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HABITAT PREFERENCES OF THE BORNEAN HORNED FROG, *Megophrys nasuta* (SCHLEGEL, 1858) (ANURA: MEGOPHRYIDAE) IN SARAWAK

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Abstract: Habitat clearance changes the ecological conditions in adjacent remnants and reduces the range of frog dispersal. Movement between remnants is possible for widely distributed *Megophrys nasuta,* thus this species could be a habitat generalist and able to disperse throughout fragmented areas. This study aims to determine habitat utilization of Sarawak *M. nasuta* as well as investigating correlation between species' habitat preferences with ambient temperature and humidity. A total of 15 vegetation types, 20 horizontal positions, 16 vertical positions and 9 substrates were sampled from 2015-2017 throughout Sarawak. Chi-square and NMDS analyses showed that this species a habitat generalist yet specialized in its horizontal and vertical positions. The results supported the hypothesis of its wide dispersal throughout fragmented areas and implied that horizontal position plays an important role at determining their breeding site in an area. *Megophrys nasuta* showed a positive correlation to ambient temperature and vegetation type, indicating species' high tolerances with temperature at various forest types. The findings suggested that *M. nasuta* is a habitat generalist and a microhabitat specialist, reflecting its response towards habitat fragmentation. Thus, this study allows early identification of the species vulnerability towards extinction and targeting for species sustainability in near future..

Keywords: *Megophrys nasuta,* fragmented habitat, habitat generalist, microhabitat specialist, temperature.

Introduction

Habitat destruction has become a major threat to species extinction and population decline in the rainforest areas throughout the world (Goldingay *et al*., 1999). Rapid development, high demand for timber products and an increase in agricultural yields are among anthropogenic activities that contribute to massive deforestation, which lead to habitat fragmentation for flora and fauna. Habitat fragmentation may cause changes in the ecological conditions among the adjacent remnants. This is crucial to physically less defensive organisms such as amphibian species, where most species are highly dependent on their environment to provide shelter, food, breeding sites and moisture for the skin. Fragmented areas also reduce the range of species dispersal resulting in inbreeding among subpopulations of connected remnants (Cushman, 2006). Movement between remnants is quite likely to some frog species, for example, the Bornean Horned frog species, *Megophrys nasuta* (Schlegel, 1858). This species possesses extensive dispersal range as reflected by its wide distribution throughout Sundaland (Inger & Stuebing, 2017). This may be possible due to its strategy to survive and sustain. *Megophrys nasuta* is a leaf litter frog of family Megophryidae that possesses extended skin appendages projected from the eyelids which mimic the leaf litters on the ground. This characteristic acts as a great tool to camouflage on forest floor against predators and prevent extensive desiccation when hiding under leaf litters during the daytime. Hence, microhabitat selection by frog species is vital to suit the adaptation strategy in the frogs' natural habitat (Bosch & Riva, 2004). Some reported that microhabitat variables may affect the thermoregulatory rate of most amphibians and reptile species thus influence their physiological behaviour (Castilla & Bauwens, 1991; Converse & Savidge, 2003). Based on the statements above, two questions were addressed; 1) Is M. *nasuta* a habitat generalist? 2) Do ambient variables influence its habitat preferences? Field observations showed that this species can be found at various habitats and microhabitats, thus we hypothesized that this species could be a habitat generalist and able to disperse throughout fragmented areas in Sarawak. In addition, the ambient temperature may affect habitat selection prior to their ecological needs. Hence the study aims to determine habitat utilization of *M. nasuta* in Sarawak and to further investigate the correlation between habitat preferences with ambient temperature and humidity.

Materials and Methods

Study Areas

Several study sites were surveyed namely Tanjung Datu National Park (N 02°02.484' E 109°39.088'), Gading National Park at Lundu (N 01°41.501' E 109°50.754'), Kubah National Park and Matang Wildlife Centre at Matang ranges (N 01°36.393' E 110°11.322'), Mount Penrissen at the Borneo Highlands (N 01°08.023' E 110°13.445'), Ranchan Recreational Park in Serian, upper regions of Sarawak in Miri (Wilmar Plantation, N 03°29.191' E 113°49.973') and Mulu National Park in Baram (N 04°03.072' E 114°51.433'). A few non-forest areas were also surveyed in this study. The sites included peat swamp areas such as Samajaya which is located at a nearby industrial area in Kuching, the compound of Universiti Malaysia Sarawak at Kota Samarahan and Pulau Satang at Telaga Ai, Kuching. The period of sampling per visit was 7days.

Frog Survey

Frogs were encountered via Visual Encounter Survey (VES) method and detected based on their vocalization. Similar sampling method was employed at each locality which started at 1800hrswhen the frogs were most active until 2300hrs. Three sampling nights were conducted at each site by wading along the stream and forest transect along the trail.

Microhabitat and Ambient Variable Documentation

Microhabitat sampling conducted in this study was one that was used by Zainudin *et al.* (2017). The habitat and microhabitat characteristics of the caught individual were recorded in a note book. A total of 15 vegetation types, 20 horizontal positions (distance from water bodies), 16 vertical positions (distance above the ground such as log) and 9 substrates were further investigated during the sampling period. A data logger probe U23-001 HOBO Pro v2 was placed on the ground at base camp during field samplings. The probe was programmed to record ambient temperature and humidity every 30 minutes during the sampling period. The environmental data were transferred via HOBOware Pro software into an excel file.

Data Analysis

Chi-square was employed to measure compositional dissimilarity in microhabitat characteristics at different localities using IBM SPSS version 21.0 (IBM Corp, 2012). The microhabitat characteristics were further analysed using Non-metric Multidimensional Scaling (NMDS) computed in IBM SPSS version 21.0 (IBM Corp, 2012) to categorize the species guild (Kruskal, 1964). PC-ORD was used to assess the relationship between the highest loading in NMDS with ambient temperature and humidity variables.

Results

Descriptive Analysis of Habitat and Microhabitat Utilization among Localities

Megophrys nasuta inhabited various types of habitats (Table 1) including hilly primary forest, (VA χ^2 =8, df=2, p=0.03), riverine forest (VRF χ^2 =8, df=2, p=0.03), agriculture (Vagr χ^2 =5.444, df=1, p=0.04), edge mixed dipterocarp forest (VE χ^2 =8, df=2, p=0.03), secondary growth, immature or regenerating forest (VG χ^2 =3, df=3, p=0.48) and rubber or oil palm plantation (VR χ^2 =8, df=2, p=0.03). The finding suggested that this species is a habitat generalist as it can adapt to different types of habitat. Additionally, species abundance differs among habitat types, indicating preferences of *M. nasuta*to a specific habitat at each locality. However, Padawan (χ^2 =2, df=3, p=0.74) and Serian (χ^2 =0.667, df=1, p=0.69) populations did not imply any habitat specificity (table 1). It could be found at various types of habitat at these two localities. Hilly mountainous area in Penrissen with small to medium-sized permanent streams, provide suitable microhabitats for the species. In contrast *M. nasuta* populations in Serian were found at conversion lands of the recreational park (Ranchan Recreational Park) and oil palm plantation (Bunan Gega), respectively. Hence, *M. nasuta* can inhabit at both disturbed areas in Padawan and Serian, thus, implying that the species is a habitat generalist.

The usage of microhabitat type in horizontal positions showed significant difference except on the bank of a permanent stream (HPC χ^2 =2.333, df=5, p=0.91) (Table 2). This horizontal position of HPC is the most commonly used by *M. nasuta* and comprises 51% total individuals observed in this study. The result indicates that *M. nasuta* occupy various horizontal positions but very common at the bank of a permanent stream. The species was found perched along the stream bank especially during the breeding season.

However, the abundance of this species at horizontal positions was significantly different at Gading, Serian, Bau and Engkelili. The frogs at these localities seemed to be confined to specific or limited horizontal positions. For example, in Gading and Serian, it preferred to sit at the bank of the permanent stream, while in Bau and Engkelili, it prefers the bank of the intermittent stream and away from the water body. However, the result showed no significant

Table 1: Vegetation types occupied by *Megophrys nasuta* in Sarawak

LOCALITY	VA	VRF	Vagr	VE	VG	VR	χ^2	χ^2 p-value	df	Total individuals
Gading	0	2	0	0	4	0	3	0.38*	2	6
Matang range	0	0	0	0	9	0	2.667	0.22*	1	9
Padawan	2	0	1	3	0	0	2	0.74 NS	3	6
Wilmar	0	0	0	0	0	6	2.667	0.22*	1	6
Tanjung Datu	21	0	0	13	0	0	3	0.38*	2	34
Mulu	0	26	0	0	1	0	3	0.38*	2	27
Serian	0	0	0	0	1	1	0.667	0.69 NS	1	2
Bau	0	0	0	0	1	0	2.667	0.22*	1	1
Engkelili	0	0	0	0	1	0	2.667	0.22*	1	1
χ^2	8	8	5.444	8	3	8				
χ^2 p-value	0.03**	0.03**	0.04**	0.03**	0.48*	0.03**				
Df	2	2	1	2	3	2				
Total individuals	23	28	1	16	17	7				92

*exact significant at p < 0.5; **exact significant at p < 0.05; NS not significant; VA: primary rain forest, hilly; VRF: riverine forest; Vagr: agriculture; VE: edge Mixed Dipterocarp Forest; VG: secondary growth, immature or regenerating forest; VR: rubber or oil palm plantation.

difference of species abundance at five other localities including the Matang range, Padawan, Wilmar Plantation, Tanjung Datu and Mulu, thus indicating that the species at these localities might have occupied various horizontal positions.

For vertical position, *M. nasuta* preferred to sit on leaf litter and on the log as reflected by no significant difference on the usage of the vertical position of leaf litter (VPG χ^2 =1.556, df=4, p=0.94) and on the log (VPJ χ^2 =0.111, df=1, p=1.00) among study localities (table 3). This is congruent with the species' ability to mimic leaf litter via its extended eyelid for foraging or predator avoidance strategy. Species abundance at vertical positions is significantly different at several localities namely Padawan, Wilmar Plantation, Serian, Bau and Engkelili that were affected by anthropogenic activities. *Megophrys nasuta* would need to select specific and the best vertical position for breeding and foraging purposes at these localities. Contrary, populations in protected areas (the Matang ranges, Tanjung Datu and Mulu with less anthropogenic activities) showed that this species can occupy various types of vertical positions with minimum threats. The results demonstrated that *M. nasuta,* regardless of where the location it was found, would always occupy the forest floor.

Seven substrates utilized by *M. nasuta* in Sarawak showed significant difference except on leaf and under the log (Table 4). The abundance of this species in the substrate used was not significantly different at three localities namely, the Matang range, Tanjung Datu and Mulu. They utilised various types of substrates available at these localities compared to the other six disturbed areas as seen in Figure 1. Geographical topology and level of disturbances at each locality in this study influenced the habitat and microhabitat selection of *M. nasuta* in Sarawak. Thus, an assessment is needed to determine the most favourable characteristics of habitat and microhabitat utilized by the species in their natural habitat.

Table 2: Horizontal positions occupied by *Megophrys nasuta* in Sarawak

LOCALITY	HPA	HPB	HP	HPE	HPF	HPG	χ^2	χ^2 p-value	df	Total individual
Gading	0	2	4	0	0	0	3	0.38*	2	6
Matang range	0	3	4	0	0	2	2	0.74NS	3	9
Padawan	0	0	1	0	3	2	2	0.74NS	3	6
Wilmar	0	1	4	1	0	0	1	0.88NS	2	6
Tanjung Datu	1	18	15	0	0	0	2	0.74NS	3	34
Mulu	0	4	17	0	0	6	2	0.74NS	3	27
Serian	0	0	2	0	0	0	2.667	0.22*	1	2
Bau	0	0	0	0	1	0	2.667	0.22*	1	1
Engkelili	0	0	0	0	0	1	2.667	0.22*	1	1
χ^2	5.444	5	2.333	5.444	8	4.778				
χ^2 p-value	0.04**	0.48*	0.91NS	0.04**	0.03**	0.23**				
df	1	5	5	1	2	3				
Total individuals	1	28	47	1	4	11				92

*exact significant at p < 0.5; **exact significant at p < 0.05; NS not significant; HPA: permanent stream, in stream; HPB: permanent stream, midstream on bar, rock or snag; HPC: permanent stream, on bank (distance to water); HPE: intermittent stream, midstream on bar, rock or snag; HPF: intermittent stream, on bank; HPG: distant from any water body

Table 3: Vertical positions occupied by *Megophrys nasuta*.

LOCALITY	VPB	VPC	VPF	VPG	VPH	VPJ	VPM	χ^2	χ^2 p-value	df	Total individual
Gading	0	0	0	0	5	1	0	4.571	0.14*	2	6
Matang range	0	0	5	2	1	1	0	1.571	0.85NS	3	9
Padawan	0	0	0	5	0	0	1	4.571	0.14*	2	6
Wilmar	0	0	4	2	0	0	0	4.571	0.14*	2	6
Tanjung Datu	0	4	5	5	17	1	2	0.714	1.00NS	5	34
Mulu	1	0	11	10	4	1	0	0.857	1.00NS	4	27
Serian	0	0	0	2	0	0	0	3.571	0.13*	1	2
Bau	0	0	0	1	0	0	0	3.571	0.13*	1	1
Engkelili	0	0	0	1	0	0	0	3.571	0.13*	1	1
χ^2	5.444	5.444	4.778	1.556	7.111	0.111	8				
χ^2 p-value	0.04**	0.04**	0.23*	0.94NS	0.15*	1.00NS	0.03**				
Df	1	1	3	4	4	1	2				
Total individuals	1	4	25	28	27	4	3				92

*exact significant at $p < 0.5$; **exact significant at $p < 0.05$; NS not significant; VPB: in or under dead leaves; VPC: under the rock; VPF: on the surface of bare soil; VPG: on the surface of leaf litter; VPH: on the rock; VPJ: on the log; VPM: on the tree or large vine (plant>7m height) above ground

Table 4: Substrates occupied by *Megophrys nasuta*

LOCALITY	SA	SC	SD	SF	SG	SH	SJ	χ^2	χ^2 p-value	df	Total individual
Gading	0	0	0	1	0	0	5	4.571	0.10*	2	6
Matang range	2	0	0	1	5	0	1	1.571	0.67 NS	3	9
Padawan	5	0	1	0	0	0	0	4.571	0.10*	2	6
Wilmar	2	0	0	0	4	0	0	4.571	0.10*	2	6
Tanjung Datu	6	2	0	1	5	3	17	0	1.00 NS	6	34
Mulu	11	0	0	1	11	0	4	1.571	0.67 NS	3	27
Serian	2	0	0	0	0	0	0	3.571	0.06*	1	2
Bau	1	0	0	0	0	0	0	3.571	0.06*	1	1
Engkelili	1	0	0	0	0	0	0	3.571	0.06*	1	1
χ^2	2.333	5.444	5.444	0.111	4.778	5.444	7.111				
χ^2 p-value	0.91NS	0.04**	0.04**	1.00NS	0.23*	0.04**	0.15*				
Df	5	1	1	1	3	1	4				
Total individuals	30	2	1	4	25	3	27				92

*exact significant at $p < 0.5$; **exact significant at $p < 0.05$; NS not significant; SA: leaf of plant;
SC: twig or branch of the woody plant; SD: the trunk of shrub or tree; SF: under the bark of log, stump or tree;
SG: bank mud or soil; SH: bank sand or gravel; SJ: bank rock

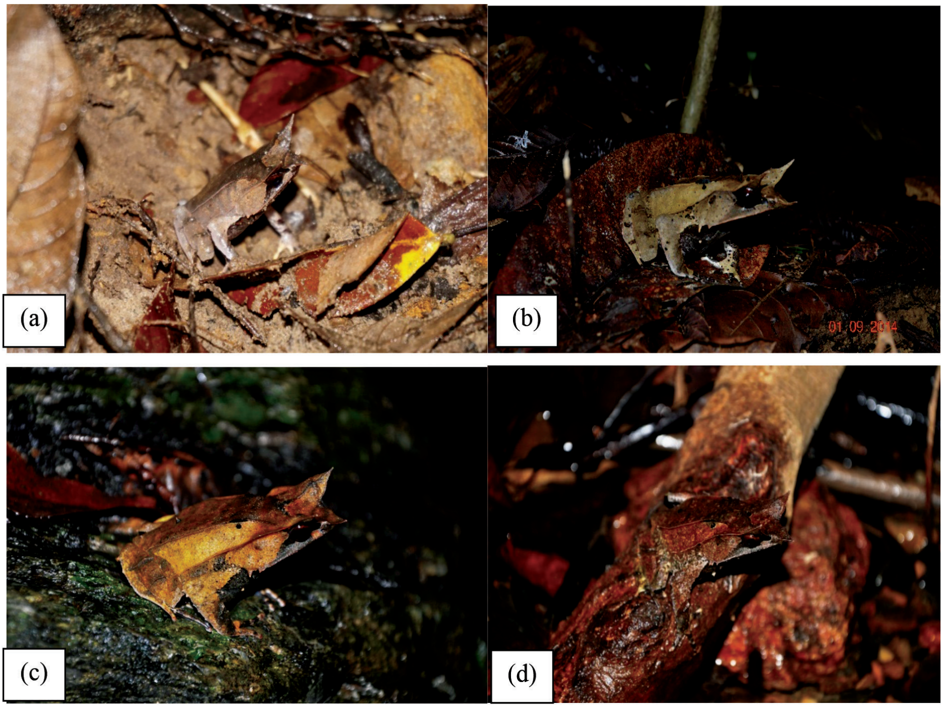

Figure 1: *Megophrys nasuta* on its most favorable nocturnal substrate observed during field sampling. The microhabitat substrates include (a) on the surface of bare soil (b) on the surface of leaf litter (c) on emerging rock covered with moss (d) on the log

Microhabitat Characteristics Utilized by the Bornean Horned Frog in Sarawak

The NMDS configuration using proximities scaling was derived in two dimensions with low stresses, (Stress-1=0.242, Stress-2=0.513, S-stress=0.167) and high coefficient (Tucker's coefficient of congruence = 0.97037), indicating a good representation of actual habitat and microhabitat dissimilarities of the *M. nasuta* in Sarawak.

Out of sixty habitat and microhabitat variables, twenty-six variables were meaningful (Table 5, Figures 2a, b) in describing habitat and microhabitat utilizations of the species. Among the meaningful variables, four variables were apparent along dimension 1 (Table 5, Figure2a) with high positive loadings of riverine forest (VRF), bank of permanent stream (HPC), on surface of leaf litter (VPG) and leaf of plant (SA) and four high negative loading of hilly primary rain forest (VA), midstream of permanent stream on bar, rock or snag (HPB), on rock (VPH) and bank of rock (SJ). Five variables were apparent along dimension 2 (Table 5, Figure 2b) with high positive loadings on bank of permanent stream (HPC), on the surface of bare soil (VPF) and bank of mud or soil (SG) and high negative loadings of edge mixed dipterocarp forest (VE) and distant from any body of water (HPG). The dominant characteristics along dimension 1 are on the surface of leaf litter or dead leaves (VPG) and with high positive loading value at0.939 (Table 5) while in dimension 2, highest positive loading is bank of the permanent stream (HPC=1.029, Table 5). The results suggested that *M. nasuta* preferred to sit on the surface of leaf litter to camouflage on the forest floor and would be abundant at the bank of the permanent stream for breeding. Thus, their presence at stream banks during the breeding season indicated that the permanent stream plays an important role as a breeding site.

The results also showed that the two dimensions of final coordinates have different domination in microhabitat usage among individuals of *M. nasuta* from Sarawak populations, whereby it indicates that this species requires riverine forest habitat with the permanent stream for breeding and utilizes leaf litter as the best substrate that fits its external morphological characteristics for survival. Most individuals also preferred to sit vertically on the surface of bare soil (0.853) which mimics its dorsal skin coloration but avoided vegetation type of edge mixed dipterocarp forest (VE= -0.694), horizontally distant from water body (HPG= -0.677), vertical on rock (VPH= -0.900) and substrate of bank rock (SJ= -0.829).

Ecological groups among individuals of *M. nasuta* defined by non-multidimensional scaling (NMDS) of the habitat and microhabitat utilizations for the entire assemblages of Sarawak populations are shown in Figure 3. The configuration of both dimensions showed that three clusters were apparent: (i) individuals from Tanjung Datu, Mulu, Wilmar Plantation and the Matang range, (ii) individuals from Tanjung Datu, Mulu and Gading, (iii) individuals from Tanjung

Table 5: Final coordinates for common space of two dimensions for each habitat and microhabitat variables of *Megophrys nasuta*

No	Habitat/Microhabitat variables	Code	FCD 1	FCD 2
1	Primary rain forest, hilly	VA	**-0.852**	-0.012
2	Riverine forest	VRF	**0.838**	0.445
3	Agriculture	Vagr	0.138	-0.113
4	Edge mixed dipterocarp forest	VE	0.322	**-0.694**
5	Secondary growth, immature or regenerating forest	VG	-0.415	-0.669
6	Rubber or oil palm planting	VR	0.346	0.180
7	Permanent stream: in stream	HPA	-0.022	-0.125
8	Permanent stream: midstream on the bar, rock or snag	HPB	**-0.902**	-0.370
9	Permanent stream: on the bank (distance to water)	HPC	**0.676**	**1.029**
10	Intermittent stream: midstream on the bar, rock or snag	HPE	0.021	-0.030
11	Intermittent stream: on bank	HPF	0.184	-0.316
12	Distant from any body of water	HPG	0.017	**-0.677**
13	In or under dead leaves	VPB	0.109	-0.050
14	Under rock	VPC	-0.179	0.088
15	On the surface of bare soil	VPF	-0.144	**0.853**
16	On the surface of leaf litter or dead leaves	VPG	**0.939**	-0.303
17	On rock	VPH	**-0.900**	0.320
18	On log	VPJ	0.064	0.174
19	On the tree or large vine (plant>7m height) above ground	VPM	-0.183	-0.177
20	Leaf of plant	SA	**0.911**	-0.479
21	Twig or branch of woody plant	SC	-0.153	-0.091
22	The trunk of shrub or tree	SD	0.035	-0.177
23	Under bark of log, stump or tree	SF	0.064	0.174
24	Bank mud or soil	SG	-0.004	**0.863**
25	Bank sand or gravel	SH	-0.079	-0.296
26	Bank rock	SJ	**-0.829**	0.453

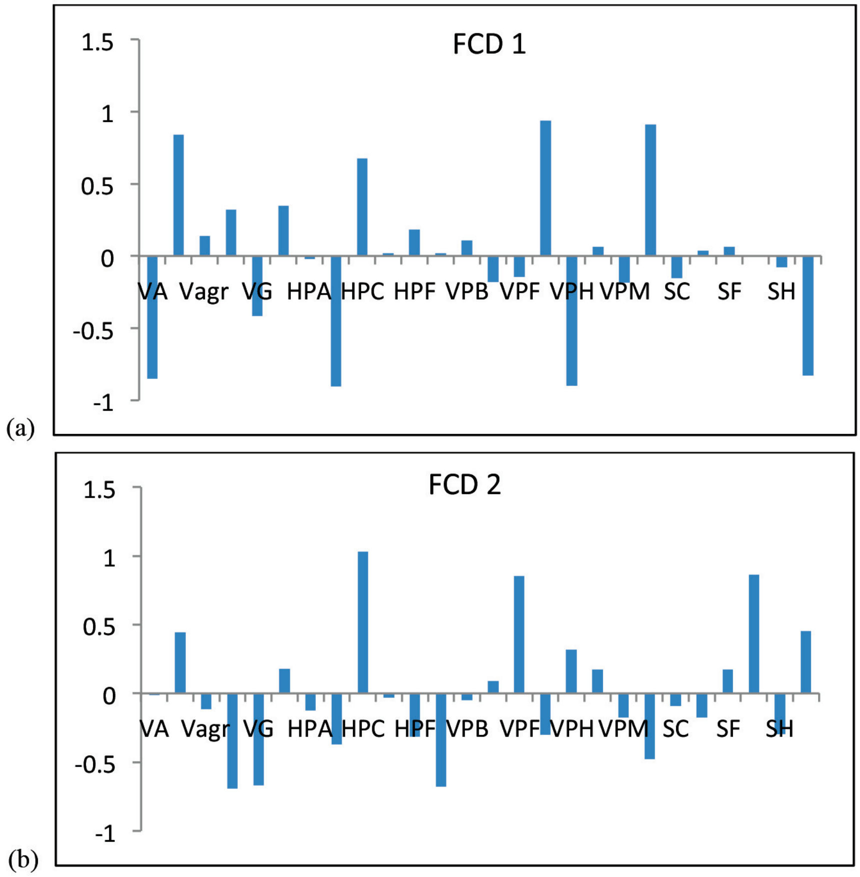

Figure 2: Final Coordinate Dimension (FCD) 1 (a) and 2 (b) of NMDS (PROXSCAL) of microhabitat characteristics of *Megophrys nasuta*

Datu, Mulu, Wilmar, Padawan, Engkelili, Serian and Bau. The clusterings were based on the overall microhabitat usages (as shown on the significant descriptive findings). However, these clusters do not differentiate population localities as no geographical separation of individuals was found in this configuration. These ecological groups were based on their preferences on microhabitat usages in whichever localities sampled. The result suggests that microhabitat variables could not distinguish the populations of Sarawak *M. nasuta* based on localities but rather on habitat and microhabitat usages. The finding is consistent with Marnell (1998) that stated discriminant analysis successfully identified which habitats were important in discriminating the sites utilized by frog species.

Correlation of Habitat and Microhabitat Preference with Ambient Variables

Ambient variables and vegetation types were strongly correlated (Table 6) and plotted as vectors with the length representing the magnitude of the correlation (Figure 4). The result showed that ambient temperature is highly positively correlated with vegetation type of edge mixed dipterocarpforest (VE) in axis 1. This indicated that the occurrence of *M. nasuta* at edge mixed dipterocarp forest was influenced by temperature (26-29°C) and dominated by *M. nasuta* from Tanjung Datu at a lower elevation (Figure 4). This high tolerance towards a wide range of temperature might be due to the edge effects. The finding is comparable with that in Wilmar Plantation which also recorded

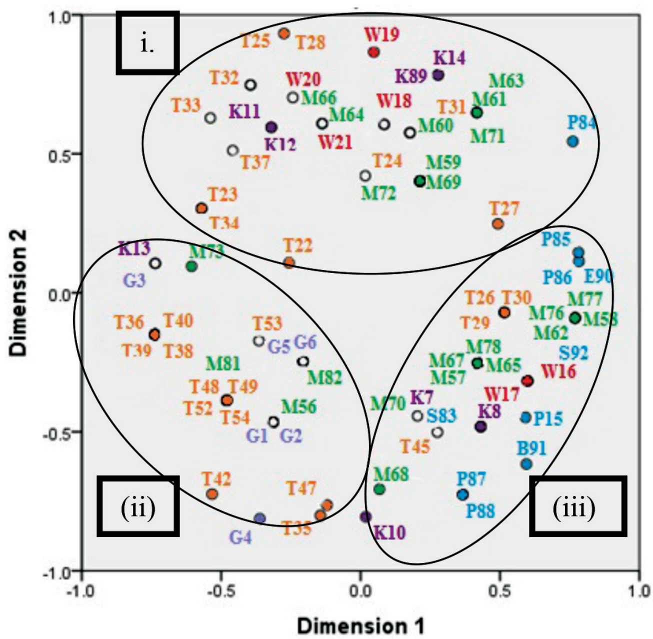

Figure 3: NMDS configuration showing ecological groups on microhabitat characteristics of *Megophrys nasuta*; each point represents individuals of this species

ambient temperature between the range of 26-29°C and showed a significant correlation with its vegetation type of VR (Table 6).The remaining microhabitat variables showed a clear negative tendency or at least no strong positive correlation, hence the result is less meaningful for this objective, indicating ambient variables have no influence on the presence of *M. nasuta* species in these localities. Yet Table 7 portrayed an inverse correlation between temperature and substrate of leaf suggesting any increment of temperature at forest floor may reduce the abundance of *M. nasuta* as the species favours leaf litter as its substrate occupancy.

Discussion

Megophrys nasuta is a habitat generalist and supports the hypothesis of its wide dispersal throughout fragmented areas. The observed individuals were mostly found perched at less dense vegetation type with visually estimated 80-90% of canopy gap. These vegetation types provide various kinds of microhabitat for amphibians specifically *M. nasuta*. The forests

Table 6: Correlation vegetation types with ambient temperature and humidity based on Kendall's coefficient

		VA	VRF	VE	VG	VR
Temperature	Tau	-0.156	**-0.374****	**0.405****	-0.089	**0.293****
	p-value	0.160	**0.001**	**0.000**	0.425	**0.009**
Humidity	Tau	**0.485****	**0.265***	**-0.303****	-0.111	**-0.393****
	p-value	**0.000**	**0.018**	**0.007**	0.322	**0.000**

* Correlation is significant at the 0.05 level (2-tailed)

**Correlation is significant at the 0.01 level (2-tailed)

Table 7: Correlation substrate with ambient temperature and humidity based on Kendall's coefficient

		SA	SD	SF	SG	SH	SJ
Temperature	Tau	**-0.240***	-0.142	0.012	0.148	0.177	0.054
	p-value	**0.031**	0.201	0.914	0.185	0.111	0.625
Humidity	Tau	0.013	-0.062	-0.056	-0.131	-0.127	0.214
	p-value	0.905	0.583	0.617	0.244	0.259	0.056

* Correlation is significant at the 0.05 level (2-tailed)

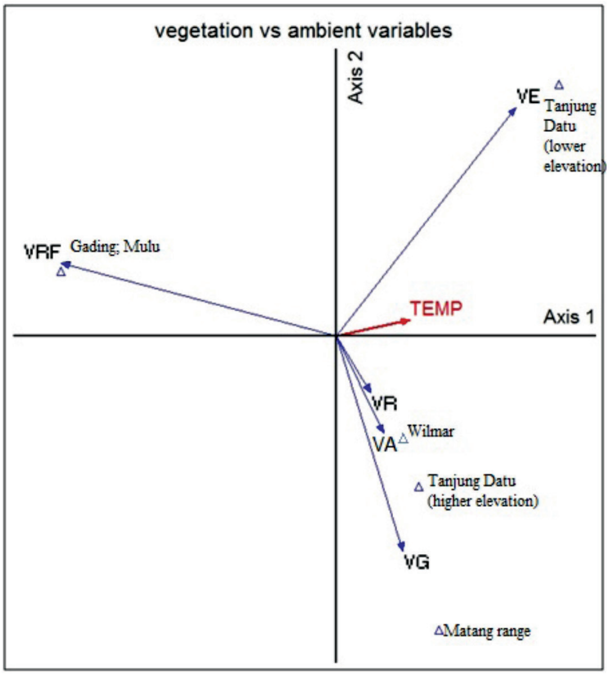

Figure 4: Ordination vegetation type and the ambient temperature of Axes 1 and 2

mostly consist of interconnecting streams from small to medium-sized streams flowing through the forest with sandy gravels at the bottom. The large canopy gap, observed during samplings, were in-line with the data on temperature and humidity recorded. Canopy gap allows light to penetrate to the forest floor, sufficient enough to warm the rock surface during the daytime. Some individuals of *M. nasuta* were found on the forest floor of primary and secondary forests which were occupied by woody plants. Microhabitat provides different microclimate to *M. nasuta* that makes this species a microhabitat specialist. It prefers to sit on bare soil that indicates bare soil as a preferred medium for this larger size of ground dweller frog (Zainudin*et al*., 2017). The species was also found abundant on rock surface along the streams especially during the daytime, that is bright and sunny and where the sunlight will warm a rock that helps in killing the microorganisms especially those that live on the surface of the outermost skin layer of the body of the species. *Megophrys nasuta* also prefers to sit on the surface of leaf litter as a good hiding place to avoid predators and giving false detection for its prey during foraging by camouflaging similarly to the leaf litters on the forest floor. In another study, leaf litter was selected as a shelter in early spring at the edge of breeding site for some frog species such as Wood Frogs (*Ranasylvatica*) (Baldwin *et al*., 2006).Therefore, change in microhabitat may threaten *M. nasuta* population in Sarawak because microhabitat has potential to buffer the climate and likely to increase mortality during extreme climate events (Scheffers *et al*., 2014). Besides, microhabitat characteristics also had greatly influenced the behavioural pattern during an advertisement call (Bosch & Riva, 2004).

The maximum and minimum habitat temperature for *M. nasuta* is between 21°C and 29°C with 59% to 100% of relative humidity indicating the species preference towards temperature and humidity in the forest. The previous study showed maximum temperature for the adults in captivity is 25°C (Wildenhues *et al*., 2012). Kohler *et al*. (2011) suggested that frogs preferred the intermediate ambient temperature to prevent water loss and physiological performance. The warmer temperature at an open area or less shaded area tends to increase body water loss on adult frogs from excessive desiccation. This study showed broad thermal tolerance of *M. nasuta* at two localities due to the forest edge effect at Tanjung Datu and open area for oil palm plantation at Wilmar plantation sites. This is consistent with Porter (2010) in stating that variables of temperature and light levels have an impact on frog species, with the highest temperatures and light readings found in the sites with fewer species and individuals. Furthermore, ambient temperature strongly influences the development of the embryonic period of anurans species. According to Bernal and Lynch (2013), frog species with the aquatic breeding mode at a lower elevation and open areas tend to have a wider range of thermal tolerances. This suggested that *M. nasuta* may have also made a thermal adjustment during the embryonic stage to suit their habitat characteristic. Normal temperature range for development of embryonic *M. nasuta* in captivityis 24-27°C (Wildenhues *et al.,* 2012) while Malkmus (1995) recorded the temperature for development between 18-21°C in their natural habitat with slower growth rate. Higher temperature may limit the physical activity of the tadpoles and adult frogs thus limiting the development of tadpoles and reducing the foraging activity, resulting in smaller body size (Navas, 1996). The shaded areas apparently supply most favourable habitat requirements to facilitate a frog to regulate its body temperature. Hence, *M. nasuta* may be affected by anthropogenic activity caused by habitat alteration and fragmentation if canopy cover at these two respective localities decreased. Kohler *et al*. (2011) predicted that body temperature regulation of *Rana temporaria* may be influenced due to deforestation and removal of canopy.

Megophrys nasuta could adapt very well in their natural habitat and successfully camouflage on the forest floor. Hence, it is crucial to minimize the impact of anthropogenic activities in their surrounding areas. Excessive human anthropogenic activities such as deforestation, logging and land clearing, may prevent seedling recruitment by altering the microhabitat of the forest floor and the soil conditions. When soil condition becomes poor, there will be a lack of productive mycorrhizal fungi to help regenerate the forest. The amount of leaf litter on the forest floor would be gradually reduced and thus, limit the shelter for *M. nasuta*. This will lead the species to high risk of exposure for predation. Meanwhile, the lack of trees will cause the canopy gap to increase which in turn increases the possibility of direct exposure to sunlight that results in desiccation. This explained the pattern of post-breeding movements by adult *Rana sylvatica* to closed-canopy area as recorded by Baldwin *et al*. (2006). Consequently, any environmental changes that occur at the forest floor may result in limiting the favourable microhabitat for this species to camouflage. The overall findings in this study are consistent with Kopp and Eterovick (2006) indicating that seasonal species abundance, vertical position and substrate preferences are crucial microhabitat characteristics to distinguish adult frog's microhabitats. Horizontal position and vegetation type are important elements to differentiate tadpole's microhabitat. Our findings showed no individual was encountered during our survey at non-forest localities. This suggested that the lack of permanent fresh water bodies (the horizontal position was a far distance from water bodies) in the study sites reflected by the absence of this species in these areas, even though the areas have canopy cover that could provide its favourable microhabitat of leaf litter on the forest floor. Thus, the horizontal position plays an important role in determining the breeding site of *M. nasuta* in an area. The study also showed a positive correlation between species abundance and temperature implying that abiotic factors influence species distribution than biotic interactions.

Conclusion

The abiotic factors playan important role in *Megophyrs nasuta* adapting well in its natural habitat. The degree of habitat generalist may be correlated with its dispersal ability, while historical events such as climatic and environmental changes may also have a profound effect on current distribution and abundance patterns of *M. nasuta* throughout Sarawak. The finding is very important as an early indicator of species response to habitat fragmentation and may be predictable, thus allowing the early identification and targeting of species vulnerability. Hence, it is recommended that when developing areas in Sarawak there is a need to consider habitat requirements of forest dweller species such as their breeding sites, connecting forest floor and canopy cover as a corridor of migration-connected habitat elements.

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