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The secrets in the twilight zone: The behaviors of litter cockroaches

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Content

1. Abstract

Opisthoplatia orientalis [1] (litter cockroach) is a kind of detritivorous insect that involves in material recycling.

In this project, our objectives are to investigate the homing behaviour and food preference of litter cockroach from a human managed area and a natural area and the significance of litter cockroach in the recycling of leaf litter.

From the data collected the experiments, it is believed that litter cockroach is a kind of group living species. However, we cannot conclude

Besides, the food preference of litter cockroaches from both artificial and natural environment is similar including *Eucalyptus calophylla* [2], *Gnetum parvifolium* [3] and *Malvaviscus arboreus var. penduliflorus* [4]. Litter cockroach also plays an important role in recycling of leaf litter as around 0.0809 gram of mass drop in leaf litter which is consumed by each litter cockroaches in 5 days was recorded. They are important in the recycling since the litter cockroaches can digest around 2.16% of their weight per day of the cellulose of the leaves.

2. Introduction

2.1 Introduction to the research topic

In Hong Kong, the most common cockroaches that can be seen in the residential areas and the restaurants are *Periplaneta americana* [5]. Some other cockroaches like *Opisthoplatia orientalis* (litter cockroaches) are also prevalent in wild. Litter cockroach has a silvery white line at the top edge of their bodies and do not have wings. Inspired by the findings of another group [6] joining the competition in 2010 on *Opisthoplatia orientalis*, we hope to carry out further investigation on the homing behaviour, food preference and significance on the recycling of leaf litter of litter cockroaches.

2.2 Objectives

1. To investigate the homing behaviour of litter cockroach from a human managed area and a natural area
2. To investigate the food preference of litter cockroach from a human managed area and a natural area
3. To investigate the significance of litter cockroach in the recycling of leaf litter

2.3 Research questions

1. Where can we find litter cockroaches?
    - Are litter cockroaches living in groups or alone?
    - Are litter cockroaches more abundant in artificially maintained parks or in the country-sides?
2. Do litter cockroaches return to the same resting place every day?
3. What do litter cockroaches eat?
    - Is there any food preference?
4. How important are litter cockroaches in the recycling of leaf litter?

2.4 Background information of *Opisthoplatia orientalis*

By using the website BioLib.cz [7], the cockroach found was identified as *Opisthoplatia orientalis*.

2.4.1 Classification [8]

Kingdom	Animalia
Phylum	Arthropoda
Subphylum	Hexapoda
Class	Insecta
Subclass	Pterygota
Order	Blattodea
Family	Blaberidae
Genus	Opisthoplatia
Species	*Opisthoplatia orientalis*

(Fig. 1) Litter cockroach in Tai Tam

3. Methodology

3.1 Field Study

	Date	Time	Venue	Event
1st field study	2017-02-25	2000-2200	Sai Tso Wan Recreation Ground (Lam Tin)	-Collection of data of the distribution of litter cockroach and environmental factors -Setting traps
	2017-02-28			-Collection of data of the distribution of litter cockroach and environmental factors - Collection of data from traps
	2017-03-08			-Collection of data of the distribution of litter cockroach and environmental factors
2nd field study	2017-03-11	2000-2200	Tai Tam Reservoir	-Collection of data of the distribution of litter cockroach and environmental factors -Setting traps
	2017-03-14			- Collection of data from traps

The two series of field studies were carried out at Tai Tam Reservoir and Lam Tin and three traps were set in both fields respectively.

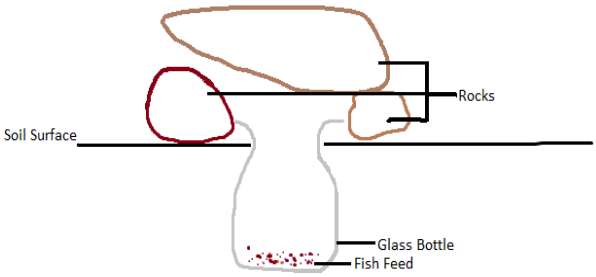
In Tai Tam Reservoir, we walked along the footpath (Fig. 5) and flipped over some rocks randomly at around 8 p.m.. The light intensity and surface temperature of the habitat where the litter cockroaches were found, measured by a photometer and an infra-red thermometer respectively. The data was recorded and was shown in appendix.

In Lam Tin, Sai Tso Wan Baseball Field was chosen as the site we studied. We walked along the rainwater drain beside the jogging trail (Fig. 6) at around 8 p.m. and recorded the litter cockroaches we had found.

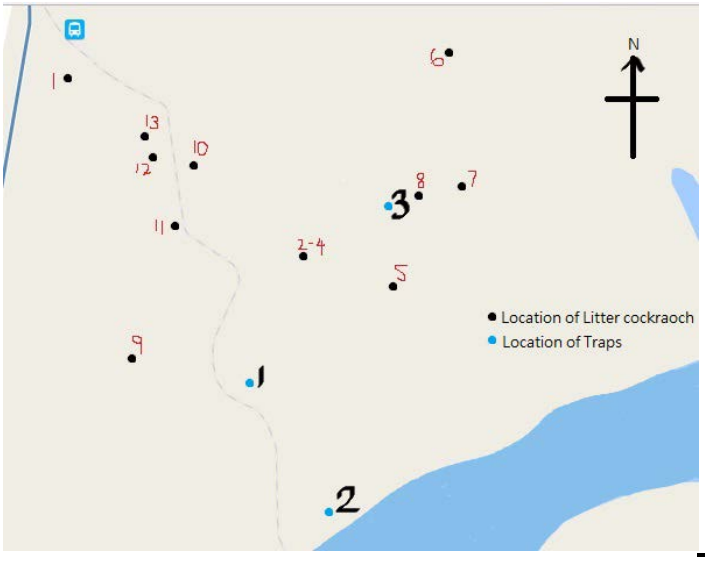
In both Tai Tam and Lam Tin, traps were set by burying a glass bottle underground and adding a small amount of 'Lucky Bamboo' Feed for tropical fish to it. The traps will be retrieved after 3 days. It is also a method to find out the distribution of litter cockroaches by counting the number of cockroaches collected in the traps. Fish food is used as it has a strong smell which is assumed to attract the litter cockroaches. A piece of rock is used to cover most of the opening of the glass bottle to prevent the rainwater from entering in which may lead to suffocation and kill the cockroaches.

After the whole experiment, all the litter cockroaches were released back to their original habitat.

(Fig.2)Trap at Tai Tam Reservoir (Fig.3) Trap at Lam Tin



(Fig. 4) Side view of trap



(Fig. 5)Location of litter cockroaches and traps in Tai Tam

(Fig. 6)Location of litter cockroaches and traps Lam Tin

3.2 Objective 1: Investigation on the homing behaviour of litter cockroach in a human managed area and a natural area

Experiment 1 was designed to find out the homing behaviour of the litter cockroach caught in Lam Tin (6/3-31/3) and Tai Tam Reservoir (16/3-31/3). The experiment was carried out in the school laboratory.

3.2.1 Principle of experimental design:

The litter cockroach were kept in four artificial hides. The artificial hides used were originally designed for keeping geckos. They are made of clay and water can be put on top to maintain the moisture inside the cave. This can provide an environment that is similar to their original habitat.

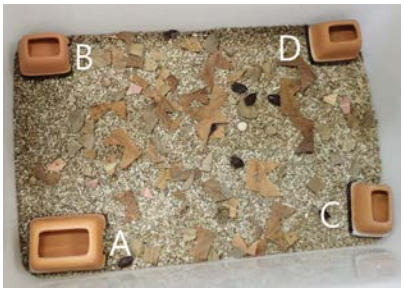
As litter cockroaches feed on dead organic matters, the bedding provided to the litter cockroach is made up of coarse sand. It ensures that litter cockroach only consumed the leaf litter rather than other matters.

Thermometers and hygrometer were used to record the temperatures and humidity. A stable environment was provided for the cockroach.

Size of the plastic containers: 64cm x 39cm x 43cm
Size of artificial hides: 6cm x 9cm x 6cm (B, C, D), 8cm x 12cm x 7.5cm (A)

3.2.2 Procedure

1. 8 litter cockroaches caught in Lam Tin and 19 litter cockroaches Tam Reservoir were marked with white acrylic paint.
2. Litter cockroaches caught in Lam Tin and Tai Tam Reservoir were put in big plastic boxes which were created as artificial habitat with four hiding place respectively.
3. The locations of each cockroach were recorded every day for a week.
4. The experiment was repeated four times for cockroaches caught in Lam Tin and two times for those caught in Tai Tam Reservoir
5. The litter cockroaches which stayed alive after the experiment were released into their original habitat.



(Fig. 7) Setting of the artificial habitat


(Fig. 8) Marking on the litter cockroach

3.3 Objective 2: Investigation on the food preference of litter cockroach from a human managed area and a natural area

3.3.1 Principle of experimental design:

First, the change in dry mass of each species of leaf litters in each trial was used to find out the food preference of litter cockroaches. Dry weight of leaf litters was measured as leaves may absorb moisture from the air, increasing in weight may lead to inaccurate measurement of the amount of leaf litter consumed. Therefore, the leaf litters were put in the oven set at 99 ℃ for 24 hours before and after putting them in each trial. 24 hours was assumed to be enough to obtain the dry mas as the dry weight data after drying for 18 hours is nearly equal to the dry weight after 24 hours according to Appendix (Table 23).

Second, the bite marks on leaf litters were also the evidences showing their food preference. In order to identify and count the bite marks from litter cockroaches, leaf litters were cut into artificial shapes with straight edges like rhombus and trapezium (Fig. 10). After each trial, by counting the bite marks on and measuring the dry mass of different leaf litters, the food preference could be known.

Third, as litter cockroaches feed on dead organic matters, the bedding used in this experiment was made up of coarse sand which would not be eaten by the cockroach. This could make sure the litter cockroaches had only consumed leaf litter but no other substances so as to get a more accurate result.

3.3.2 Trials

This experiment was carried out together with Experiment 1 (homing behavior of litter cockroaches).

Two trials were carried out on the litter cockroaches from Lam Tin:

- ➔ Objective of 1st trial: To find out the food preference of litter cockroaches with the leaf litter collected at the field study site.
- ➔ Objective of 2rd trial: To find out the food preference of litter cockroaches with the food mixed from both Lam Tin and Tai Tam Reservoir.

Two trials were carried out on the litter cockroaches from Tai Tam Reservoir:

- ➔ Objective of 1st trial: To find out the food preference of litter cockroaches using the leaf litter collected at the field study site.
- ➔ Objective of 2nd trial: To find out the food preference of litter cockroaches with the food mixed from both Lam Tin and Tai Tam Reservoir.

3.3.3 Procedures

1. Leaf litter was randomly collected from both Lam Tin and Tai Tam Reservoir.
2. The leaf litter collected from both sites was assorted into 8 species: *Eucalyptus calophylla, Bauhinia x blakeana, Malvaviscus arboreus var. penduliflorus, Hibiscus tiliaceus* [9], *Gironniera subaequalis* [10], *Gnetum parvifolium, Bambuseae sp.*, and one unknown species. (Cannot be identified) (Fig. 9)

(Fig. 9) Unknown species of leaf

Table 1 Showing the location of different species of leaves collected

Location	Species of leaf litter collected
Lam Tin	*Eucalyptus calophylla, Bauhinia x blakeana* and *Malvaviscus arboreus var. penduliflorus*
Tai Tam	*Hibiscus tiliaceus , Gironniera subaequalis , Gnetum parvifolium, Bambuseae sp.* and one unknown species

Table 2 Showing the origin of the leaf

	Species of leaf litter
Local species	*Bauhinia x blakeana, Gironniera subaequalis, Gnetum parvifolium, Hibiscus tiliaceus*
Foreign species	*Eucalyptus calophylla, Malvaviscus arboreus var. penduliflorus,*

3. The identified leaf litter was cut into artificial shapes with straight edges (Fig. 10) so that the bite marks of litter cockroaches could be identified.
4. The prepared leaf litter was put in the oven set at 99 ℃ for 24 hours in order to obtain the dry mass.
5. The initial dry mass of the leaf litter were weighed and the data were recorded.
6. The leaf litters collected from the two places were put together with the 6 and 19 litter cockroaches collected from Lam Tin and Tai Tam respectively.
7. The leaf litters were collected after 5 days and were put into the oven for 24 hours.
8. The final dry mass of leaf litter was weighed and the data were recorded.
9. The bite marks of the leaves were observed and counted.
10. Steps 4 to 9 were repeated with leaves from both places mixed for trial 2.

	
(Fig. 10) Leaf litter cut into artificial shape	(Fig. 11) Different types of leaf litter cut into artificial shape

Method of identification on the leaf litters

Sai Tso Wan: Species of leaf litter are identified via observing the labels marked on the trees.

Tai Tam:

1. The distinct characteristics of each species of leaf litter are identified.
2. The leaf species are identified according to their characteristics using an illustrated handbook [10] or by searching the characteristics on the internet [2-4, 9-12].

3.4 Objective 3: Investigation on the effectiveness of litter cockroach in the recycling of leaf litter

3.4.1 Principle of Experimental design:

In order to find out the effectiveness of litter cockroaches in the recycling of leaf litter, faeces of the litter cockroaches and the gut contents from a dead litter cockroach was also collected from the upper part of the gut and the contents are examined under the microscope. Grounded leaf litter is used to compare with those leaf litters which had pass through the gut of the litter cockroach. This can show the effectiveness of digestion.

By comparing the amount of cellular structure in grounded leave, the upper gut and the faeces, the content digested by the litter cockroach can be found. The presence of certain material in the faeces means that the litter cockroaches were not able to digest it. The acidified phloroglucinol is used to show whether lignin can be digested by litter cockroaches. The ability of litter cockroaches in recycling leaf litter can be known.

3.4.2 Procedure

1. Faeces of the litter cockroach were collected.
2. The faeces were softened in water.
3. The faeces were put on a slide and stained by acidified phloroglucinol (concentrated hydrochloric acid)
4. The faeces were observed under microscope in 100X and 400X.
5. The leaves collected were grounded and observed under microscope.
6. A dead cockroach was dissected to analyse the gut content under the microscope.
7. The images in the microscope were captured to record the material found in faeces.

4. Result

4.1 Result on objective 1: Investigation on the homing behavior of litter cockroach in a human managed area and a natural area

Lam Tin Trial 1 (6/3-10/3)

Table showing the number of litter cockroach in each house from 6/3 to 10/3

Date	Average temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
6/3	20.3	86	4	0	3	1
7/3	18.0	87	2	1	2	2
8/3	16.3	87	3	0	1	3
9/3	17.0	87	7	0	0	0
10/3	17.8	87	7	0	0	0

Table 3

Table showing the place where each cockroach is staying from 6/3 to 10/3

Cockroach number	No. of times at each house			
	A	B	C	D
1 (dead on 7/3)	0	0	0	1
2	3	0	1	1
3	2	0	1	2
4	3	0	2	0
5	5	0	0	0
6	4	0	1	0
7	3	0	1	1
8	3	1	0	1

Table 4

Lam Tin Trial 2 (13/3-17/3)

Table showing the number of litter cockroach in each house from 13/3 to 17/3

Date	Average Temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
13/3	21.7	87	7	0	0	0
14/3	19.1	87	6	0	0	1
15/3	16.8	86	4	0	2	0
16/3	17.8	87	4	0	0	2
17/3	18.1	86	5	0	0	1

Table 5

Table showing the place where each cockroach is staying from 13/3 to 17/3

Cockroach number	No. of times at each house			
	A	B	C	D
1 (dead on 7/3)	/	/	/	/
2	4	0	1	0
3	4	0	0	1
4	4	0	0	1
5	3	0	0	2
6	5	0	0	0
7	4	0	1	0
8 (dead on 15/3)	2	0	0	0

Table 6

Lam Tin Trial 3 (20/3-24/3)

Table showing the number of litter cockroach in each house from 20/3 to 24/3

Date	Average Temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
20/3	21.9	85	6	0	0	0
21/3	22.9	85	5	0	0	1
22/3	18.8	86	5	0	0	1
23/3	21.2	88	3	0	1	2
24/3	20.2	87	4	0	2	0

Table 7

Table showing the place where each cockroach is staying from 20/3 to 24/3

Cockroach number	No. of times at each house			
	A	B	C	D
1 (dead on 6/3)	/	/	/	/
2	4	0	0	1
3	4	0	1	1
4	2	0	1	2
5	4	0	0	1
6	5	0	0	0
7	5	0	0	0
8 (dead on 15/3)	/	/	/	/

Table 8

Lam Tin Trial 4 (27/3-31/3)

Table showing the number of litter cockroach in each house from 27/3 to 31/3

Date	Average Temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
27/3	18.9	86	1	0	3	2
28/3	20.6	84	1	1	3	1
29/3	21.7	85	1	0	1	4
30/3	21.9	84	1	2	3	0
31/3	20.1	87	0	1	3	1

Table 9

Table showing the place where each cockroach is staying from 27/3 to 31/3

Cockroach number	No. of times at each house			
	A	B	C	D
1 (dead on 6/3)	/	/	/	/
2	0	0	4	1
3	0	0	3	2
4 (dead on 31/3)	2	1	0	1
5	1	1	1	2
6	1	2	1	1
7	0	0	4	1
8 (dead on 15/3)	/	/	/	/

Table 10

Tai Tam Trial 1 (16/3-24/3)

Table showing the number of litter cockroach in each house from 16/3 to 24/3

Date	Average Temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
16/3	17.8	86	12	3	0	4
17/3	18.1	87	11	4	1	3
20/3	21.9	86	13	2	3	1
21/3	22.9	84	13	4	0	2
22/3	18.8	88	10	6	3	0
23/3	21.2	86	6	8	1	2
24/3	20.2	87	10	3	2	2

Table 11

Tai Tam Trial 2 (27/3-31/3)

Table showing the number of litter cockroach in each house from 27/3 to 31/3

Date	Average Temperature (°C)	Relative Humidity (%)	No. of cockroaches in each china houses for Leopard gecko			
			A	B	C	D
27/3	18.9	86	10	3	2	1
28/3	20.6	84	9	4	3	0
29/3	21.7	86	10	1	2	3
30/3	21.9	84	8	4	3	1
31/3	20.1	85	10	3	1	2

Table 12

Tai Tam Trial 1 (16/3-24/3)

Table showing the place where each cockroach is staying from 16/3 to 24/3

Cockroach number	No. of times at each house			
	A	B	C	D
1	6	1	0	0
2	5	2	0	0
3	4	2	1	0
4	6	1	0	0
5	0	7	0	0
6	7	0	0	0
7	3	0	1	3
8	0	7	0	0
9	5	0	2	0
10 (dead on 25/3)	2	4	1	0
11	4	1	0	2
12	6	0	0	1
13 (dead on 23/3)	5	0	0	0
14	2	1	1	3
15	6	1	0	0
16	5	0	0	2
17	2	1	2	2
18	3	2	0	1
19	4	1	2	0

Table 13

Tai Tam Trial 2 (27/3-31/3)

Table showing the place where each cockroach is staying from 27/3 to 31/3

Cockroach number	No. of times at each house			
	A	B	C	D
1	0	0	4	1
2	3	0	2	0
3	4	0	1	0
4	1	2	1	1
5	5	0	0	0
6	3	2	0	0
7	5	0	0	0
8	2	2	0	1
9	2	1	0	2
10 (dead on 23/3)	/	/	/	/
11	3	2	0	0
12	4	0	0	1
13 (dead on 23/3)	/	/	/	/
14	4	0	1	0
15	3	2	0	0
16	5	0	0	0
17	3	1	0	1
18 (dead on 26/3)	/	/	/	/
19	1	3	1	0

Table 14

From the results, about two-thirds of the litter cockroaches stay at the same house every day. Most goes to one particular house frequently (3-4 days in a 5-day trial).

Field Study results from Sai Tao Wan Recreation Ground

Table 15 Showing the number of litter cockroach found in different locations in Lam Tin

	Mean Light intensity (lx)*	Mean Temp. (℃)*	Rainfall (mm)	Number of individuals				
				A1	A2	E1	E2	Outside of a hide
25/2	0	11.3	0.7	12	14	10	7	2 (dead) 2 ♀ 2(unsexed)
28/2	0	14.8	0.0	16	16	8	8	3♀ 1juvenile
8/3	0	13.8	2.8	>15	8	7	14	5♀ 3♂ 4juvenile

* The light intensity and surface temperature of the habitat where the litter cockroaches were found, measured by a photometer and an infra-red thermometer respectively.

The location of the crevices of a rainwater drain (A1,A2,E1,E2) (Fig. 12)

From Table 15, most litter cockroaches found were staying at the crevices of a rainwater drain along a jogging trail. They were living together with at least seven members while only a few litter cockroaches left their refuges individually. It was found that during the rainy day (8/3), more litter cockroaches were found out of the crevices when compared to non-rainy days.

Field Study results from Tai Tam Reservoir

Referring to figure 5, each black dot represent one litter cockroach found.
From graph along the footpath of Tai Tam Reservoir, when we randomly flipped over the rocks, usually only one litter cockroach was found under one rock. This shows they live independently.

Table 16 Showing the comparison of homing behavior of the litter cockroaches living in the foot path of Tai Tam Reservoir and along the jogging trail in Sai Tao Wan Recreation Ground

	No. of litter cockroaches hiding in groups	No. of litter cockroaches left their refuge
Tai Tam (11/3)	3	10
Lam Tin (25/2)	47	1

4.2 Result on Objective 2: Investigation on the food preference of litter cockroach from a human managed area and a natural area

Lam Tin Trial 1 (20/3-24/3)

Table showing the change in weight of leaf litter and the no. of bite marks

Species	Initial weight (g)	Final weight (g)	Percentage Change (%)	No. of bite marks		No. of leaves without bite marks
				Large	Small	
Eucalyptus calophylla	2.05	1.85	-9.76	16	7	6
Bauhinia x blakeana	1.74	1.69	-2.87	3	13	22
Malvaviscus arboreus var. penduliflorus	1.87	1.84	-1.60	0	11	21
Total	5.66	5.38	-4.95	19	31	49

Table 17

Tai Tam Trial 1 (20/3-24/3)

Table showing the change in weight of leaf litter and the no. of bite marks

Species	Initial weight (g)	Final weight (g)	Percentage Change (%)	No. of bite marks		No. of leaves without bite marks
				Large	Small	
Gnetum parvifolium	3.41	2.95	-13.5	3	7	3
unknown	0.99	0.71	-28.3	13	20	13
Hibiscus tiliaceus	1.25	1.02	-18.4	8	2	2
Bambuseae sp.	2.36	2.34	-0.847	0	14	48
Gironniera subaequalis	1.95	1.93	-1.03	0	7	0
Total	9.96	8.95	-10.1	24	50	66

Table 18

Trial 2 (27/3- 31/3)

Table showing the change in weight of leaf litter

Species	Weight of leaf litter in the box with cockroaches from Tai Tam (g)		Percentage Change (%)	Weight of leaf litter in the box with cockroaches from Lam Tin (g)		Percentage Change (%)
	25/3	30/3		25/3	30/3	
Eucalyptus calophylla	3.24	2.56	-21.0	2.98	2.53	-15.1
Bauhinia x blakeana	0.83	0.81	-2.41	0.52	0.51	-1.92
Malvaviscus arboreus var. penduliflorus	0.90	0.84	-6.67	0.93	0.90	-3.23
Gnetum parvifolium	0.90	0.80	-11.1	1.19	0.94	-21.0
unknown	0.39	0.36	-7.69	0.28	0.25	-10.7
Hibiscus tiliaceus	0.82	0.71	-13.4	0.57	0.49	-14.0
Bambuseae sp.	1.05	0.94	-10.5	0.78	0.75	-3.85
Gironniera subaequalis	0.90	0.88	-2.22	0.73	0.70	-4.11
Total	9.03	7.9	-12.5	7.98	7.07	-11.4

Table 19

(Fig. 13) Bite marks on leaf litter

After each trial, the percentage change in different species of leaves were calculated. The percentage decrease of leaves *Eucalyptus calophylla* (Fig.14) and *Gnetum parvifolium* is the largest.

According to table 17, *Eucalyptus calophylla* has the greatest percentage decrease (-9.76%) in dry mass among different types of leaves which were found in Lam Tin. Most litter cockroaches in Lam Tin consumed *Eucalyptus calophylla*.

According to table 18, the unknown leaf has the greatest percentage decrease (-28.3%) in dry mass among different types of leaves which were found in Tai Tam. Most litter cockroaches in Tai Tam consumed the unknown leaf. The consumption is less significant in the last trial.

According to table 19, with the leaves mixed from both Lam Tin and Tai Tam, for the litter cockroaches in Lam Tin, *Gnetum parvifolium* has the greatest percentage decrease (-21.0%) in dry mass among different types of leaves. For the litter cockroaches in Tai Tam, *Eucalyptus calophylla* (-21.0%) has the greatest percentage decrease in dry mass among different types of leaves.

The consumption of *Eucalyptus calophylla* and *Gnetum parvifolium* are the largest among different trials. *Eucalyptus calophylla* is from Western Australia [11] which is a foreign specie introduced to Hong Kong. *Gnetum parvifolium* can be found in Southeast Asian [12] which is a local species. This shows that litter cockroach have no preference to local species than foreign species.

It was found that the litter cockroaches in Lam Tin consumed *Eucalyptus calophylla* most when they only fed on the leaf litter from Tai Tam but they consumed *Gnetum parvifolium* most when the leaf was mixed. The percentage decrease in weight of *Gnetum parvifolium* in second trial is even larger than that of *Eucalyptus calophylla* in the first trial. While the litter cockroaches in Tai Tam consumed unknown leaf most when they fed on the leaf litter from Tai Tam but consumed *Eucalyptus calophylla* most when the leaf was mixed. Both of the litter cockroaches from Lam Tin and Tai Tam changed their food preference when their food was mixed.

Table 20 Showing the amount of leaf litter consumed by litter cockroaches in 5 days

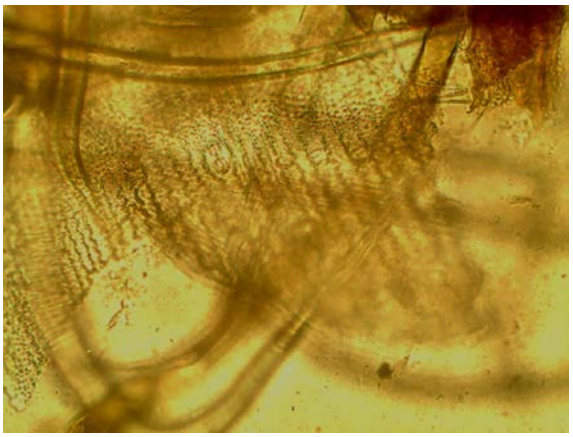
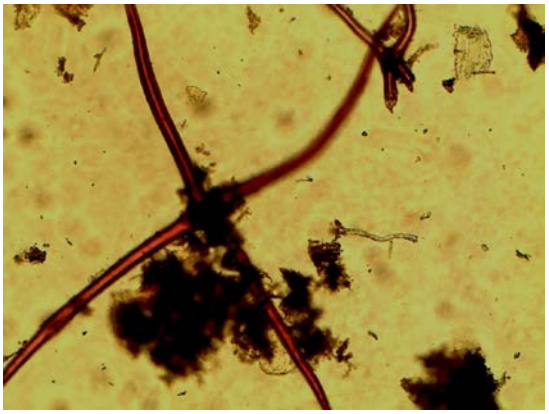
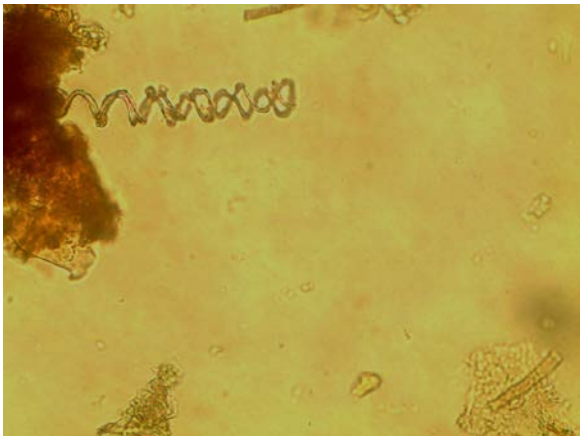
	Amount of leaf litter consumed by litter cockroaches (g/litter cockroach)*			
	Trial 1	Trial 2	Average	Final average of Lam Tin and Tai Tam
Lam Tin	0.0467	0.152	0.0994	0.0809
Tai Tam	0.0543	0.0706	0.0624	

*Amount of leaf litter consumed per litter cockroaches
= amount of leaf litter consumed in 5 days (g) / number of litter cockroaches
Number of litter cockroaches in Lam Tin: 6 adults in both trial 1 and 2
Number of litter cockroaches in Tai Tam: 8 adults plus 11 juveniles in trial 1
8 adults plus 8 juveniles in trial 2
* Some litter cockroaches were died during the experiment, the calculation is adjusted according to their proportion contributed to the recycling of leaf litter

*Average weight of litter cockroach: 3.75g
*Percentage of leaf litter weighs on weight of litter cockroach: 2.16%
Percentage of leaf litter weighs on weight of litter cockroach
= Final average/ weight of litter cockroach

4.3 Result on Objective 3: Investigation on the significance of litter cockroach in the recycling of material

The lignin was stained by using the above method. There are many cells observed in the grounded leaves and upper gut content of litter cockroach (Fig. 14& Fig. 15). However, only lignin of plants and remains of epidermal hair were observed in the faeces (Fig.16 & 17).

	
(Fig. 14) Artificially ground leaf tissue showing cellular structures (400X)	(Fig. 15) Upper gut content of litter cockroach showing undigested leaf epidermis (400X)
	
(Fig. 16) Faeces of litter cockroach showing undigested epidermal hair (100X)	(Fig.17) Faeces of litter cockroach showing undigested lignin (400X)

4.4 Extra findings

1. Different in adult to juvenile ratio

Table 21 Showing the comparison of age of the litter cockroaches living in the foot path of Tai Tam Reservoir and in the crevices of jogging trail in Sai Tao Wan Recreation Ground

	No. of adults	No. of juveniles	Adult: juvenile ratio
Tai Tam	2	11	1:5.5
Lam Tin	35	3	11.7: 1

During the field study in Lam Tin, only three out of the 38 litter cockroaches found are juvenile field study in Tai Tam, only two out of the 13 little cockroaches found are adults.

2. On the 29th-31st March, 3 parasitic horsehair worms [13] (Fig.18 & 19) were found.

(Fig.18) Parasitic horsehair worms

(Fig.19) Parasitic horsehair worms

3. During the field studies in Lam Tin, some other animals were found living together with the cockroaches in the crevices. *Physopelta gutta* (Fig. 20) and Asiatic painted frogs (*Kaloula pulchra*) (Fig.21).

(Fig. 20) *Physopelta gutta* in a crevice

(Fig.21) *Kaloula pulchra* in a crevice

4. The creatures we captured from the traps are mostly not litter cockroaches. Only small invertebrates were caught. The number of litter cockroaches captured by this method in the two places is very small.

Results of trap setting experiment

Three pitfall traps were set at two different locations for 72 hours using fish food as bait.

Table 22 Showing different organisms found in the traps

Site	Trap 1	Trap 2	Trap 3
Sai Tao Wan Recreation Ground (Fig.5)	1 juvenile litter cockroach	/	/
Tai Tam(Fig.6)	2 ants (Fig.22)	3 millipedes (Fig.23) 1 earwig (Fig.24) 2 small crickets (Fig.25)	1 very small litter cockroach

(Fig.22) Ants

(Fig.23) 3 Millipedes

(Fig.24) Earwig

(Fig.25) 2 Small crickets

5. Discussion

5.1 Discussion on Objective 1: Investigation on the difference in homing behaviour of litter cockroach in a human managed area and a natural area

The litter cockroaches found in Tai Tam were living individually and litter cockroaches in Sai Tso Wan are living in groups during our field trips. A reason suggested is that the space is too limited in Sai Tso Wan and they have no choice but to live together. Therefore, in our experiment, as much space as possible was provided.

However, they still like to stay in the same house more: about two-thirds of the litter cockroaches stay at the same house every day. Even the litter cockroaches collected from Tai Tam preferred staying together more during our experiments.

The possible reason why the litter cockroaches from Tai Tam stayed together in our experiments is that the plastic container is too small. Another reason is that the number of hides is too small as well, only four clay gecko houses are used in each plastic container, they may not stay together if more hiding places were provided. These are also the limitations of our experiments.

About the field study result, according to table 15, the litter cockroaches in Lam Tin were found more active during the rainy day where 12 were found outside the hide compared with around 6 were found in normal days. The condition under damp area may be favorable for the reproduction of litter cockroaches.

5.2 Discussion on Objective 2: Investigation on the food preference of litter cockroach

Eucalyptus calophylla and *Gnetum parvifolium* are consumed the most which align with the numbers of bite marks on the leaf litter. Therefore, the results are highly reliable. The largest percentage error in measuring the weight of leaf litter is only 0.005/0.51 x100%=0.98%, which is quite small. The result is accurate. A possible reason is the special fragrances [15] from the leaves which attract the litter cockroaches.

According to table 20, the amount of leaf litter consumed during trials in Lam Tin varies. The amount of leaf litter consumed by litter cockroaches is 3 times greater in trial 2 than trial 1. One possible reason is that litter cockroaches had got used to the living environment and their appetite had changed. Also, the average amount of leaf litter consumed per litter cockroaches in Tai Tam (0.0624) is smaller than that of Lam Tin (0.0994). It is because the adult to juvenile ratio is almost 1:1 in the setup of Tai Tam but only adults were put in the setup of Lam Tin. Juvenile may consumed less food than adult.

There are some limitations in this experiment, total 5 litter cockroaches died during the experimental period. This indicates that some cockroaches may not be in healthy conditions. The food preference of the 'sick' cockroaches may not be the same as those healthy ones and cannot show the exact amount of leaves consumed.

5.3 Discussion on Objective 3: Investigation on the significance of litter cockroach in the recycling of material

According to section 4.3, the cell-like structures appeared in the upper gut content but not in the faeces. Refer to a finding conducted by Michael M. Martin, C. G. Jones and E. A. Bernays in 1991 [16], it was proposed that the digestion in insects is usually mediated by microorganisms and the microorganisms that normally reside in their hindguts. This can explain why the cellulose is being digested after passing through the gut.

As shown in Table 20, 0.0809 gram of leaf litter was consumed by one litter cockroach. This showed that litter cockroaches can digest the cellulose and recycle leaf litter. They are important in the recycling since the litter cockroaches can digest around 2.16% of their weight per day of the cellulose of the leaves.

5.4 Discussion on Extra Findings

1. According to Table 21, the adult to juvenile ratio was totally different in two places. A possible reason is the use of chemical fertilizers in Sai Tso Wan, a human-managed area. The artificial fertilizers may contain toxic substances, these harmful materials accumulates in the producers and builds up to a high level when transferred to higher trophic levels. Thus, the use of fertilizers is more detrimental to predators. Fewer predators are present in Sai Tso Wan.

2. Horsehair worms come out to lay eggs when they are mature inside the host [14] in order to complete their life cycles. At late March, the temperature and the relative humidity become higher, and these conditions may be favourable for the hatching of horsehair worm eggs. Moreover, they were only found in the plastic container holding the litter cockroaches captured in Tai Tam. None was found in the container holding litter cockroaches captured in Lam Tin. The artificially made area may not be favorable to the survival of the horsehair worms.

3. Two different types of animals were found to live together with the litter cockroaches in Lam Tin. As *Physopelta gutta* is herbivorous which would not cause life danger to the litter cockroaches, they can live together. However, *Kaloula pulchra* are carnivores but the litter cockroaches did not escape. One of the reason explaining this may be *Kaloula pulchra* did not live in the crevice permanently but was just passing by.

4. Only small invertebrates were caught in the trap setting experiment which is different from the expected result. Therefore, the design of this trap (Fig. 4) may not be suitable for capturing litter cockroaches. The fragrance of fish food may not be attractive to the litter cockroach as they mainly consume leaf litter as food. The setting of traps can be improved by putting leaf litter into the traps as this is the food that they usually intake.

5.5 Question for further investigation

1. Why the Asian painted frog can live with litter cockroaches although the frog is a carnivore?
2. What is responsible for the digestion of cellulose?
3. Are the horsehair worms universal or host specific?
4. Why is the adult to juvenile ratio different in two areas?

6. Conclusion

In our research, we were not able to find their homing behaviour. Based on the experiment we had done, it shows that both litter cockroaches from artificially made park and country-sides were more likely to stay together as a group in the plastic boxes. But we failed to explain why the litter cockroaches in Tai Tam were found independently during the field studies.
More adult cockroaches were found in artificially made parks, while more juvenile cockroaches were found in the country-sides.

From the experiment, they prefer eating *Eucalyptus calophylla* from Western Australia and *Gnetum parvifolium* from Southeast Asian.

According to Section 4.1, two-third of litter cockroaches return to the same resting place every day which shows that they tend to stay in the same place at most of the time. However, we cannot conclude whether they have homing behavior or not as we could not make observation in the wild.

Litter cockroach also plays an important role in recycling of leaf litter as around 0.0809 gram of mass drop in leaf litter which is consumed by each litter cockroaches in 5 days was recorded. They are important in the recycling since the litter cockroaches can digest around 2.16% of their weight per day of the cellulose of the leaves.

7. Bibliography

1. Opisthoplatia orientalis. http://www.inaturalist.org/taxa/347785-Opisthoplatia-orientalis. Retrieved April 21, 2017
2. Tree http://www.toyogreen.com/plant%20species/Tree/Eucalyptus%20calophyllaCHN.htm Retrieved April 24, 2017
3. Tree Canyon http://www.hktree.com/tree/Gnetum%20lofuense.htm.Retrieved April 24, 2017
4. The Green Touch http://www.treehk.com/%E5%9E%82%E8%8A%B1%E6%87%B8%E9%88%B4%E8%8A%B1. Retrieved April 21, 2017
5. American cockroach https://en.wikipedia.org/wiki/American_cockroach. Retrieved April 21, 2017
6. Searching for Nature Stories http://ifieldstudy.net/sns/outstanding_reports/2010/files/team6_report.pdf. Retrieved April 21, 2017
7. Opisthoplatia orientalis http://www.biolib.cz/en/image/id224103/ Retrieved April 25, 2017
8. Opisthoplatia orientalis. http://www.inaturalist.org/taxa/347785-Opisthoplatia-orientalis. Retrieved April 21, 2017
9. 2008 Field guide to trees in Hong Kong countryside. Agriculture, Fisheries and Conservation Department
10. Field guide to trees in Hong Kong's countryside (ISBN： 978-988-99377-3-7). Retrieved April 21, 2017
11. Eucalyptus urophylla http://www.treehk.com/%E5%B0%BE%E8%91%89%E6%A1%89. Retrieved April 21, 2017
12. Gnetum https://en.wikipedia.org/wiki/Gnetum. Retrieved April 21, 2017
13. Nematomorpha http://eol.org/pages/1539/details/. Retrieved April 21, 2017
14. Horsehair Worms https://entomology.ca.uky.edu/ef613. Retrieved April 21, 2017
15. How to Maintain the Smell of Eucalyptus Leaves http://www.ehow.com/how_7607757_maintain-smell-eucalyptus-leaves.html. Retrieved April 21, 2017
16. The Evolution of Cellulose Digestion in Insects https://www.jstor.org/stable/55614?seq=1#page_scan_tab_contents. Retrieved April 21, 2017

8. Appendix

Table 23 Initial dry mass of leaves for the feeding experiment of Sai Tso Wan Recreation Ground specimen (trial 1)

Date and time after putting in oven Plant species	Mass of leaves after putting in oven for different period of time (g)	
	14/3/17, 12:50	14/3/17, 17:00
Malvaviscus arboreus var. penduliflorus	1.61	1.58
Eucalyptus urophylla	2.19	2.19
Bauhinia x *blakeana*	1.69	1.69

Note:
The leaves had been put in the oven set at 99 ℃ on 13/3/17, 1700.