and limits to the richness of ecological communities: a theoretical perspective. *Journal of Animal Ecology* 61(1): 1-12.

Daicus, B., Hashim, R., Rosli, R. & Sofian-Azirun, M. 2006. Herpetofauna of two habitat in northeast Pulau Langkawi, Kedah, Peninsular Malaysia. *Malaysian Journal of Science* 24: 199-204.

Das, I., Jankoski, A., Makmor, M.I.B. & Haas, A. 2007. Species diversity, elevational distribution and reproductive modes in an amphibian community at the Matang range, Sarawak (Borneo). *Mitteilungen des hamburger Zoologischen Museums und Instituts* 104: 141-174.

Gotelli, N.J. & Graves, G.R. 1996. *Null Models in Ecology*. Washington and London: Smithsonian Institution Press.

Grismer, L.L. & Norhayati, A. 2010. A new insular species of *Cyrtodactylus* (Squamata: Gekkonidae) from the Langkawi Archipelago, Kedah, Peninsular Malaysia. *Zootaxa* 1924: 53- 68.

Grismer, L.L. & Chan, K.O. 2008. A new species of *Cnemaspis* Strauch 1887 (Squamata: Gekkonidae) from Pulau Perhentian Besar, Terengganu, Peninsular Malaysia. *Zootaxa* 1771: 1- 15.

Grismer, L.L. 2011. *Lizards of Peninsular Malaysia, Singapore and their Adjacent Archipelagos*.Edition Chimaira: Fraankfurt am Main.

Grismer, L.L. 2008. A new species of insular skink (Genus *Sphenomorphus* Fitzinger 1843) from the Langkawi Archipelago, Kedah, west Malaysia with the first report on the herpetofauna of Pulau Singa Besar and an updated checklist of the herpetofauna of Pulau Langkawi. *Zootaxa* 1691: 53-66.

Grismer, L.L., Youmans, T.M., Wood Jr., P.L., Ponce, A., Wrught, S.B., Jones, B.S., Johnson, R., Sanders, K.L., Gower, D.J., Norsham S.Y. & Lim, K.K.P. 2006. Checklist of the herpetofauna of Pulau Langkawi, Malaysia, with comments on Taxonomy. *Hamadryad* 30: 61-74.

Guo, Q. & Rundel, P.W. 1997. Measuring dominance and diversity in ecological communities: Choosing the right variables. *Journal of Vegetation Science* 8: 405-408.

Heaney, L.R. 2001. Small mammal diversity along elevational gradient in: An assessment of pattern and hypotheses. *Global Ecology and Biogeography* 10: 15-39.

Hsieh, H.L. & Li, L.A. 1998. Rarefaction diversity: A case study of Polychaete communities using an amended FORTRAN program. *Zoological Studies* 37(1): 13-21.

Ibrahim, J., Shahrul Anuar, M.S., Norhayati, A., Shukor, M.N., Shahriza, S., Nurul Ain, E., Nor Zalipah, M. & Mark Rayyan, D. 2006. An annotated checklist of herpetofauna of Langkawi Island, Kedah, Malaysia. *Malayan Nature Journal* 57(4): 369-381.

Inger, R.F. 2003. Sampling biodiversity in Bornean frogs. *The Natural History Journal of Chulalongkorn University* 3(1): 9-15.

Inger, R.F. & Stuebing, R.B. 1992. The montane amphibian fauna of northwestern Borneo. *Malayan Nature Journal* 46: 41-51.

Khatiwada, J.R. 2012. Amphibian species richness and composition along an elevational gradient in Chitwan, Nepal. Master Thesis. Norwegian University of Life Sciences. Norway (Unpublished).

Körner, C. 2007. The use of 'altitude' in ecological research. *Trends in Ecology & Evolution* 22(11): 569-574.

Lim, B.L., Noor Alif Wira, O., Chan, K.O., Daicus, B. & Norhayati, A. 2010. An updated checklist of the herpetofauna of Pulau Singa Besar, Langkawi, Peninsular Malaysia. *Malaysian Applied Biology* 39(1): 13-23.

Lomolino, M.V. 2001. Elevation gradients of species-density: Historical and prospective views. *Global Ecology and Biogeography* 10: 3-13.

MacArthur, R.H. 1957. On the relative abundance of bird species. *Proceedings of the National Academy of Sciences* 43: 293-295.

Malkmus, R., Manthey, U., Vogel, G., Holfmann, P. & Kosuch, J. 2002. *Amphibians and Reptiles of Mount Kinabalu (North Borneo)*. Königstein: Koeltz Scientific Books. p. 424.

Murray, B.R. & Westoby, M. 2000. Properties of species in the tailof rank-abundance curves: The potential of species for increase in abundance. *Evolutionary Ecology* 2: 583-582.

Naniwadekar, R. & Vasudevan, K. 2007. Pattern in diversity of anurans along an elevational gradient in the Western Ghats, South India. *Journal of Biogeography* 34: 842-853.

Navas, C.A. 2002. Herpetological diversity along Andean elevational gradients: Links with physiological ecology and evolutionary physiology. *Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology* 133(3): 469-485.

Owen, J.G. 1989. Pattern of herpetofaunal species richness: Relation to temperature, precipitation and variance in elevation. *Journal of Biogeography* 16: 141-150.

Porembski, S., Seine, R. & Barthlott, W. 2000. Factor controlling species richness of Inselbergs. In. *Inselbergs: Biotic Diversity of Isolated Rock Outcrops in Tropical and Temperate Regions,* edited by Porembski, S. & Barthlott, W. Location: Publisher. pp. 451-481.

Qian, H., Wang, X., Wang, S., Li, Y. 2007. Environmental determinants of amphibians and reptile species richness in China. *Ecography* 30(4): 471-482.

Rahbek, C. 2005. The role spatial scale and the perception of large-scale species richness pattern. *Ecology Letters* 8: 224-239.

Rahbek, C. 1997. The relationship among area, elevation and regional species richness in Neotropical birds. *The American Naturalist* 149: 875-902.

Rahbek, C. 1995. The elevational gradient of species richness: a uniform pattern? *Ecography* 18(2): 200-205.

Rosenzweig, M.L. 1995. *Species Diversity in Space and Time*. Cambridge: Cambridge University Press.

Soetaert, K. & Heip, C. 1990. Sample-size dependence of diversity indices and the determination of sufficient sample size in a high diversity deep sea environment. *Marine Ecology Progress Series* 59: 305-307.

Stuart, B.L., Chuaynkern, Y., Chan-ard, T. & Inger, R.F. 2006. Three new species of frogs and new tadpole from Eastern Thailand. *Fieldiana: Zoology:* 111: 1-19.

Vonesh, J.R. 2001. Pattern of richness and abundance in a tropical African litter-frog herpetofauna. *Biotropica* 33(3): 502-510.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. *Ecological Monographs* 30: 279-338.

Wilgers, D.J. & Horne, E.A. 2006. Effects of different burn regimes on tallgrass prairie herpetofaunal species diversity and community composition in the Flint Hills, Kansas. *Journal of Herpetology* 40(1): 73-84.

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