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External Environmental and Insects Factor for Attraction of Edible Bird Nest Swiftlet (*Aerodramus fuciphagus*) in Sarawak

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ABSTRACT

Edible Bird Nest (EBN) swiftlet industry plays a significant role in the economic growth in Sarawak. This study aimed at identifying both the external environmental factors and types of insects that are important for a successful swiftlet farmhouse (SFH). For this purpose, a total of 21 SFHs from the southern areas of Sarawak were selected. The external environmental factors of SFH and the type of insects present in relation to the number of EBN swiftlet populations were analysed using descriptive statistics. The results showed that external environmental locations, namely rural and remote areas, were highly selected (71.42%) for the construction of SFHs ($p<0.05$) compared to the other location categories, as analysed using the Kruskal-Wallis test. Significant relationships ($p<0.05$) were observed between environmental factors (habitat origin and predation) and the population of EBN swiftlets in the SFHs. Large densities of the EBN swiftlet populations were found in SFHs located in areas with fewer disturbances. The highest population of insect types in most SFHs was Diptera (52.38%). This study can be used as a guideline for swiftlet ranchers looking to startup their EBN swiftlet farming.

Keywords: Edible Bird Nest, environment, insects, Sarawak, swiftlet farm house

INTRODUCTION

The Edible Bird Nest (EBN) swiftlets, also called *Aerodramus* and belonging to the family Apodidae, is commonly found in South East Asian countries. Many indigenous local people in Sarawak take the opportunity to be engage in EBN swiftlet ranching using alternative man-made habitats or buildings called Swiftlet Farm House (SFH). The ranchers capitalise the chance to explore swiftlet ranching, as EBN swiftlets are known to migrate from one place to another in search of areas with lower environmental stress, such as air pollution (Heil & Goldammer, 2001). Moreover, due to the high price of EBN, local harvesters who collect EBN from the natural caves might contribute to the overharvesting and environmental stress for the EBN swiftlets.

In response, the swiftlet ranchers discover alternative ways to produce sufficient amounts of EBN by building alternative habitats called SFH. The SFHs are built in areas where EBN swiftlets tend to socialise, increasing the likelihood of EBN swiftlets adopting the new man-made habitats (Rahman *et al*., 2016). In addition, the only challenges swiftlet ranchers face when constructing the SFHs are food availability, water sources, and mitigating environmental disturbances. The success rate of swiftlet ranching in every region in Malaysia is only around 25% (Nurshuhada *et al.*, 2015).

According to Phang (2008), it is a waste of time and effort for swiftlet ranchers to build SFHs without proper planning, as they will face difficulties in attracting EBN swiftlets to fly and inhabit SFHs in a new environment. The swiftlet ranchers must possess knowledge about the fundamental importance of the environment, especially the vegetation that provides food sources for these insectivorous birds (Manchi & Sankaran, 2010). According to Koay (2014), the presence of EBN swiftlets in areas known as the

flying paths indicates the existence of EBN swiftlets sources within these flying ranges. The presence of EBN swiftlets along the flying paths, suggests that the area represents a suitable external environment and a potential location for swiftlet ranching.

This study aims to understand the desirable external environmental factors for SFH which will successfully attract EBN swiftlets and the types of insects that influence the population.

MATERIALS AND METHODS

Selection of the Swiftlet Farm House

There were 21 selected SFHs which might have different external environmental characteristics, population of EBN swiftlets and types of insects in this study. This study was conducted in five divisions in the southern part of Sarawak (Figure 1) with the SFH locations shown in Table 1. The study of SFHs was done together with the Department of Veterinary Sarawak.

Table 1. The longitude and latitude of selected swiftlet farm house (SFH)

Bird House Number	Location [latitude, longitude]
Bird House 1	1.4808711, 110.2898360
Bird House 2	0.9684613, 110.5333081
Bird House 3	0.9738783, 110.5227607
Bird House 4	0.9711358, 110.5358576
Bird House 5	0.9709119, 110.5351233
Bird House 6	0.9706775, 110.5337966
Bird House 7	1.3888751, 111.2282185
Bird House 8	1.3895109, 111.2275054
Bird House 9	1.3427223, 111.1670481
Bird House 10	1.3421341, 111.1671071
Bird House 11	1.1911131, 111.4793933
Bird House 12	1.2092676, 111.4909563
Bird House 13	1.195303, 111.469947
Bird House 14	1.8900522, 111.1999651
Bird House 15	1.7982834, 111.1135323
Bird House 16	1.695770, 110.033663
Bird House 17	1.041738, 111.832518
Bird House 18	1.042646, 111.831261
Bird House 19	1.046219, 111.832807
Bird House 20	1.039798, 111.839956
Bird House 21	1.048386, 111.845095

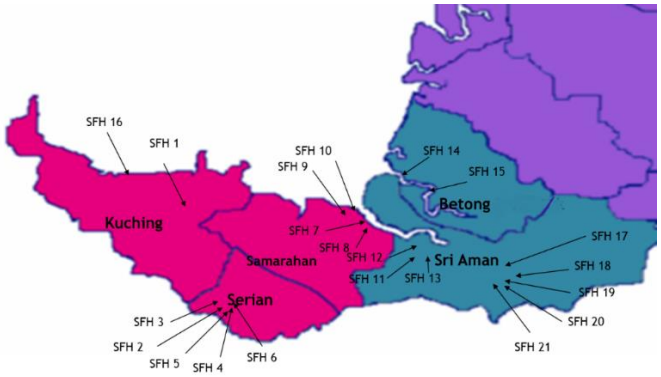


Figure 1. Location of Swiftlet farmhouses in Sarawak

Data Collection

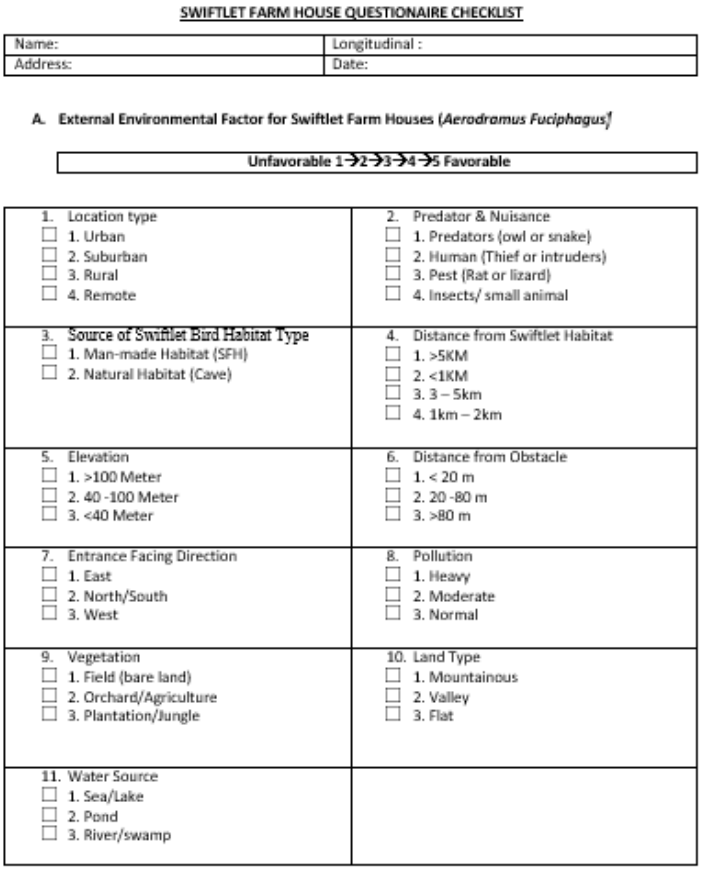
This study was based on a qualitative study on each SFH selected. The observations on the siting, structure, and design of the buildings and the response of 21 SFH owners were carried out through questionnaires and checklist form.

Experimental Design for Identifying External Environmental Factors

The scoring technique (Table 2) was designated to compare the different environmental factors of every SFH, the population of EBN swiftlets, and insects. In these questionnaire forms, the observations made were given scores ranging from "Favourable" to "Unfavourable". Table 3 shows the categories of external environmental of SFH and their respective scores and description. The population of insects and EBN swiftlets were recorded in the questionnaire in Figure 3.

Table 2. The scoring number with favourability score

Scoring	Unfavourable	Neutral/Partially Favourable	Favourable
1 – 2	1	-	2
1 – 3	1	2	3
1 – 4	1 – 2	-	3 – 4
1 – 5	1 – 2	3	4 – 5



SWIFTLET FARM HOUSE QUESTIONAIRE CHECKLIST

Name:	Longitudinal :
Address:	Date:

A. External Environmental Factor for Swiftlet Farm Houses (*Aerodramus Fuciphagus*)

Unfavorable 1→2→3→4→5 Favorable

1. Location type ☐ 1. Urban ☐ 2. Suburban ☐ 3. Rural ☐ 4. Remote	2. Predator & Nuisance ☐ 1. Predators (owl or snake) ☐ 2. Human (Thief or intruders) ☐ 3. Pest (Rat or lizard) ☐ 4. Insects/ small animal
3. Source of Swiftlet Bird Habitat Type ☐ 1. Man-made Habitat (SFH) ☐ 2. Natural Habitat (Cave)	4. Distance from Swiftlet Habitat ☐ 1. >5KM ☐ 2. <1KM ☐ 3. 3 – 5km ☐ 4. 1km – 2km
5. Elevation ☐ 1. >100 Meter ☐ 2. 40 -100 Meter ☐ 3. <40 Meter	6. Distance from Obstacle ☐ 1. < 20 m ☐ 2. 20 -80 m ☐ 3. >80 m
7. Entrance Facing Direction ☐ 1. East ☐ 2. North/South ☐ 3. West	8. Pollution ☐ 1. Heavy ☐ 2. Moderate ☐ 3. Normal
9. Vegetation ☐ 1. Field (bare land) ☐ 2. Orchard/Agriculture ☐ 3. Plantation/Jungle	10. Land Type ☐ 1. Mountainous ☐ 2. Valley ☐ 3. Flat
11. Water Source ☐ 1. Sea/Lake ☐ 2. Pond ☐ 3. River/swamp	

Figure 3. The example of questionnaire sheet for survey the external environmental characteristic of SFH

Table 3. The categories of external environmental characteristics of Swiftlet Farm House and its scores

No.	Categories	Score	Description
1	Location Type	1	Urban (Developed area, less vegetation nearby)
		2	Suburban (Developing area, with vegetation nearby)
		3	Rural (More vegetation, less development)
		4	Remote (Large landmass of vegetation)
2	Predator/ Nuisance	1	Predators (owl or snake)
		2	Human (Thief or intruders)
		3	Pest (Rat or lizard)
		4	Insects/ small animal
3	Source of Swiftlet Bird Habitat Type	1	Man-made Habitat (Habitat is SFH)
		2	Natural Habitat (Habitat Cave)
4	Distance from Swiftlet Habitat	1	More than 5 km distance from original habitat
		2	Less than 1 km distance from original habitat
		3	Distance from (3 – 5) km
		4	Distance from (1 – 2) km
5	Elevation	1	>100 Meter above sea level
		2	40 – 100 Meter above sea level
		3	<40 Meter above sea level
6	Distance from Obstacle	1	Less than 20 m between obstacle and SFH
		2	(20 – 80) m between obstacle and SFH
		3	More than 80 m between obstacle and SFH
7	Air Pollution Description	1	Heavy
		2	Moderate
		3	Normal
8	Vegetation	1	Bush/field (Vegetation were less dense)
		2	Orchard (Vegetation were partially dense)
		3	Plantation/Jungle (Vegetations were high dense)
9	Land Type	1	Mountainous Land
		2	Valley Land
		3	Flat Land
10	Water Source	1	Sea/lake
		2	Pond
		3	River/swamp

Experimental Design for the Population Size of EBN Swiftlets and Insects

Direct counting the number of available EBN swiftlets was done within a 30 m radius in the SFH. The direct counting was done four times within the one and a half hours to determine the average number of EBN swiftlets. The counting was performed from 17.30 – 19.00 daily in the evening using digital counter app called Click Counter (FunCoolApps) via a smartphone.

Experimental Design for Insects

The collection of insects took place in the evening from 17.00 – 18.30 hours. Butterfly nets were employed to capture the insects within a 30 m radius area within the SFH. The insects were categorised into various orders, such as Coleoptera, Hymenoptera, Diptera, and Isoptera. A Digital Counter App on a smartphone was used to tally the insect count.

Statistical Analysis

Descriptive analysis was used to analyse the results using the Statistical Package for the Social Sciences (SPSS) and Likert Scale Data. The statistical analysis involved chi-square and Kruskal-Wallis tests to analyse the data, with a significance level set $p<0.05$. Chi-square analysis was used to examine the relationship between the external environment of SFH and the population of EBN swiftlets outside the SFH, as well as the relationship between the external environment of SFH and the types of insects outside the SFH with significance level of $p<0.05$.

Table 4. The unfavourable and favourable scale scores for each category from the selected SFH

No.	Categories	Score	Description	SFH Number	Percentage (%)
1	Location Type	1	Urban	17, 18, 19	14.29
		2	Suburban	1,11,12	14.29
		3	Rural	2, 3 ,4, 5, 6, 7, 8, 9, 10, 13, 15, 20, 21	61.90
		4	Remote	14, 16	9.52
2	Predator/ Nuisance	1	Predators (owl or snake)	15	5.76
		2	Human (Thief or intruders)	7, 8, 9, 10, 11, 12, 14	33.33
		3	Pest (Rat or lizard)	1, 2, 3, 4, 5, 6	28.57
		4	Insects/ small animal	13, 16, 17, 18, 19, 20, 21	33.33
3	Source of Swiftlet Bird Habitat Type	1	Man-made Habitat (SFH)	1, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 19, 20, 21	76.19
		2	Natural Habitat (Cave)	2, 3, 4, 5, 6	23.81
4	Distance from Swiftlet Habitat	1	>5 km	-	0.00
		2	<1 km	7, 8, 9, 10, 11, 15	28.57
		3	3 – 5 km	1, 14, 17, 18, 19, 20, 21	33.33
		4	1 km – 2 km	2, 3, 4, 5, 6, 12, 13, 16	38.10
5	Elevation	1	>100 m	-	0.00
		2	40 – 100 m	2, 3, 4, 5, 6, 17, 20, 21	38.10
		3	<40 m	1, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19	61.90
6	Distance from Obstacle	1	<20 m	4	4.76
		2	20 – 80 m	2, 3, 5, 6, 9, 11, 12, 13, 14, 15, 16, 17, 18, 19	66.67
		3	>80 m	1, 7, 8, 10, 20, 21	28.57
7	Air Pollution	1	Heavy	-	0.00
		2	Moderate	1, 11, 12, 17, 18, 19	28.57
		3	Normal	2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 15, 16, 20, 21	71.43
8	Vegetation	1	Bush/field	7, 8, 9, 10, 14, 16	28.57
		2	Orchard	2, 3, 6, 13, 17, 18, 19, 20	38.10
		3	Plantation/Jungle	1, 4, 5, 11, 12, 15, 21	33.33
9	Land Type	1	Mountainous	-	0.00
		2	Valley	3, 4, 5, 6, 17, 18, 19, 20, 21	42.86
		3	Flat	1, 2, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	57.14
10	Water Source	1	Sea/lake	16	4.76
		2	Pond	4, 5, 6, 9, 10, 13	28.57
		3	River/swamp	1, 2, 3, 7, 8, 11, 12, 14, 15, 17, 18, 19, 20, 21	66.67

RESULTS

Categories of SFH External Environment

From Table 4, it is evident that the categories with the highest percentage of favourability were location type, distance from swiftlet habitats, and air pollution level, all with favourable percentage of 71.43%. On the other hand, the category with the lowest percentage of favourability among SFHs was the source of EBN swiftlets at 23.81%. This is further supported by the Kruskal-Wallis H score of 7.121% with a p-value <0.05.

The Population Size of EBN Swiftlet and External Environment of SFH

From Table 5, SFH at percentage of 57.14% for score 5 experience the most population size of EBN swiftlets and SFH at percentage 19.05% for score 4 with the total of 76.19% of SFH are Favourable score. The SFH 1, 5 and 6 experienced fewer occurrences of EBN swiftlets flying and foraging in the area. It shows that score 1 represents only 14.29% of SFHs (SFH: 1, 5 & 6) in variable the population size of EBN swiftlets outside the SFHs. In score 3 (Neutral: 50 – 100 EBN Swiftlets), represents only 9.52% of SFHs (SFH: 2 & 3). Additionally, the data reveals that there are 0.00% of SFHs in score 2 (Unfavourable: 20 – 50 EBN Swiftlets).

From Table 6, the chi-square result of habitat origin and predatory/nuisance categories was significance (p<0.05), while the remaining external environment categories failed to reject the null hypothesis that predatory/nuisance categories cause negative effect on EBN swiftlet populations, and it is suggested that habitat origin must be adjacent to cave habitats.

Table 5. Populations size of EBN swiftlets outside of SFH

Score	Population of EBN swiftlets foraging outside SFH	SFH	Percentage (%)
1	Less than 20	1, 5, 6	14.29
2	20 – 50	-	0.00
3	50 – 100	2, 3	9.52
4	100 – 250	4, 10, 13, 15	19.05
5	>250 (TNTC)	7, 8, 9, 11, 12, 14, 16, 17, 18, 19, 20, 21	57.14

Table 6. The relationship between population of EBN swiftlets and the external environmental categories of SFH

Categories	Value	df	Asym. Significance
Location	0.890	2	0.641
Water Source	3.323	4	0.505
Elevation	1.664	2	0.435
Obstacle	1.323	4	0.857
Habitat Origin	12.157	2	**0.002***
Habitat Distance	2.625	2	0.269
Air pollution	0.890	2	0.641
Vegetation	5.789	4	0.215
Land Type	0.537	2	0.765
Predatory	16.406	6	**0.012***

The Relationship Between the Insects Types and SFH Natural Environments

The insect type in each SFH were caught to investigate the available diet of EBN swiftlets at the farm. As shown in Table 7, it shows that most of SFHs have the greatest number of Diptera insects, including mosquito and fly. The insect species of Diptera shows the most populated insect order in SFH (1, 2, 7, 8, 11, 12, 13, 15, 18, 19, and 20) and the percentage of Diptera population among SFH was 52.38%. There are 23.81% of SFHs (SFH 5, 6, 9 and 10) are dominated by Hymenoptera insects while 14.29% of SFHs 165 (SFH 4, 16 and 17) are dominated by Coleoptera insects. Finally, the insects of Isoptera are or known as termites, are the most common insect order in SFH 3 and 14, constituting 9.52% of the total SFH. The chi-square result (Table 8) reveals significant relationship (p<0.05) between the water source and insects' types.

Table 7. Total of Swiftlet Farm House (SFH) with most type of insects

SFH Number	Order of insects that are majority caught and their average population				Total of insects for each SFH
	Coleoptera	Hymenoptera	Diptera	Isoptera	
1	18	7	31	7	63
2	22	35	42	2	101
3	24	13	26	28	91
4	38	30	27	10	105
5	35	41	19	13	108
6	22	43	21	12	98
7	12	10	32	27	81
8	17	8	33	21	79
9	27	37	31	27	122
10	29	44	22	37	132
11	23	21	37	35	116
12	19	12	45	36	112
13	18	17	33	26	94
14	21	9	15	30	75
15	20	27	38	23	108
16	41	27	32	29	129
17	28	6	19	16	69
18	13	17	20	9	59
19	11	20	27	18	76
20	33	28	37	35	133
21	29	35	33	23	120
Total Type of Insects	500	487	620	464	
SFH and Majority (Blue Shaded) of Insects Percentage (%)	14.29	23.81	52.38	9.52	

Table 8. The significant chi-square results between insects' type of SFH and the natural environmental categories of SFH

Categories	Value	df	Asym. Significance
Location	4.370	3	0.224
Vegetation	2.431	6	0.876
Water Source	16.121	6	**0.013***
Air Pollution	4.370	3	0.224

DISCUSSION

Ideal Geographical Structure for Swiftlet Farming

The flat terrain, or land at elevations equal to the sea level, is desirable for swiftlet ranchers due to its economic benefits. It not only saves time but also provides a straightforward foundation structure that is easy to construct, thereby reducing additional construction costs. Additionally, the SFH design enhanced visibility for EBN swiftlets to locate the SFHs. In comparison to scoring 2 or even scoring 1 of land type and elevation, this situation leads to complex logistical challenges when transporting the SFH building materials across the rugged terrain of SFH sites (Giyasov, 2020).

The valley land with an elevation ranging from slightly above (scoring 2) area can still be 1 deemed preferable for the SFH site, provided the owner chooses to construct atop a hill or any location that ensures unobstructed access. This finding aligns with Looi and Omar (2016), who showed that no swiftlet ranchers choose a mountainous site. Mountainous regions are unsuitable because due to their uneven and substantial geographical structures, which obstruct the view of EBN swiftlets and complicate the process of locating the SFH. Furthermore, these areas make it difficult for EBN swiftlets to identify the source of the calling sound from SFHs due to the echo effect, leading to confusion and disrupting the flight stability of EBN swiftlets due to wind speed (Koay, 2014; He *et al*., 2019). Koay (2014) recommends that SFHs should be positioned further away from any obstacles that are taller than the SFHs, such as tall trees, buildings, or hills. Otherwise, SFH owners should be advised not to have the SFH entrance holes facing toward the obstacles or building the SFH on top of hills.

The natural environments were known to have dense vegetation and rich in ecology, as seen in rural and remote areas. On the other hand, developed environments were mostly man-made and had lower vegetation density (Rahman *et al*., 2016). According to Argiro and Marialena (2003), the developed areas like SFHs, located in unfavourable location types (scores 1 and 2), may experience high environmental temperatures, poor air quality, and elevated noise levels. These factors could have a limited positive impact on the environment of SFH for EBN swiftlet ranching.

These factors also interfered with the ecology between the EBN swiftlets and its food sources. The scenario mirrors the findings of Munirah *et al*. (2018), the SFHs that situated in rural and remote areas, reported abundant food and water supplies in sufficient quantities to sustain the reproduction of the EBN swiftlets colony. Reduced noise disturbance also decreases the interference of calling sound by EBN swiftlets, facilitation navigation back to their habitats (Argiro & Marialena, 2003).

Natural Environments of Swiftlet Farming

The favourable location for a swiftlet ranching is in remote and rural areas, which are ideal for swiftlet ranching activities due to their lower levels of disturbance from human activities compared to unfavourable locations such as urban and suburban areas. Rural and remote areas are also preferred by most swiftlet ranchers, as they do not need to worry about food and water shortages in the long run. Similar to the findings of Idris *et al*. (2014), choosing the right location for building SFHs is crucial, as it requires consider the natural surroundings, especially water sources and suitable vegetation. All types and categories of vegetation guarantee a food supply for EBN swiftlets since insects come from any kind of vegetation (Rahman *et al*., 2016). According to Porter *et al*. (1991), both natural and cultivated vegetation habitats play a crucial role in influencing the ecology of the insects EBN swiftlets. In any type of vegetation, insects naturally interact with the plants, aiding in pollination, serving as herbivores, carnivores, and decomposers, and providing a food source for higher consumers in the food chain, such as the EBN swiftlets (Idris *et al*., 2014). The vegetation like bush or field are less desirable for swiftlet ranching because the bushes or field are known to provide only a few species of flying insects (Salekat, 2009).

Based on Aziz and Azimullah (2008), their recommendation to many swiftlet rancher expertise was to consider building SFHs close to a water source, such as a lake, pond, river, swamp, or ocean. These large bodies of water are known to support the food chain for the EBN swiftlets which involve breeding large quantities of flying insects and allow EBN swiftlets glide slowly into the water surface to get their water supply. These EBN swiftlets rely on some of these water sources and forage for food in the nearby jungle and orchards. The land with abundant of forest and trees retains moisture above the canopy and EBN swiftlets could consume the water droplet during the flight. The majority of the swiftlet ranchers prefer swamps and river as water sources since these areas are rich in the food chain. Also, the presence of nearby water sources has been reported to favor the required humidity in the SFH areas (Ibrahim *et al*., 2009).

Most swiftlet ranchers prefer to build their SFHs in areas that offer a favourable EBN swiftlets source, particularly locations with natural cave formation such as those designated in this project SFH: 2, 3, 4, 5 and 6. This preference stems from the fact that EBN swiftlets originate from such caves, as noted by (Lim & Cranbrook, 2014). The rural and remote sites hold greater potential for swiftlet ranchers to attract a higher number of EBN swiftlets. This is attributed to the similarity in physical and natural environments between these areas and natural caves (Looi *et al*., 2015). Despite being considered less ideal EBN swiftlets sources, the existing man-made habitats (SFHs) are capable of attracting EBN swiftlets. However, a longer duration is required for these man-made habitats to become populated with EBN swiftlets, to the point where a new generation of EBN swiftlets ventures out in search of new shelters for habitation (Lim & Cranbrook, 2014). Koay (2014) recommends that, swiftlet ranchers steer clear of unfavourable distances from EBN swiftlet sources, particularly distance classified as a score 1 (too far) and score 2 (too close). Being situated too far away from EBN swiftlets sources prolongs the time needed to attract EBN swiftlets, while being too close to such sources can lead to physical structural competition between new SFHs and existing one.

The Threats in the Swiftlet Farming

Predators/nuisance like eagle, snake and intruder and pollution like noises and air pollution are common threats in swiftlet ranching activities. These threats contribute to heightened stress levels among the EBN swiftlets colonies, thereby adversely impacting their reproductive and swiftlet EBN production (Aziz & Azimullah, 2008). Bell (2000) noted that the reproductive cycle of every insect can be significantly affected by air pollution, resulting in reduces insect populations, particularly in

regions with heavy pollution- an environment unsuitable for EBN swiftlets to find sufficient food sources while noise pollution may disrupt the quality live of EBN swiftlets. Notably, a "Favourable" pollution score of 3 was observed in rural and remote areas, even though certain southern regions of Sarawak experienced high levels of hazardous air pollution, thereby affecting numerous SFH management practices (Ten, 2019).

The swiftlet ranchers believed that the presence of predators/nuisances could also contribute to the failure of SFH operations. This is because EBN swiftlets require a shelter that is free from enemies and stress, which are fundamental prerequisites for successful reproduction (Hilden, 1965). While the EBN swiftlets are not easily frightened by pests (score 3), these pests could potentially introduce diseases and contamination. These factor, in turn, might negatively impact the quality of the EBN swiftlet nests and pose risks to the health of the young EBN swiftlets (Phang, 2008). Nuisance and predators, scored 1 and 2 respectively, hold the potential to scare the EBN swiftlets, compelling them to permanently avoid these SFH due to the inherent life-threatening conditions. In response, the EBN swiftlets may actively seek out alternative shelters and abstain from returning to their original habitats. This potential consequence could significantly impact the swiftlet ranching operations and outcomes (Koay, 2014).

Insects and the External Environment of SFH

The majority of SFHs were strategically located in areas with "Favourable" areas, particularly in rural (score 3) and remote (score 4) regions. This choice was driven by their proximity to abundant vegetation such as forests/plantations. Such dense vegetation holds great significance as essential role as food sources within the ecosystem of insects. It is noteworthy that SFHs located near such vegetation exhibit a diverse populations of dipteran insects, which are found near the favourable vegetation. This setup replicates the original natural external environment between EBN swiftlets and insects (Rahman *et al*., 2016).

Insects require water for their daily activities, including sustenance and assistance in reproduction. Insects prefer areas with abundant water sources, such as rivers (Favourable: score 3), which has led to the construction of most SFHs in close proximity to rivers. The predominant insect type in these SFHs is dipteran insects. The ample water availability typically facilitates the widespread reproduction of insects, showcasing the significant link between insects and water sources, a dimension of their environmental diversity (Noble-Nesbiti, 1990).

Many swiftlet ranchers hold the belief insects density tends to be lower in urbanized and developed areas due to air pollution. Bell (2000) reported that these, ranchers are aware of the absence of EBN swiftlets in regions with high risk air pollution, owing to the diminished insect population caused by pollution. However, certain insects, such as dipteran species like flies and mosquitoes, have demonstrated resilience to air pollution effects (Kozlov & Zvereva, 1997).

CONCLUSION

The southern part of Sarawak boasts an extensive land mass with a favourable geographical environment in terms of land type, water sources, and elevation. In relation to the natural surroundings, this study indicates that most of the SFHs were built with favourable vegetation and locations. These areas are categorised by dense vegetation and limited urban development, creating a scenario where man-made habitat (SFH) closely resembles the natural environmental habitat (caves). Additionally, the research showed that the type of vegetation did not have a discernible impact on the population of EBN swiftlets in the vicinity of SFHs. However, the population of Diptera insects was found to be higher around SFHs situated in orchards, plantations, or jungles. Notably, SFH situated near the sea exhibited a lack of preference for seawater as a water source by EBN swiftlets.

The potential risks of air pollution and the presence predators or nuisances are factors that could impact the long-term survival of EBN swiftlets. Air pollution poses a threat to the health of EBN swiftlets and the diversity of insects, which are vital to their diet. In addition, the favourable external environment surrounding SFHs offer an ample supply of flying insects, beneficial for swiftlet ranching endeavors. Furthermore, for successful ranching

of EBN swiftlets, a suitable habitat within an appropriate SFH environment is imperative. This environment should minimize environmental stress and provides adequate security, a reliable food source, and promote insect reproduction. Therefore, establishing EBN swiftlet ranching operations does not necessitate an intricate external environmental description. This simplicity allows swiftlet ranchers to understand the fundamental prerequisites of the external environment and effectively plan for SFH startup.

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