HERPETOFAUNA ASSEMBLAGES AND MICROHABITAT ASSESSMENT AT ROYAL BELUM STATE PARK, PERAK

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HERPETOFAUNA ASSEMBLAGES AND MICROHABITAT ASSESSMENT AT ROYAL BELUM STATE PARK, PERAK

by

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HIMPUNAN HERPETOFAUNA DAN PENILAIAN MIKROHABITAT DI TAMAN NEGERI ROYAL BELUM, PERAK

ABSTRAK

Amfibia dan reptilia, dikenali secara kolektif sebagai herpetofauna, adalah komponen yang amat penting dalam ekosistem. Oleh sebab kepentingan mereka dalam ekosistem, herpetofauna telah mendapat perhatian daripada seluruh dunia mengikuti pengurangan populasi mereka yang disebabkan oleh pencemaran yang semakin meningkat, kemusnahan habitat dan perubahan iklim. Walaupun sebahagian besar daripada kajian herpetofaunal yang dijalankan kebanyakannya bertumpuan pada biodiversity mereka, hanya segelintir kajian yang memberi penekanan terhadap keperluan mikrohabitat dan iklim makro herpetofauna terutamanya di Malaysia. Kajian ini memberi tumpuan kepada biodiversiti, pilihan mikrohabitat dan iklim makro oleh herpetofauna di Taman Negeri Royal Belum yang kini diancam dengan peningkatan aktiviti ekopelancongan, penuaian hasil hutan dan pemburuan haram. Biodiversiti herpetofauna diselidik dengan menggunakan perangkap lubang berpagar dan kaji selidik visual (VES) dalam tempoh 12 bulan. Kajian ini berjaya mendokumenkan sebanyak 38 spesies dengan 199 individu yang berasal dari 6 keluarga amfibia dan 8 keluarga reptilia dari tiga tapak persampelan di Taman Negeri Royal Belum. Walaupun spesies yang baru untuk sains tidak ditemui dalam kajian ini, tetapi 5 rekod baru telah didokumentasikan untuk keseluruhan Kompleks Hutan Belum-Temengor, menjadikan jumlah amfibia dan reptilia masing-masing ke 42 dan 73. Di antara 38 spesies, *Ingerophrynus parvus* dari Order *Anura* adalah spesies amfibia yang paling banyak manakala *Eutropis multifasciata* dari Order *Squamata* adalah spesies reptilia yang paling banyak. *Heosemys spinosa* adalah satu-

satunya spesies yang ditemui untuk Order *Testudines*. Tiga belas pembolehubah mikrohabitat juga direkodkan dari tapak perangkap lubang berpagar manakala tiga pembolehubah iklim makro diperolehi daripada Jabatan Pengairan dan Saliran, Perak dan laman web Weather2 untuk mengkaji kesan pembolehubah ini terhadap kelimpahan, kepelbagaian dan kekayaan herpetofauna. Di antaranya, kelimpahan dan kepelbagaian herpetofauna dikaitkan secara positif dengan jarak transek dari trek manusia. Selain itu, kelimpahan herpetofauna juga dikaitkan secara negatif dengan ketebalan timbunan daun manakala kepelbagaian spesies dikaitkan secara negatif dengan ketinggian. Kekayaan spesies tidak dikaitkan dengan mana-mana satu pembolehubah mikrohabitat. Sebaliknya, purata hujan bulanan didapati merupakan faktor utama dalam pengagihan dan kelimpahan herpetofauna di hutan hujan tropika. Daripada tiga pembolehubah iklim makro yang dikaji, kelimpahan herpetofauna hanya dikaitkan secara positif dengan purata hujan bulanan. Kepelbagaian dan kekayaan spesies tidak dikaitkan dengan mana-mana satu pembolehubah makrolimat. Kesimpulanya, pengagihan dan kelimpahan herpetofauna adalah dikaitkan dengan ciri-ciri mikrohabitat dan corak iklim makro habitat mereka dengan beberapa pembolehubah memberikan pengaruh yang lebih mendalam terhadap mereka daripada pembolehubah yang lain.

HERPETOFAUNA ASSEMBLAGES AND MICROHABITAT ASSESSMENT AT ROYAL BELUM STATE PARK, PERAK

ABSTRACT

Amphibians and reptiles, known collectively as herpetofauna, are significant components of various ecosystems. Due to their important roles in the ecosystem, herpetofauna around the world is now the focus of scrutiny as their populations continue to decline due to increased pollution, habitat destruction and climate change. While most of the herpetofaunal studies conducted were mainly on their biodiversity, there are only a handful of studies that emphasise on the microhabitat and macroclimate requirements of herpetofauna especially in Malaysia. This study focused on the biodiversity, microhabitat and macroclimate preferences of herpetofauna in Royal Belum State Park that is now threatened with increased ecotourism, harvesting and poaching activities. The biodiversity of herpetofauna was investigated using Drift-fenced Pitfall Traps in conjuction with Visual Encounter Survey (VES) throughout a 12 month-sampling period. The study successfully documented a total of 38 species with 199 individuals that came from 6 families of amphibians and 8 families of reptiles from the three sampling sites in Royal Belum State Park. Although species new to science was not discovered in this study, but five new records were documented for the whole Belum-Temengor Forest Complex, bringing the total number of amphibians and reptiles to 42 and 73 respectively. Among the 38 species, *Ingerophrynus parvus* from the Order *Anura* was the most abundant amphibian species whereas *Eutropis multifasciata* from the Order *Squamata* was the most abundant reptile species. *Heosemys spinosa* was the only species found for the Order *Testudines*. Thirteen microhabitat variables were also recorded from the pitfall trap sites while three macroclimate variables were acquired from the Department of Irrigation and Drainage, Perak and Weather2 website to study the effect of these variables on herpetofauna abundance, diversity and richness. Among these, herpetofauna abundance and diversity were positively associated with distance of transects from human tracks. Besides that, herpetofauna abundance was also negatively associated with thickness of leaf litter whereas species diversity was negatively associated with altitudes. Species richness was not associated with any of the microhabitat variables. On the other hand, average monthly rainfall was found to be the key factor in the distribution and abundance of herpetofauna in tropical rainforests. Out of the three macroclimate variables studied, herpetofauna abundance was only positively associated with average monthly rainfall. Species diversity and richness were not associated with any of the macroclimate variables. It can be concluded that the distribution and abundance of herpetofauna are associated with the microhabitat characteristics and macroclimate patterns of their habitats with some of these variables having greater influences on them than the other variables.

1.0 Introduction

Malaysia is a tropical country located in South East Asia, just north of the equator. It is blessed with a collection of unrivaled beautiful rainforests and national parks that are made up of different types of forests ranging from the lowland dipterocarp forests, hill dipterocarp forests, upper hill dipterocarp forests, montane oak forests, lower ericaceous forests, montane subalpine forests, semi-evergreen forests, peat swamp forests to mangrove forest (Manokaran, 1992). These different forest types create a variety of different habitats which serve as great sanctuaries to a wide collection of flora and fauna including amphibians and reptiles, some of which are threatened with extinction. According to Ibrahim *et al.* (2008), there were a total of 103 species of amphibians and 270 species of reptiles inhabiting the Peninsular Malaysia. Currently, new species of anura are still being unearthed in Peninsular Malaysia, with many unknown species yet to be discovered (Shahriza *et al.*, 2011).

Located in the Perak state of peninsular Malaysia, the Belum-Temengor Forest Complex (BTFC) is the second largest remaining contiguous primary forest right after the Taman Negara Nature Reserve (Joann Christine *et al.*, 2011). The BTFC is divided into two segments: the Belum division which is composed of the Royal Belum State Park, is a pristine forest located north near to the Malaysia-Thailand border; and the Temengor division consisting of disturbed forests with logging activities which is situated south of Belum (Kaur *et al.*, 2011). This age-old forest dates back to around 130 million years old, making it even older than the Amazon and Congo which are known for their biodiversity (Schwabe *et al.*, 2014). Although there are still parts of the forest complex that are undisturbed, however, rapid declines and extinction of herpetofauna could still be occurring in pristine environments due to other factors such as UV radiation, climate change, and emerging contagious disease (Sodhi and Brook, 2006, Whitfield *et al.*, 2007).

Amphibians and reptiles, collectively known as herpetofauna, are in the forefront of biodiversity crisis around the world and are constantly exposed to habitat destruction and degradation, climate change, disease, invasive species and other anthropogenic activities. Among these, habitat and climate related changes are known to be the biggest threats to the global population of amphibians and reptiles due to their low vagility, strict microhabitat requirements and high sensitivity to environmental pollution (Cushman, 2006). To make matters worse, the effect of microhabitat and macroclimate changes may act synergistically and have devastating consequences on global herpetofauna populations.

Amphibians are often used as biological indicator in determining the ecosystem health as they are extremely sensitive to changes in both terrestrial and aquatic microhabitats due to their permeable skin and biphasic life histories. Their life cycles are often interrupted by habitat pollution, alteration and fragmentation which reduces the avaibility of microhabitats and breeding sites (Becker *et al.*, 2010, Hayes *et al.*, 2010). Besides that, habitat fragmentation such as construction of trails is known to cause spatial disjunction in amphibians population particularly in aquatic larvae with forest-associated adults (Fonseca *et al.*, 2013). Furthermore, wetlands in which amphibians are usually associated with are constantly subjected to alteration by anthropogenic activities that remove vegetation (Purrenhage and Boone, 2009).

Conversely, reptiles are more resistant to environmental changes than amphibians due to their more advanced adaptations. In spite of that, their habitats and microhabitats are still largely affected by habitat alteration and fragmentation due to their specific microhabitat requirements. Most reptiles are usually associated with microhabitat such as fallen trees, rocks, buttress roots or leaf litters (Kanowski *et al.*, 2006). Removal or distruptions of these elements by collectors or forest clearings significantly altered the microhabitats beneath it (Lovich, 2012). Moreover, some reptile species are senstivie to disturbance and only thrive in pristine habitats (Wanger *et al.*, 2010). Disturbances to these areas reduce the availability of microhabitats, causing the extirpation of said species from certain geographical area.

In addition to habitat related issues, herpetofauna ecologies, abundance and dispersal tend to mirror that of climate change (Bickford *et al.*, 2010). Herpetofauna, as ectotherms, are dependent on external temperature for thermoregulation. Changes in climate parameters such as temperature can have adverse effect on the physiological process of herpetofauna due to their narrow range of optimal temperature (Bovo *et al.*, 2010). Furthermore, the hatching rate and the sex ratio of certain reptile species are reliant on temperature (Burger and Zappalorti, 1988). Changes in temperature can significantly reduce the hatching rate and alter the sex ratio which can have a dire effect on the affected populations.

Herpetofauna reproduction, on the other hand, is closely associated with rainfall pattern as it provides environmental cues that trigger breeding in herpetofauna (Maltchik *et al.*, 2008, Shine and Brown, 2008). Additionally, climate-induced hydrology is the major determining factor for the availability of breeding sites such as freshwater environments and moist soils which are crucial for both terrestrial and aquatic herpetofauna species (Walls *et al.*, 2013). Asides from this, herpetofauna especially amphibians are also constantly affected by the humidity related issue which are important in maintaining body water content due to their moist permeable skin and skin shedding in reptiles (Mitchell and Bergmann, 2016, Chastain, 2017).

Considering the diversity in life histories, modes of locomotion, habitat preferences and effect of climate change on herpetofauna, it is crucial to employ a combination of different sampling techniques for a comprehensive inventory of herpetofauna (Garden *et al.*, 2007). Moreover, each sampling method is specifically tailored for targeting specific species and thus, they vary in their effectiveness and applicability for different species (Menkhorst and Knight, 2001). For instance, pitfall traps used in conjunction with drift-fence are more effective in capturing anurans, terrestrial lizards, salamanders, small snakes and cryptic species whereas funnel traps are effective at capturing large squamates, geckos and both terrestrial and arboreal lizards (Crosswhite, 1999, Thompson and Thompson, 2007). On the other hand, VES is effective at surveying the species richness (Sung *et al.*, 2011). Although it is always best to employ multiple sampling techniques, limiting factors such as financial costs and time constraints continuously influence the choice of sampling techniques chosen by researchers (Mesquita *et al.*, 2013). As a result, it is critical to select sampling techniques that can complement each other for the greatest success and optimal results (Garden *et al.*, 2007).

In this study, the biodiversity of herpetofauna at Royal Belum State Park were determined via two sampling methods: Drift-Fenced Pitfall Traps as the primary sampling technique and Visual Encounter Survey (VES) as the secondary sampling technique. It has been observed during the survey period that parts of the State Park are being burned down near to the orang asli settlements to open way for rubber plantation which was observed by Kamarudin *et al.* (2014a) as well back in 2014 at Sungai Tiang of Royal Belum State Park. Hence, it is a race against time to collect as much material to complete the ever lacking information on herpetofauna biodiversity in this area before the extinction of certain species due to the increased popularity of ecotourism, rapid progression of habitat destruction and climate change. These materials will serve as the foundation to the microhabitat requirements and the effect of climate change on herpetofauna which is crucial in creating awareness and proper habitat management.

1.1 Rationale of Research

Despite the high biodiversity in this area, studies on wildlife especially amphibians and reptiles remain the least compared to other parts of the country. With the exception of the herpetofauna study carried out by Norsham *et al.* (2000) in the northern Belum region, the other eight herpetofauna-related studies that were conducted in the area were focused on the Temengor region and Pulau Banding (Kiew *et al.*, 1995, Diong *et al.*, 1995, Lim *et al.*, 1995a, Lim *et al.*, 1995b, Sukumaran, 2002, Grismer *et al.*, 2004, Hurzaid *et al.*, 2013a, Jaafar *et al.*, 2014). This study also represents the first long term and in depth study performed with drift-fenced pitfall traps on the biodiversity, microhabitat and macroclimate association of herpetofauna in the Belum-Temengor Forest Complex.

1.2 Objectives

With the ultimate objective of conserving herpetofauna species which are the key biological indicator to the environmental health, this study aims to achieve the following objectives:

1. To investigate biodiversity of herpetofauna and at the same time survey for new record that has yet to be documented in Royal Belum State Park.
2. To evaluate the association of herpetofauna with microhabitat variables.

3. To evaluate the association of herpetofauna with macroclimate variables.

1.3 Expected results

With only a handful of studies conducted on a huge land mass covered by Belum-Temenggor Forest Complex and its numerous isolated islands, it was expected that some new herpetofauna records could be documented at the end of the survey, which would be wonderful additions to the current inventory list. This documentation allows us to know the species of herpetofauna in the area which will greatly ease the conservation effort.

Moreover, the habitat and climatic preferences of herpetofauna species in Royal Belum State Park were expected to be identified through the microhabitat and macroclimate studies as they play a very crucial role in the physiology, ecology and behaviour of herpetofauna. With a better understanding of their habitat choices, habitat and forest management plans can be adapted according to the habitat or area of interest with the associated herpetofauna species. The macroclimate study, on the other hand, allows the prediction of herpetofauna responses towards climate change, giving us more informed judgement on which species are particularly vulnerable to the consequences of climate change.

2.0 Literature review

2.1 Ecology of Amphibians

Amphibians are ectothermic, tetrapod animals that live in both water and land; displaying features intermediate of aquatic fishes and terrestrial amniotes (Duellman and Trueb, 1994). Although amphibians share similarities with other groups of tetrapods, they have very distinct features that make them distinguishable. Amphibians have moist and scaleless skin which is permeable to water, oxygen and ions (Pough, 2007). Their skins contain various glands such as the mucous glands that aid in keeping the skin moist, and the poison glands that help protect them against predators (Wells, 2010).

The extant amphibian consists of three lineages with over 4700 documented living species. They are the Anura (frogs and toads), Gymnophiona (caecilians), and Caudata (salamanders) (Pough, 2007). Of the three lineages, the order Anura is the largest, with more than 4000 species worldwide. This is followed by the order Caudata, with 390 species of salamanders which makes up not more than 10% of total amphibian species. The smallest order of the extant amphibians would be Gymnophiona with a total of 162 species which is occupied by limbless worm-like amphibians (Seburn and Seburn, 2000).

All adult amphibians are carnivorous. At the larval stage, however, many of the amphibians are herbivorous (Gentz, 2007). In order to reach adulthood, most amphibians are required to undergo metamorphosis comprising of several significant physical and biochemical changes (Barnes-Svarney and Svarney, 1999). In nature, most amphibian species are secretive and nocturnal, spending most of the day time in their shelter and surfacing only at night to forage for food (Pough, 2007). Some species of amphibians also tend to congregate around freshwater environments during breeding season for communal mating (Hatch *et al.*, 2001).

2.2 Ecology of reptiles

Reptiles are ectothermic, tetrapod animals that live either temporarily or permanently on both land and water. Unlike amphibians, the skin of all reptiles is dry and protected with keratinous plates called "scutes" of various sizes. These plates shed regularly through a process known as ecdysis (Sirois, 2015). With this thick and usually glandless skin, reptiles are able to protect themselves from injuries and loss of body moisture (Debenedictis, 2014).

Currently, living species of reptiles can be grouped into four orders. They are the Chelonia which includes turtles of over 250 species in the world; the order Squamata that comprises of more than 6300 species of lizards and snakes worldwide; the order Crocodylia contains crocodiles and alligators with an estimate of only 20 species, and the order Rhynchocephalia with only 2 surviving species of lizard-like tuataras (Seburn and Seburn, 2000).

Unlike amphibians, reptiles lay amniotic eggs in terrestrial environment and the sex of the hatchlings is dependent on the incubation temperature of the egg during the middle third of incubation (Linzey, 2012). The reptile hatchlings do not have a larval stage and do not undergo metamorphosis to reach its adult stage. Instead, the hatchlings look like the miniature version of the adult and shed their skin as they grow (Conant *et al.*, 1999).

2.3 Importance of amphibians and reptiles

Amphibians and reptiles share similarity in some of their features. Both are ectothermic, live in habitats near to water sources and are vulnerable to habitat destruction and fragmentation, invasive species, epidemic disease, climate change, pollution, over-exploitation, and other anthropogenic activities (Valencia-Aguilar *et al.*, 2013). With the ectothermic property of herpetofauna and biphasic life cycle of amphibians, they are very sensitive to even the slightest change as well as contaminants in both aquatic and terrestrial environments, making them useful biological indicators for the evaluation of environmental health (Simon *et al.*, 2011).

Besides that, herpetofauna play a crucial role in the ecosystem where they inhabit, playing both predator and prey in the food webs. Many herpetofauna are predators that keep the number of their prey in check and are important biological pest control (Mittermeier *et al.*, 1992, Cortes-Gomez *et al.*, 2015). At the same time, herpetofauna can be found on the lower level of food chain, serving as prey to many other species like birds and mammals (Dincauze, 2000). This predator and prey role of herpetofauna in the ecosystems is vital in keeping the trophic structure in equilibrium.

2.4 Amphibians and Reptiles in Belum-Temengor Forest Complex

Malaysia has been acknowledged as one of the world's twelve mega-diverse countries with 70% of the country consisting of tropical rain forest, housing about 20% of the world's animal species. As stated by the Malaysian Ministry of Natural Resources and Environment (NRE), Malaysia has been estimated to have a stunning number of 229 species of mammals, 242 species of amphibians, 567species of reptiles, 742 species of birds, more than 290 species of freshwater fish and over 500 species of marine organisms (Abdullah *et al.*, 2011).

Out of the many species found in the forest, 24 species of frogs and toads which makes up to 26% of total amphibians in Peninsular Malaysia were identified in Belum (Kiew *et al.*, 1995). In the northern part of Belum Forest Reserve, 26 species of amphibians and reptiles encompassing 10 species of lizards and geckos, 9 species of frogs, 4 species of snake, 1 species of varanid, 1 species of skink, and 1 species of turtle were documented (Norsham *et al.*, 2000). In 2004, 32 species of amphibians which makes up five families and 23 species of reptiles consisting of seven families were collected in the Temengor region (Grismer *et al.*, 2004). This includes the 25 newly discovered species of frogs, caecilian, lizards and snakes (Hurzaid *et al.*, 2013b). According to Table 2.1, a total of 7 families of amphibians and 12 families of reptiles were cumulatively discovered by survey done from 1995 to 2013. The master list of herpetofauna species documented in Belum-Temengor Forest Complex is tabulated in Appendix A.

2.5 Herpetofauna Sampling Techiniques

Sampling and inventorying of herpetofauna involve the use of several different techniques depending on the goal of the survey as different species have different life history. A combination of variety of survey methods is necessary to yield thorough inventories of herpetofauna throughout all niches. These techniques include pitfall traps, visual encounter survey, acoustic sampling, funnel traps, cover boards, and transects (Manley *et al.*, 2006). These techniques can be categorized into two major trapping techniques. They are the active traps, and the passive traps. Active traps are sampling traps that attract animals but require active collection of animals by collector. As opposed to active traps, passive traps are sampling traps (that actually trap animals) which can be left in the sampling site over a period of time. Although it does not involve active collection by the collector, passive traps require considerable amount of time and effort (Willson and Gibbons, 2010). The

Table 2.1 List of amphibians and reptiles known from Belum Temengor Forest Complex (Kiew *et al.*, 1995, Diong *et al.*, 1995, Lim *et al.*, 1995a, Lim *et al.*, 1995b, Norsham *et al.*, 2000, Sukumaran, 2002, Grismer *et al.*, 2004, Hurzaid *et al.*, 2013a, Jaafar *et al.*, 2014)

No.	Families	Kiew *et al.* 1995	Diong *et al.* 1995	Lim *et al.* 1995a	Lim *et al.* 1995b	Norsham *et al.* 2000	Sukumaran 2002	Grismer *et al.* 2004	Hurzaid *et al.* 2013	Jaafar *et al.*, 2014
	Amphibians					**Number of species**				
1	*Bufonidae*	2	0	0	0	3	4	4	3	1
2	*Megophryidae*	2	0	0	0	0	3	3	2	0
3	*Microhylidae*	2	0	0	0	0	2	3	1	3
4	*Dicroglossidae*	5	0	0	0	3	5	6	3	0
5	*Ranidae*	7	0	0	0	3	7	8	3	1
6	*Rhacophoridae*	3	0	0	0	0	5	7	0	1
7	*Ichthyophidae*	0	0	0	0	0	0	1	0	0
	Reptiles									
1	*Agamidae*	0	11	0	0	6	4	10	5	0
2	*Eublepharidae*	0	0	0	0	0	0	1	0	0
3	*Gekkonidae*	0	4	0	0	4	0	4	3	0
4	*Scincidae*	0	3	0	0	1	0	3	0	0
5	*Varanidae*	0	2	0	0	1	0	1	0	0
6	*Typhlopidae*	0	0	1	0	0	0	0	1	0

7	*Phythonidae*	0	0	2	0	1	0	0	0	0
8	*Colubridae*	0	0	13	0	1	1	4	4	0
9	*Elapidae*	0	0	3	0	2	0	0	0	0
10	*Viperidae*	0	0	3	0	0	1	0	1	0
11	*Emydidae*	0	0	0	5	0	0	0	0	0
12	*Trionychidae*	0	0	0	2	1	0	0	1	0

good thing about passive traps is that the samples obtained are more standardized, yielded with higher capture rates, and not dependent on the experience of researcher added with cheap cost and can be replicated easily between sampling sites (Mendes *et al.*, 2015).

2.5.1 Drift-fenced Pitfall Trapping

One of the most prevalent trapping method used in herpetofauna research is the pitfall trapping in combination with drift fences (Hutchens and Deperno, 2009). The reasons for widespread usage are that its cost effectiveness for large-scale research and is essential in the detection of rare or cryptic species (Ribeiro-Júnior *et al.*, 2008). Besides that, drift-fenced pitfall trapping is effective in estimating species richness and abundance, particularly for secretive herpetofauna and small mammals (Ribeiro-Júnior *et al.*, 2011).

According to the study carried out by Ribeiro-Júnior *et al.* (2008) in the Amazonian primary forest, the number of herpetofauna species captured and the catch rate of leaf litter species including arboreal species that descend to the leaf litter is the highest in pitfall traps among the other three trapping methods (funnel traps, glue traps, and active sampling) that were evaluated. On the other hand, the catch rate of herpetofauna in pitfall traps is most likely positively correlated with the trap size, as larger traps lower the risk of large specimens escaping which result in better containment (Cechin and Martins, 2000). According to (Rocha *et al.*, 2015), it was shown that a 60L pitfall traps captured considerably more specimens as compared to a 30L pitfall traps during the herpetofaunal survey.

2.5.2 Visual Encounter Survey (VES)

Three samplings designs are normally used for visual encounter survey in the biodiversity study of herpetofauna. They are opportunistic walking, transect, and quadrat sampling. Among all the sampling methods, visual encounter survey has the widest versatility in terms of its usefulness across all terrains and ease of execution. Besides that, visual encounter survey has several notable advantages over other sampling methods such as being less destructive towards the sampling site, almost harmless to the welfare of herpetofauna, and being effective in a wide variety of environments be it aquatic or terrestrial biomes (Manley *et al.*, 2006). Despite that, visual encounter survey relies heavily on ideal sampling conditions and considerable searching effort in order to be effective.

Visual encounter survey is usually carried out in the morning for diurnal species as most lizard species tend to be active during the day, dusk for crepuscular species, and night for nocturnal species of herpetofauna as most members of anura and gecko tend to be active at night.

2.6 Microhabitats

Microhabitat is a small, limited extent of a habitat that differs in climatic variables from the surrounding, more extensive habitats. Examples of microhabitat in the forest include rotting log, tree stumps, epiphytes, leaf litter and vegetation. Similar to habitats, microhabitats can vary in variables such as light exposure, humidity, temperature, air flow and disturbance (Keppel *et al.*, 2017). Different microhabitats have different levels and combinations of each of these factors which in turns affect the species residing in each microhabitat.

Generally, habitats with greater structural diversity or heterogeneity have greater number of microhabitats which in turn are able to support higher number of species (St Pierre and Kovalenko, 2014). The different types of microhabitats shaped by both biotic and abiotic factors are important in sustaining the biodiversity in every ecosystem.

2.6.1 Importance of Microhabitat

The effects of global climate change have become more apparent with global warming, extreme drought, floods, snowstorms and heat waves happening around the world. These changes have significant impacts on the physiology and ecology of herpetofauna and are even associated with the decline of their populations (López-Alcaide and Macip-Ríos, 2011b).

As the earth becomes warmer due to climate change, the role of microhabitats in various ecosystems becomes more important. In his study, Scheffers *et al.* (2014b) observed that the thermal buffering ability of microhabitats was consistent trans-continentally, capable of moderating the ambience temperature on a macro-scale. In this aspect, microhabitats serve as refuges to animals especially thermal sensitive species by offering them with different microclimates from those of the macrohabitats and allow them to thermoregulate effectively. This is particularly critical during extreme weather events such as heat waves as microhabitats have the remarkable potential to act as a buffer and possibly increase the survival chances of thermal sensitive species such as herpetofauna (Scheffers *et al.*, 2014a). According to Scheffers *et al.* (2014b), microhabitats are able to buffer temperature by 3.9°C and mediate maximum temperatures up to 3.5°C. For species endemic to small geographical area due to evolution over time which restricted them with specific niche, microhabitats serve as the last resort from the daily climatic variation (Bae and Park, 2017).

Besides that, natural microhabitats are able to enhance the camouflage of herpetofauna, making them indistinguishable from the background by predators (Marshall *et al.*, 2016). At the same time, microhabitats such as rock crevices and rain puddles are suitable breeding grounds for herpetofauna (Brooks and Wardrop, 2013). Aside from this, herpetofauna also tend to inhabit similar microhabitats with their prey, making microhabitats such as leaf litter a foraging ground for herpetofauna (Whitfield *et al.*, 2007).

2.6.2 Effect of Microhabitats Changes on Herpetofauna

Reptiles and amphibians require specific microhabitat to thrive in (Èeirâns, 2007). With their comparatively poor dispersal capabilities, physiological limitations and strict preferences for microhabitats, they are very sensitive to local changes in their microhabitats (Demaynadier and Hunter, 1998). Some changes, even the slightest one, to the variables in their microhabitat could be detrimental to their population. According to Scherrer and Körner (2011), a 2 K increase in temperature resulted in the loss of 3% of the coldest microhabitats, decrease in abundance of 75-80% of rather cold microhabitats and increase in abundance of the warmest microhabitats. This leads to the displacement of species either at the current range or at higher elevation as species moves to cooler microhabitats (Raxworthy *et al.*, 2008). This is due to increased competition and alteration of community structure at these elevations that ultimately lead to the decrease in biodiversity as weaker species are extirpated (Bickford *et al.*, 2010). Furthermore, increased temperature in freshwater environments reduces the amount of dissolved oxygen, significantly increasing the mortality rate of amphibians larvae as their swimming and evasion performances are compromised (Wassersug and Seibert, 1975).

Besides that, changes in environments such as wetland water level and construction of dams reduce microhabitats availability by submerging or exposing the microhabitats of herpetofauna (Markle *et al.*, 2018). Some of the microhabitats are important as they are used by herpetofauna especially amphibians for breeding, development, refuge and foraging (Hecnar, 2004). These disturbances can be detrimental to the herpetofauna population as their life cycle is disrupted (Hopkins, 2007). For instance, fluctuation of water level may reduce water temperature due to increased water movement. This increases the mortality rate of amphibian larvae as their growth rate is slowed down which lengthen the larvae stage, making them vulnerable to pathogen and predator (Wilbur, 1980). On the other hand, drying of water bodies forces amphibian larvae to develop faster but at the expense of size and mass which reduced their fitness post-metamorphosis (Burraco *et al.*, 2017). In addition, the natural microhabitats may be replaced by new microhabitats with species composition different from the previous microhabitats (Muslim, 2017). Clearing of forest for agricultural uses or development also destroyed microhabitats and the herpetofauna residing in it (Mitchell *et al.*, 2006).

2.6.3 Microhabitat of Herpetofauna

Despite reptiles and amphibians being known collectively as herpetofauna and share some similarities especially in terms of their body metabolism, they are different when it comes to the selection of habitats and microhabitats. Generally, their choices for the microhabitats are dictated by their very different life histories and adaptations (Welsh, 1990, Greenberg, 2002). Nevertheless, reptiles and amphibians tend to select favourable microhabitats for thermoregulation. As ectotherms, reptiles and amphibians favour warm microhabitats as it improves locomotors performance and thus increases the survival rate and fitness (Köhler *et al.*, 2011). In addition to that, microhabitats may have an effect on the overall wellness of reptiles and amphibians as it affects individual physiology, population dynamics and community structures (Kacoliris *et al.*, 2009).

2.6.3(a) Microhabitats of amphibians

Amphibians are susceptible to rapid desiccation due to their highly permeable skin that needs to be constantly moist, and thus tends to be closely tied to moist microhabitats as they rely on water far more than reptiles. Besides that, amphibians are inclined to select their microhabitats based on their hydration state (Mitchell and Bergmann, 2016). In addition to moisture, amphibians require warm microhabitats for thermoregulation and maintain their physiological performance (Spotila, 1972). In spite of that, amphibians are not limited to only one microhabitats but may inhabit multiple microhabitats that serve different purposes such as foraging, breeding and shelter to avoid predators (Delima *et al.,* 2006).

Amphibians typically avoid low humidity microhabitats with high temperature to prevent extensive water loss (Spotila, 1972). As most amphibian species are nocturnal in nature, the chances of them experiencing overheating and desiccation are slim but they have to exploit microhabitats such as rock crevices and burrows that have been heated during the day for active thermoregulation (Farallo and Miles, 2016). Most amphibians prefer microhabitats such as leaf litter, rock crevices, wood debris, tree holes, tree roots and tree buttress, bromeliads, stream vegetation and substrates that regulate the temperature and moisture (Farallo and Miles, 2016). According to Demaynadier and Hunter Jr (1995), populations of amphibian species show a positive correlation with the leaf litter depth and moisture, quality and quantity of coarse wood debris, density of understory vegetation, and canopy cover of the overstory.

2.6.3(b) Microhabitat of Reptiles

Reptiles have scaled water tight skin that allows them to venture into a wide range of habitats. Their scaly skin significantly reduces water loss and the chances of desiccation, even in dry environments. Although they are resistant against water loss, reptiles habitually choose microhabitats that allow them to thermoregulate, just like amphibians. In tropical countries, the selection of microhabitats by reptiles is mostly driven by the need to avoid high temperature that would result in overheating (Price-Rees *et al.*, 2013). Some reptiles such as lizards select their microhabitats based on different time periods of the day. They tend to stay near to microhabitats that allow basking such as rocky outcrops and logs during early morning and late afternoon while utilize a wider array of microhabitats during noon (Castilla and Bauwens, 1991). Examples of microhabitats used by reptiles include dead vegetation and coarse wood debris, shrubs, tree trunks, rock crevices, caves (Song *et al.*, 2017).

Vegetation structure plays an important element in microhabitats selection by reptiles as it is usually associated with mates, shelters and abundance of preys (Kacoliris *et al.*, 2009). The selection of favourable microhabitats is important for reptiles as different microhabitats have differential effects on the growth, reproduction, survival and physiological performance (Smith and Ballinger, 2001). This is because some microhabitats such as vegetation have higher food availability than others which promotes growth and reproduction (Hews, 1993, Iraeta *et al.*, 2006). Moreover, reptiles that utilize open microhabitats are more exposed and are vulnerable to predators than densely vegetated microhabitats which significantly reduced their survival rate (Vanhooydonck and Van Damme, 2003).

Besides that, microhabitat preferences of reptile also seem to be related to age, sex, diet, behaviour, competition, predator avoidance, presence of water bodies and spatial heterogeneity of microhabitats as well (Butler *et al.*, 2007, Èeirâns, 2007). Juveniles usually distance themselves voluntarily or involuntarily from the adults to avoid competition by using different microhabitats (Delaney and Warner, 2017).

This occurrence could also be due to the different foraging and predator avoidance behaviours of juveniles which are observed in females and males as well (Reaney and Whiting, 2003). Furthermore, reptiles may favour or avoid certain microhabitats based on their previous experience with predators or competitors (Vanhooydonck *et al.*, 2000).

2.7 Macroclimate

Macroclimate refers to the general climates of a large geographical area that varies in temperature, humidity, rainfall and other meteorological measurements which are relatively more constant than the highly variable microclimates which are in part dependent on the macroclimates (Jamaludin *et al.*, 2015). These macroclimates variables are interdependent and have important synergistic impacts on the ecology, distribution, physiology and behaviour of herpetofauna (Perrow, 2017).

2.7.1 Temperature

Herpetofauna are extremely sensitive to temperature alterations due to their ectothermic properties. In fact, temperature is one of the most important factor that affects the distribution of herptofauna as it plays a significant role in the physiological processes of herpetofauna by controlling the oxygen intake rate, heart rate, locomotors performance, hydration state, food digestion, growth rate, sex determination, and immune response (Bartlett, 2011, Dervo *et al.*, 2016). High temperatures affect the distribution of herpetofauna by forcing them to retreat to cooler parts of the forest such as higher elevation to avoid dessication or overheating (Disi, 2011). According to Bickford *et al.* (2010), temperature also affects amphibians in terms of water regulation, emergence, breeding, development, metamorphosis and sex reversal.

Increased temperatures speed up the development rate of herpetofauna embryo and larvae (Shine, 2005). This accelerated embryogenesis can have adverse effects on the phenotypes of the hatchlings as it greatly affects the size, scalation and locomotors performance (Lourdais *et al.*, 2004). Additionally, the sex of many taxa of reptiles and sex reversal in amphibians are determined by temperature (King, 1910, Eggert, 2004, Shine, 2005). Rising temperatures tend to produce more or all female offspring in some of the taxa of reptiles such as most species of turtle and crocodilian but more or all male offspring in taxa of reptiles such as sphenodontia (Mitchell and Janzen, 2010, Fisher *et al.*, 2014). On the other hand, high temperatures may induce sex reversal of females in amphibians which was observed by Witschi (1929) in his experiment on the tadpole of *Rana sylvatica*. Thus, an increase or decrease in temperature may alter the population sex ratio of herpetofauna which will ultimately result in single sex populations (Robert, 2004).

Besides that, increase in temperature also increases the metabolic rate of herpetofauna which is associated with increased demand for food (Seebacher and Grigaltchik, 2014). This is especially problematic for herpetofauna that live in resource limited environment as their increase in demand for food can increase competition (O'regan *et al.*, 2014). In addition to increased food demand, changing in temperature also compromised the enzymatic activity and thus the physiological function of herpetofauna as they have a very narrow range of optimal temperature (Saint Girons, 1980). Moreover, the immune responses of herpetofauna are very sensitive to alteration of temperature. These immune responses usually work at optimal temperature that is species specific (Lillywhite *et al.*, 2016). Consequently, changes especially increase in temperatures render herpetofauna susceptible to diseases.

2.7.2 Precipitation

Precipitation affects reptiles and amphibians differently due to the difference in the skin permeability, reproductive adaptations of the two taxa with amphibians confined to moist climate and reptiles are more adapted to a drier climate. Precipitation may affect herpetofauna in terms of breeding, dispersal, metamorphosis, and migration shift (Amburgey *et al.*, 2012, Duan *et al.*, 2016).

The pattern and timing of precipitation serve as a breeding cue for most species of reptiles and amphibians especially those that reproduce seasonally, with their breeding time coinciding with the wet season of the year (Cynthia *et al.*, 2005, Brown and Shine, 2006, Othman *et al.*, 2011). In amphibians, precipitation initiates the calling of males and induces spawning in females whereas in reptiles, precipitation induces the reproduction of females as well as the hatching process of some turtles, crocodiles and monitor lizards (Patterson, 1991, Browne and Zippel, 2007, Doody, 2011). With decreased precipitation which resulted in reduced water availability, eggs and larvae of amphibians will also be more vulnerable to desiccation and face increased mortality as they are concentrated in limited water bodies, leading to increased competition and predation (López-Alcaide and Macip-Ríos, 2011b). Reptiles eggs, although are shelled, are no better as they are incubated in soil with decrease moisture which reduces hatching success and hatchling survival (Marco *et al.*, 2004). On the other hand, heavy precipitation increases the chances of amphibians eggs, larvae and metamorphosing individuals being washed away by the flooding water and fungal infection of reptile eggs (Divers and Mader, 2005, Lowe, 2012). These precipitation changes may reduce population size and potentially cause the extinction of vulnerable amphibian species.

Temporary aquatic habitats such as ephemeral wetlands are strongly dependent on the precipitation. Decrease in precipitation dries out aquatic habitats and inhibit the spawning of many herpetofauna especially amphibians, thus potentially influencing their distribution and migration (Mcmenamin *et al.*, 2008). This is especially true for species that live in water scarce environments in which precipitation serves as the major climatic factor that affect the species distribution (Araújo *et al.*, 2006). According to Palis (1997), the movement and migration of some amphibians are positively correlated with precipitation. It is also stated by Cunningham *et al.* (2016) in his study that amphibian distribution, at large, is determined by precipitation but to a lesser extent for reptiles as their distribution is mostly driven by temperature. Conversely, Araújo *et al.* (2006) stated that the colonization of reptiles in a particular area seemed to be mostly driven by the alteration in precipitation. Moreover, changes in precipitation also alter the annual hydrological cycle which modifies the developmental timing and emergence of many herpetofauna species, thereby affecting the species composition and diversity (Amburgey *et al.*, 2012).

2.7.3 Relative Humidity

Relative humidity in a geographical area is usually associated with temperature and precipitation, changing according to the changes in the two macroclimatic variables. Reptiles and amphibians are sensitive towards the relative humidity in the atmosphere with the latter requiring high humidity due to their proneness to desiccation (Jadhav and Patil, 2017).

Humidity-related variables are the significant environmental elements that influence the richness and diversity of amphibians (Vasconcelos *et al.*, 2014). In fact, regions with high humidity levels are more likely to support more varieties of reproductive modes of amphibians and have greater levels of phylogenetic diversity than the drier regions (Silva *et al.*, 2012). According to Haddad and Prado (2005), humidity or predicted rainfall tend to be relied on by amphibian species with reproductive modes that are less dependent on the permanent aquatic habitats, thereby restricting the occurrence of amphibian species especially for those with specialized reproductive modes. In addition, the eggs of direct developing species such as many plethodontid salamanders and some of the rhacophorid frogs require high humidity as they are permeable and thus prone to desiccation (Harvey Pough, 2007).

In some species of reptiles, the hormone levels and the rate of water evaporating from skin are influenced by the humidity level (Summers and Norman, 1988, Brown, 2013). Besides that, humidity level is important during ecdysis, a process of shedding the old skin which is experienced by most reptiles. A low humidity level can cause dysecdysis in reptiles which is detrimental to the overall health (Carlson *et al.*, 2014).