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Diversity of the insects in the diet of edible nest swiftlets in oil palm plantations

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Abstract

The Edible Nest Swiftlet (*Aerodramus fuciphagus*) is a small bird from the family Apodidae which is commonly found in the South-East Asian region which characteristically roost and nest in cave or cavern-like situation. Swiftlet farming in specially designed building has recently developed due to high consumer demand for the edible bird nest. The farms are not the natural habitat of the swiflets and there are greater chance that this will affect in one way or the other way of their dietary habit and composition. The focus of this study was to investigate the diversity of insects found in the diet of *A. fuciphagus* in their habitats in oil palm-growing areas in Malaysia. This was achieved by investigating the relationship between insect composition in oil palm and insect prey composition in the feeding bolus of *A. fuciphagus*. The most common insects order found in the sampled fields of the three states in the study was Diptera (26.53%) and followed closely by Hymenoptera (21.26%). The difference between the sample sites as far as insects order composition is not significantly different (t test = 3.759 and 2.9). We failed to accept the H_0 that the diversity of insect in the fields and diet of the swiftlets in all locations was the same.

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Introduction

The diversity of insects in a field has several economic importance in the oil palm plantation. Insects inherently play diverging roles in the oil palm plantation ecosystem. Their influence expands from pollination to damage on oil palm to maintain an ecologically balanced in oil palm ecosystem. However, one of the primary management challenges of oil palm plantation is to manage and assessing the economic loss due to insect interference with oil palm trees.

Swiftlets are insectivorous birds that feed on their wings; catching their prey in flight by their superb eyesight (Thompkins and Clayton, 1999). The swiftlets feed on insects by flying over various tree canopies which are termed as foraging. Foraging areas are areas where swiftlets are hunting for insects which include forest, plantations (oil palm, rubber and paddy), and fruit orchards.

Areas in the town and city where their houses are located are considered as socializing areas where swiftlets met before they call off the day and enter their respective house. At the same time, physical translocation whereby the swiftlet chicks are removed from cave, hand raised and released back to natural habitat and some returned to houses is also taking place (Kamarudin and Anum, 2011).

A suitable swiftlet farm is usually designed in ways that will control light intensities, humidity levels, air flow standards, pressure levels, safety perceptions, heat standards, odors and smells and swiftlet flight-paths in order to mimic swiftlet cave environments in order to encourage nesting of the birds (Fujita, 2012).

Almost 99% of all swiftlet farms in Malaysia are geared towards the production of white edible birds' nests. Swiftlet basic food constitute of aerial insects. Knowledge of edible-nest swiftlet diet may assist attempts to establish and maintain artificial swiftlet colonies for the purpose of edible-nest farming (Lourie and Tompkins, 2000).

It has been a recent practice by Malaysian planters to integrate the rearing of swiftlet in the oil palm plantations (Ibrahim and Baharun, 2009). Apart from the obvious economic gains from rearing of edible swiftlet nest, the birds may have some impact on the insect assemblage in oil palm plantation.

The integrated farming of swiftlets in oil palm plantations have seen important upturn in Malaysia in recent years and this has important implications on insect management. Apart from the commercial sales of the edible nests, the swiflets may have some ecological importance in the fields that may be beneficial to the management of the plantations (Kamarudin, 2009), particularly control of insects they survive on. These farms are not the natural habitat of the swiftlets and there are greater chances than not that this will affect in one way or the other their dietary habit and composition. Particularly in the oil palm habitat, it is hope that the swiftlets can be used as biological agent for the various insect found in the plantation.

Hence, this study was revolved around the following objectives in trying to establish whether swiftlet can be used for biological insect control purpose in the plantations. The objective of this study was to survey the taxonomic diversity of insects in the diet of edible bird nest swiftlet *A. fuciphagus*, possible up to family level and to see whether swiflets can be used as biological control agent for the various insects found in the plantation and to compare diversity of insects in the diet of swiftlet in different oil palm plantations in Malaysia. Having established some findings of the insect prey density one can postulate one or several impact or implications on swiftlet ranching in oil palm plantations.

Material and methods

In order to actualize the objectives identified above in this project, the following methods were employed: Collection of food bolus, food bolus analysis, insect sampling in oil palm habitat and an analysis on the relationship between the insects found in the diet of the swiftlets and those found in the oil palm habitats. There are five locations (Fig. 1) that was chosen to collect the sample of swiftlet food bolus and carried out the insect sampling which are Ladang Besout, Sungkai, Perak, oil palm plantation in Pontian, Johor, oil palm plantation in Tanah Merah, Kelantan, oil palm plantation in Bachok, Kelantan and oil palm plantation in Pasir Mas, Kelantan.

Fig. 1. Map showing 5 different sampling location of oil palm plantation.

Collection of food bolus

Food bolus of swiftlets was collected from their different oil palm habitats in Malaysia. Initially, the swiftlets were caught and handled with utmost care to avoid traumatizing them (Fig. 2). After the swiftlets are caught, they will inherently regurgitate the food bolus they have in their mouths and this will be collected and preserved. A 95% alcohol solution is used in the preservation and to facilitate further analysis.

Analysis of the food bolus

The collected food bolus from the swiftlets were analysed to identify whole or part of the insects in their diet. It was achieved by using a light microscope and the insects were identified by magnifying them 20× using the light microscope.

Sampling of insect in the oil palm habitat

Insect sampling in the oil palm plantations where the swiftlets are dwelling was evaluated. This was conducted within a period of two months. Sampling in this context involved setting up traps either by means of using Malaise trap, and yellow pan trap. Equal number of traps were used at every sampling and placed at the same location. The sampling time was in the evening between 1700 – 1900 hrs and processes taken were also being the same for each sampling session. All samplings were done at the period of favourable weather condition. All insects sampled were preserved in 95% alcohol for later identification in the lab. High concentration of alcohol prevent the membranous wings from become twisted and folded, hairs from matting and soft body parts from shriveling. Some kinds of insects are best kept dry.

Sampling techniques

According to the Agriculture Research Service of United States Department of Agriculture (USDA), a trap is defined as anything that impedes or stops the progress of an organism; this subject is extensive, including devices used with or without baits, lures, or other attractants. Besides its construction, the performance of a trap depends on such factors as its location, time of year or day, weather, temperature, and kind of attractant used, if any. A little ingenuity coupled with knowledge of the habits of the insects or mites sought will suggest modifications or improvements in nearly any trap or may even suggest new traps.

Yellow pan trap

A tray was placed on the ground (Fig. 3) and sprayed with bright yellow colour since most insects attracted to the bright yellow colour. Next, liquid detergent was added to break the surface tension of the water so that insects that trapped into it will be drown and cannot escape. The best collection time is done daily. In case the trap is mean to place for a long period, salt solution should be added as to preserve the trapped insects. Insects in the order of Lepidoptera, Coleptera, Homoptera, Hemiptera, Diptera, Orthoptera and Hymenoptera can be collected using this trap.

Malaise trap

One of the most widely used insect traps was developed by the Swedish entomologist René Malaise and that now bears his name. Malaise trap (Fig. 4) is a tent-like structure designed to trap flying insects such as Hymenopteran and Dipteran. The concept is simple. Insects will fly into the net and hit the middle mash. After that, insects will fly upward into the collecting bottle containing alcohol. Attractants may be used to increase the efficiency of the traps for special purposes.

Statistical analysis

Data obtained during the sampling processes, was analysed using SAS 9.1 software by a comparison of the insects prey found in the food bolus and that of insects found in the sample in the oil palm habitat. Then a student's Statistic (t-test) was used to gauge whether the composition of insects in the food bolus of the swiftlets reflect the population of insects in oil palm habitat. T-test is a statistical test used to gauge the correctness of the assumption made in the null hypothesis.

Results

The result of this project paper was centred on the effect on the diversity of insect as measured by their interaction with a natural enemy, edible nest swiflet. The results were analysed on 3 fronts which are the diversity of insects in selected fields of oil palm plantations in Malaysia, the diversity of insects in the diet (food bolus) of edible swiftlet bird and a comparison of the order of insects found in the oil palm plantation and those found in the diet of edible swiftlet (paired T -test).

Table 1. Diversity of insects' family in oil palm plantation.

Perak	Percentage (%)	Kelantan	Percentage (%)	Johor	Percentage (%)
Coleoptera		Coleoptera		Coleoptera	
Lampyridae	7.69	Scarabidae	11.54	Coccinellidae	21.43
Carabidae	3.85	Coccinidae	3.85	Curculionidae	7.14
Cantharidae	3.85				
Nitidulidae	3.85				
Odonata		Odonata		Odonata	
None	0	Coenagrionidae	3.85	None	0
Diptera		Diptera		Diptera	
Muscidae	3.85	Tabanidae	3.85	Muscidae	21.43
Dolichopodidae	15.38	Caliphoridae	3.85	Tipulidae	14.29
Psycodidae	3.85	Muscidae	7.69	Culicidae	28.57
Asilidae	3.85	Dolichopodidae	19.23		
Tipulidae	3.85	Drosophilidae	3.85		
Tachinidae	3.85	Tachinidae	11.54		
Tephritidae	3.85	Tephritidae	7.69		
Culicidae	3.85	Asilidae	7.69		
Ceratopogonidae	3.85	Culicidae	11.54		
Lepidoptera		Lepidoptera		Lepidoptera	

Satyridae	3.85	Satyridae	19.23	Noctuidae	7.14
Pyraustinae	11.54	Noctuidae	11.54	Pyrallidae	14.29
Noctuidae	7.69	Aulacophora	3.85		
		Pyraustinae	7.69		
Orthoptera		Orthoptera		Orthoptera	
Gryllidae	15.38	Acrididae	3.85	Acrinidae	35.7
		Gryllidae	7.69		
Hemiptera		Hemiptera		Hemiptera	
Reduviidae	3.85	Reduviidae	3.85	None	0
Ricaniidae	3.85	Cynidae	7.69		
		Miridae	11.53		
		Coreidae	7.69		
Homoptera		Homoptera		Homoptera	
Cicadellidae	11.54	Cicadellidae	19.23	Cicadellidae	21.43
Isoptera		Isoptera		Isoptera	
None	0	None	0	Thermitidae	7.14
Blattodea		Blattodea		Blattodea	
Blattidae	3.85	None	0	None	0
Thysanura		Thysanura		Thysanura	
Lepismatidae	3.85	None	0	None	0
Hymenoptera		Hymenoptera		Hymenoptera	
Apidae	3.85	Formicidae	34.62	Braconidae	7.14
Formicidae	23.08	Apidae	7.69	Formicidae	42.86
Ichneumonidae	3.85	Ichneumonidae	19.23	Ichneumonidae	21.43
Braconidae	7.69			Andrenidae	14.29

Measure of diversity of insects in selected oil palm plantations in Malaysia

A combined total of 12 orders of insects were found in different plantations across the sampled areas (Table 1). The order of insects found were Hymenoptera, Lepidoptera, Diptera, Homoptera, Odonata, Blattaria, Isoptera, Orthoptera, Coleoptera, Hemiptera, Dermaptera, and Thysanura. On average the most common order of insects found in the sampled fields of the three states in the study was Diptera (26.53%) and followed closely by Hymenoptera (21.26%). Lepidoptera was also found to be common in the sample fields, with over 15% of the sampled population of insects, while rest of the order of insect are less than 10% (table 1 and 2).

Table 2. The diversity of insects order in oil palm plantation.

Order	The diversity of insects in oil palm plantation/bolus												Average (Bolus)
	L1	%	B	%	L2	%	B	%	L3	%	B	Average	
Hymenoptera	7	17.95	0	0	18	25	2	28.57	10	20.83	0	21.26	14.26
Lepidoptera	4	10.26	0	0	12	16.67	0	0	10	20.83	0	15.92	0
Diptera	11	28.21	1	100	19	26.39	1	14.29	12	25.00	0	26.53	57.14
Homoptera	2	5.13	0	0	6	8.33	2	28.57	3	6.25	0	6.57	14.29
Odonata	1	2.56	0	0	0	0	0	0	0	0	0	0.85	0
Blattodea	3	7.69	0	0	2	2.78	0	0	1	2.08	0	4.18	0
Isoptera	1	2.56	0	0	1	1.39	1	14.29	0	0	0	1.32	7.14
Orthoptera	4	10.26	0	0	5	6.94	0	0	3	6.25	0	7.82	0
Coleoptera	3	7.69	0	0	5	6.94	0	0	6	12.5	0	9.05	0
Hemiptera	3	7.69	0	0	3	4.17	1	14.29	2	4.17	0	5.34	7.14
Dermaptera	0	0	0	0	1	1.39	0	0	0	0	0	0.46	0
Thysanura	0	0	0	0	0	0	0	0	1	2.08	0	0.69	0
Total	39	100	1	100	72	100	7	100	48	100	0	100	100

L: Location, %: Percentage of the insects in each location, B: Bolus

In the bolus of the swiftlet, however, the diversity of the insects is much reduced to only 5 different orders, with over 50% of the insect identified belonging to the order of Diptera. Hymenotera and Homoptera were found to be over 14% of the order insects found in the bolus of the swiftlet.

Specifically, insect abundance and distribution was found to be more in Location 1 and Location 2, having over 10 order of insects sampled out of the overall 12 order of insects found in all the three locations (Table 1).

Location 3 had 9 different orders of insects, one short of the other two locations. In location 2, Diptera and Hymenotera were the two orders with the largest relative abundance and distribution, over 26% and 25% respective.

Table 3. Paired T-test (comparison of the order of insects found in the oil palm plantation; Location1, 2, 3 and those found in the diet of edible swiftlet).

Location 1		
	Variable 1	*Variable 2*
Mean	3.25	0.083333333
Variance	9.840909091	0.083333333
Observations	12	12
Pearson Correlation	0.778004359	
Hypothesized Mean Di	0	
df	11	
T Stat	3.759211699	
P(T=t) one-tail	0.001579492	
T Critical one-tail	1.795884814	
P(T=t) two-tail	0.003158983	
T Critical two-tail	2.200985159	

Location 2		
	Variable 1	*Variable 2*
Mean	6	0.583333333
Variance	45.27272727	0.628787879
Observations	12	12
Pearson Correlation	0.494122811	
Hypothesized Mean Di	0	
df	11	
T Stat	2.943783053	
P(T=t) one-tail	0.006678536	
T Critical one-tail	1.795884814	
P(T=t) two-tail	0.0013357073	
T Critical two-tail	2.200985159	

Location 3		
	Variable 1	*Variable 2*
Mean	4	0
Variance	19.27272727	0
Observations	12	12
Pearson Correlation	0.534532145	
Hypothesized Mean Di	0	
df	11	
T Stat	3.156305459	
P(T=t) one-tail	0.004569453	
T Critical one-tail	1.795884814	
P(T=t) two-tail	0.009138906	
T Critical two-tail	2.200985159	

The results are a good reflection of the mean of the three locations that are sampled. Location 3 is also the location were 5 out of 5 orders of insects found in the bolus of the swiftlet were found. Most of the order of insect found in these bolus are Hymenoptera and Homoptera (28.5% each), followed by Diptera, Isoptera and Hemiptera (14% each). Similar identification was done for the insect sampled in location 3, with order Diptera among the leading order found (25%). However it must be noted that Lepodiptera had a significant presence in the entire three fields, almost the third largest order identified in all the location accounting for over 10%, 16% and 20% of the insects identified in the sampled areas in Location 1, 2 and 3 respectively. Diptera was the only order of insect found in the food bolus of swiftlet in Location 1 and the study could not obtain any food bolus from location 3 and thus no analysis was done in that respect.

Fig. 2. *Aerodramus fuciphagus*

The whole point of using a paired experimental design and a paired test was to control for experimental variability. Some factors we do not control in the experiment will affect the before and the after measurements equally, so they will not affect the difference between before and after. By analysing only the differences, therefore, a paired test corrects for those sources of scatter.

The null hypothesis (Ho) of the experiment is that there was no significant difference in the population of insects found in the field and those found in the diet of the swiftlet. This means that swiftlets, besides being a commercial venture to earn return on the proceeds of its edible swiftlets-nest, it can be used as an effect biological control for varieties of orders of insects. The alternative hypothesis (Ha) thus claims the opposite dimension, that is, there was a significant difference between the sample population and those found in the bolus of the edible swiftlets. SPSS software was used in the analysis of paired t-test and the results were analyzed below.

Fig. 3. Yellow pan trap used for insect sampling in oil palm plantation.

In this project, the critical level for rejection of the null H_0 had been set at $\alpha = 0.05$, that is at 95% confidence level. Thus we refused to concord with null hypothesis statistically if the p-value falls anywhere below $\alpha = 0.05$. This approach should be in agreement with the t-critical approach, which is set at $t = 2$, where all t-values obtained in the paired t-test that are above the critical limit will result in the rejection of the null hypothesis.

Location 1 Ladang Besout Sungkai Perak

In Location 1, the diversity of insects was higher than the other two locations which is 9 orders of insects are found from Hymenoptera, Coleoptera, Diptera, Lepidoptera, Orthoptera, Hemiptera, Homoptera, Blattodea and Thysanura which consists of 25 families. However for the boluses, 4 families Formicidae (Hymenoptera), Psycodidae, Ceratopogonidae and Asilidae (Diptera) were found.

The paired t-test conducted for the data collect in Location 1 is presented in the Table 3. The mean order of insect found in the field is 3.25 with variance of 9.8. This indicates that the number of insects belonging to a particular order is heavily skewed to the top three orders, while the rest of the nine others were not that common in the fields observed. This is more acute when compared with the bolus, which gives a mean of 1 order of insects being more dominant. The t-value of the paired t-test is 3.759, and thus statistically significant. We fail to accept the H_0 that the diversity of insect in the fields in location one and diet of the swiftlets in location one was the same. This is in tandem with p-value of 0.003 which is way less than $\alpha = 0.05$

Fig. 4. Malaise trap that has been set up during the sampling of insect in the oil palm plantation.

Location 2: Oil palm plantation in Kelantan

In Location 2, the insects found in the sampling were from 8 different orders which were Hymenoptera, Coleoptera, Diptera, Lepidoptera, Orthoptera, Hemiptera, Homoptera, and Odonata and consist of 26 families of insects (Table 1) which was not a very huge difference from Location 1. For the boluses, 6 families of insects were found which are Formicidae (Hymenoptera) and Cicadellidae, Miridae (Hemiptera),Tephritidae, Cuilicidae (Diptera),and Rhinotermitidae (Isoptera).

The mean order of insects found in location 2 was rather more even, representing 6 order of insect. It symbolizes the fact that the relative abundance and frequency of insect found in the respective fields in location 2 is higher. Even the t-value observed (t = 2.9) (Table 3), although statistically significant, represent a closer value to the t-critical (t = 2). Having said, it must be noted that even it diversity is much richer based on the number of representation by the orders of insects, it is not a full representation of the whole diversity composition of the fields of population sampled and insect identified in the bolus. H0 was failed to be proven right.

Location 3: Oil palm plantation in Pontian, Johor

In Location 3, the diversity of insects was merely small (Table 2) which is 7 orders of insects found in the sampling from Hymenoptera, Coleoptera, Diptera, Lepidoptera, Orthoptera, Homoptera and Isoptera which consists of 13 different insect families. However, there was no bolus obtained. Similarly observation can be made for Location 3 as well. With the mean order of insect standing at 4, the skewness of the 4 dominant orders identified in the field is manifested. Bolus comparison cannot be achieved in this area as there was no bolus obtained. This has diminished the significance of the paired t-test and thus will not take stake in this analysis.

Discussion

In natural or domesticated habitat of insects, climate, plant quality, and resource limitation are very crucial in determining the abundance and distribution (diversity) of insects. Climate, the prevailing atmospheric phenomena and conditions of temperature, humidity, wind, has profound influence on insect diversity, whether large scale such as typhoons or droughts, or small scale such as relative humidity (Porter *et al.,* 1991). These abiotic factors can have fundamental influences on the ecology of insects – ranging from reproductive success and dispersal to growth and interactions within and among species.

Similarly the quality of the plant in which the insects feed on is fundamental in sustaining a broad and rich base of insects (Strauss and Zangerl, 2002). But due to limited resources that will support live in particular habitat, insects will compete among themselves for survival growth. This concept was observed by Begon *et al.,* (1996), who gave following description

"Competition among living organism is an interaction between individuals, brought about by a shared requirement for a resource in limited supply, and leading to a reduction in the survivorship, growth, and/or reproduction of the competing individuals concerned."

There were great variations forms day to day in the species caught, depending on the weather and on where the birds were feeding and on the seasonal cycle of insect's life (Janzen, 1973). The insects are most numerous in the air on fine, warm, and still days and much scarcer on wet, cold or windy days (Lack, 1951). The location of bird house also one of the factors affecting the swiftlet diet. Bird house which is located in the centre or near of city, with the increase of houses and smoke reflect the abundance of insects which might have become scarcer than formerly and also the journey to the food source would presumably take the swifts too long (Elkins *et al.,* 2004).

Another factor that affects the result obtained is the bird house itself. Bird house building should provide good environment and accomplished some parameters for swiftlet breeding such as air temperature, relative humidity and air velocity (Hansell, 2000). In Location 3, no bolus was obtained because of less swiftlet populations in the bird house. This might due to unsuitable environment for the swiftlet to live and breed even though it is built near to oil palm plantation which has abundance of insects as a food source.

From the results obtained in the two analyses, we can conclude that the relative abundance and distribution of insects found in sampled oil palm fields in the three states are relatively diverse with 12 different orders of insects. Almost all of the orders of insects found in the fields were herbivores and representation to the insects found in most tropical rain forest. The two dominant orders of insects were Diptera and Hymenoptera, found in most sampled fields and bolus of edible-nest swiftlets. It was not possible statistically to link the diversity of insect found in the field and those in the food bolus of the edible-nest swiftlets, as it showed a statistically significant relationship.

Conclusion

Thus, amid the limitation of the project, it cannot be conclusive to imply that edible-nest swiftlet can be used as an effective biological control for most order of insect in the oil palm plantations. However, it is evident that it can be effective in certain order like Lepidoptera which is mostly pest in oil palm such as nettle caterpillars, bagworms and diamond back moths. The limitations of this project include the insufficient bolus collection that has impact the statistical analysis of the result, although appropriate parameters have been employed in the analysis. The time span of the project do not facilitate the collection of extensive raw data and the accessibility of secondary data is remote in this area of study. Although predator-prey relationship is one of the factors that affect the diversity of the prey (insects in this case) there are a variety of variables, biotic and abiotic that affects the diversity of insect, which were not measured in this project.

References

Tompkins D, Clayton D. 1999. Host resources govern the specificity of swiftlet lice: size matters. Journal of Animal and Ecology **68,** 489-500.

Kamarudin MI, M Anum. 2011. "Foraging activity of *Aerodramus fuciphagus* swiftlet over oil palm canopy and its effect on Elaeidobius spp pollinator population". In Proceeding 32nd Annual Conference of Malaysian Society of Animal Production. 23-24 o.

Fujita MS. 2012. Sustainable use of Rich Bird Diversity in "Biomass Society". Newsletter for Southeast Asian Studies Kyoto University. No 66 Autumn. 19-21 o.

Lourie SA, Tompkins DM. 2000. The diets of Malaysian swiftlets. Ibis **142,** 596-602.

Ibrahim SH, Baharun A. 2009. A study on suitable habitat for swiftlet farming. Journal of Civil Engineering **1,** 1-7.

Kamarudin MI. 2009. Development of domesticated swiftlet (A. fuciphagus) and establishing its husbandry practices in Malaysia. Dana R&D Pertanian Science Fund Research Project Summary.

Porter JH, Parry ML, Carter TR. 1991. The potential effects of climatic change on agricultural insect pests. Agricultural and Forest Meteorology **57,** 221-240.

Strauss SY, Zangerl AR. 2002. Plant-insect interactions in terrestrial ecosystems. Blackwell Publishing: Oxford, UK. 77-106.

Begon M, Harper JL, Townsend CR. 1996. Ecology: individuals, populations and communities. Blackwell Science Ltd.

Janzen DH. 1973. Sweep samples of tropical foliage insects: effects of seasons, vegetation types, elevation, time of day, and insularity. Ecology **54,** 687-708.

Lack E. 1951. The breeding biology of the swift *Apus apus*. Ibis **93(4),** 501-546.

Elkins N. 2010. Weather and bird behaviour. Bloomsbury Publishing.

Hansell M. 2000. Bird nests and construction behaviour. Cambridge University Press.