

# Final Report: Kampung Admiralty Biodiversity, Social & Ecosystem Services Audit

Submitted 2 October 2018. By Dr. Anuj Jain  
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## 1.0 Introduction

A combination of several greening typologies exists at Kampung Admiralty (KA). These include the water feature and surrounding greenery on the ground plane, planter beds at level 3 and 6, sky gardens and a community farm. Given that different species respond to different building heights and typologies, we quantified the diversity (which species) and abundance (how many) of species found in and/or using KA.

Measures of diversity become particularly meaningful when compared with reference sites (e.g., a nearby park) so one can begin to tease apart the impact of the building greenery with the surrounding environment. For this reason, we set up the audit to compare the biodiversity at KA with its surroundings – a roadside transect with wayside trees in KA's immediate vicinity, a managed park (Woodlands Admiral Garden) and another park in the neighbourhood (Woodlands Crescent Park). We also conducted social surveys about user perceptions towards KA's greenery to inform how people perceive greenery and biodiversity at a building in Singapore.

## 2.0 Methodology



**Figure 1 – Relative locations of the Road Transect, Woodlands Crescent Park (top), Kampung Admiralty (centre) and Woodlands Admiral Garden (bottom).** Woodlands Crescent Park and Kampung Admiralty are ~ 530 meters apart. Kampung Admiralty and Woodlands Admiral Garden are ~ 100 meters apart. The boundary around the marked sites indicate the surveyed areas.

## 2.1 Site recce

A site recce was conducted on 1 July 2018 during which time locations to survey inside KA and nearby habitats were determined. Nearby habitats included the road transect, Woodlands Admiral Garden and Woodlands Crescent Park.

## 2.2 Biodiversity surveys

Six biodiversity surveys were conducted during conditions of good weather from July to September 2018 at four locations (see below). These comprised of 5 day surveys and one evening/night survey (1 Sep 2018).

**Table 1 – Survey effort for biodiversity surveys across locations**

Date	Kampung Admiralty	Woodlands Admiral Garden	Woodlands Crescent Garden	Road Transect	Time
28/Jul/18	1 hr	30 m	30 m	15 m	8 - 10:30 AM
31/Jul/18	1.5 hrs	30 m	30 m	15 m	8 - 11:00 AM
10/Aug/18	1 hr	30 m	30 m	15 m	8 - 10:30 AM
24/Aug/18	1 hr	30 m	30 m	15 m	8 - 10:30 AM
25/Aug/18	3.5 hrs	-	-	-	5:15 - 8:45 PM
1/Sep/18	2 hrs	30 m	30 m	15 m	6 - 8:30 PM
9/Sep/18	1.5 hrs	30 m	30 m	15 m	8 - 11:00 AM
9/Sep/18	1 hr	-	-	-	5:45 - 6:45 PM
<b>TOTAL</b>	<b>12.5 hrs</b>	<b>3 hrs</b>	<b>3 hrs</b>	<b>1.5 hrs</b>	

In addition, 2 night surveys were conducted on 25 Aug 2018 and 9 Sep 2018 at KA. Overall, KA was surveyed on 7 days and the other three locations on 6 days.

All biodiversity was recorded during each survey. These included birds, butterflies, dragonflies, other insects, mammals, amphibians, reptiles, snails, fish etc. Observations on the feeding behaviours of observed animals were made. Binoculars were used to identify the animals and where possible, a photographic record was made. The number of species and the number of individuals (per species) were recorded.

At KA, the water feature/pond and vegetation on level 1 and level 3 as well as the gardens on level 6, 8, 9 and the community farm were visited. Level 4 was surveyed from level 6 due to accessibility. We spent more time at level 8, 9 and the community farm as they had the most numerous and diverse plantings.

### Data analysis

To quantify if we recorded enough number of species at each site during the surveys, we created species accumulation curves using the statistical computing software RStudio Version 1.1.442. A species accumulation curve is a graph that records the cumulative number of species as a function of the cumulative effort expended searching for them using a statistical technique of 'rarefaction'. Rarefaction can be used to predict the number of species that are expected to be present at a site based on the number of species and their abundance (number of individuals) recorded during the surveys. The number of predicted/expected species were calculated based on the bootstrap index.

The outputs are an average of simulating 1000 iterations. They represent the number of species that can be expected on an average if the biodiversity surveys were conducted 1000 times.

### Biodiversity projections

Species (S) and area (A) follow a power law function governed by the equation  $S = c * A^z$  where c and z are constants. To derive a species-area function for KA, data from level 3 – 6 (planting areas = 0.135 ha) and level 7 – 9 (planting area = 0.074 ha) were treated as independent observations. This is not entirely accurate because biodiversity at both areas interacts with each other and is, therefore, not independent. However, for lack of other buildings in Singapore with

similar planting intensities and diversity as KA that can be treated as replicates, this was the only dataset available. Overall, the total planting/vegetation area at KA that was surveyed (includes level 1, thoroughfare, levels 3 – 6, levels 7 – 9)  $\sim 4037 \text{ m}^2 \sim 0.4 \text{ ha}$ . Projections were made for species diversity at different vegetation area.

### 2.3 Social surveys

To understand the perceptions of a variety of stakeholders about the greenery at KA, we asked the building users (people who live there or visit) a set of questions (see Appendix 6) on 3 days – 25 Aug, 1 Sep and 9 Sep 2018. The user groups were selected on a random basis to get a balanced viewpoint across age groups, gender, race, appearance etc. The age and race of respondents were profiled by the surveyors. The biodiversity and social survey team comprised of 3 people.

### 2.4 Ecosystem service assessments

The ecosystem services of KA were evaluated using the Ecosystem Services Identification & Inventory (ESI) tool (<http://www.esiitool.com/>).

To do this, KA's greenery was first classified into 3 main vegetation types based on the vegetation density and characteristics –

- i) Ground vegetation – vegetation on level 1 including the aquatic plants around the water feature and thoroughfare vegetation. The vegetation characteristic was largely multi-layered consisting of a mix of shrubs and trees (typically of height 3 – 5 metres). This total area was  $1943 \text{ m}^2$ .
- ii) Multi-layered roof gardens – vegetation on roof gardens from level 3 – 9 where it comprises of multi-layered plantings consisting of a mix of shrubs and trees. The trees were generally smaller than the ground plane and varied from 2 – 5 metres in most cases. This vegetation type covered an estimated area of  $1743 \text{ m}^2$ . The roof gardens on level 8 and 9 also had a slope feature because of the ramps that lead up to the community farm.
- iii) Shrubs – patches of vegetation on level 2, 6, 7, 8 and 9 which are dominated by grasses or shrubs. No trees are present in this vegetation type. The shrubs layer generally varied from 1 – 3 ft and covered an estimated area of  $873 \text{ m}^2$ .
- iv) Green wall – which occupies levels 2, 3, 4, 6, 7, 8, 9 on the façade facing the Admiralty MRT. Initially, the green wall was hypothesized as if it was on the ground plane and formed an imaginary ground of short shrubs of equivalent mesh area. However, this approach would have limitations because it cannot account for true climber heights. Additionally, soil plays a key component in ecosystem service and it can only be accounted for if the soil area, which the climbers are grown on, is factored in the calculations. Therefore, the planter bed area for the green wall was used as a proxy for the amount of ground cover for this vegetation type. It covered an area of  $24.5 \text{ m}^2$  per level and therefore, a total area  $\sim 171.5 \text{ m}^2$  across 7 levels. The average height of a climber, particularly the woody growth, was considered to be 2 – 3 m.

The total green areas of KA, in the context of ecosystem services, is  $4730 \text{ m}^2$  which is **53%** of the total building plot area of  $8980 \text{ m}^2$ . Therefore, to reference the ecosystem services of KA's vegetated areas with a pristine rainforest (reference habitat) of the same size as KA's building footprint, a **scaling factor of 0.53** needs to be applied.





**Figure 2 – The different vegetation types at KA - i) Ground vegetation, ii) multi-layered roof gardens, iii) shrubs and iv) greenwall**

Next, KA's green areas were virtually mapped in the ESII Tool project workspace. Physical site conditions such as soil type/composition, vegetation type and height, density, percentage coverage of standing live/dead stems, trunks, aerial cover, slope gradient, etc. were entered on the iPad-based workspace during field data collection.

The analysis generated outputs which relate to 4 types of ecosystem services – provisioning, regulating, supporting and recreational. The output parameters were provided as percentage performance which are referenced to the ecosystem services of an undisturbed pristine site calculated based on the defined latitude and abiotic (weather, wind etc.) conditions.



**Table 2 – The number of recorded (actual) and projected species across the four locations.** Refer to the section on data analysis for details on the calculation of projected species.

\* Site area was calculated using - [http://www.mapdevelopers.com/area\\_finder.php](http://www.mapdevelopers.com/area_finder.php)

Location	Area (hectares)	All groups		Birds		Insects		Mammals & other groups	
		Species (actual)	Species (projected)	Species (actual)	Species (projected)	Species (actual)	Species (projected)	Species (actual)	Species (projected)
Kampung Admiralty total	0.95	50	56.5 ± 4.0	19	21.7 ± 1.7	22	25.7 ± 2.3	9	9.1 ± 1.1
Road transect	0.2	15	18.9 ± 2.4	9	11.1 ± 1.3	5	6.4 ± 1.6	1	1.3 ± 0.5
Woodlands Admiral Garden	1.05	33	39.2 ± 3.5	15	17.3 ± 1.4	15	18.2 ± 1.9	3	3.8 ± 1.0
Woodlands Crescent Park	1.9	44	51.6 ± 4.1	22	24.7 ± 1.7	16	19.1 ± 2.4	6	7.7 ± 1.9

### 3.0 Results

#### 3.1 Biodiversity surveys

##### **The recorded number of species across locations**

Kampung Admiralty (KA) had the highest total species diversity (50 species), second highest bird diversity (19 species), highest insect diversity (22 species) and highest mammals, amphibians, reptiles and fish diversity (9 species; Table 2; Appendix 1,2 and 3).

Woodlands Admiral Garden, comparable in size to KA, had only 33 species. Woodlands Crescent Park which was nearly double the size of KA had 44 species. All the three habitats comprised of landscaped vegetation (no natural forest) and high human visitation rates and, therefore, comparable in terms of habitat quality and use.

The road transect, only 0.2 ha in size, had much lower diversity (only 15 species in all).

For birds, Woodlands Crescent Park had the highest diversity (22 species) with a flock of Red-breasted Parakeets and Pink-necked Green Pigeons occasionally seen roosting at night. It also had relatively uncommon urban species such as the Oriental Magpie-Robin and Pied Triller (Appendix 1). Kampung Admiralty had the second highest bird diversity (19 species) with species with a healthy mix of birds ranging from the nectar-feeders (Olive-backed Sunbirds, Scarlet-backed Flowerpecker) to insect eaters (Long-tailed Shrike). Two raptors – Brahminy Kite and White-bellied Sea Eagle were also observed circling above Kampung Admiralty likely in search of food.

For insects, Kampung Admiralty had the highest diversity (22 species). Of these, the community farm had a particularly high diversity and abundance of bees (5 species) and dragonflies.

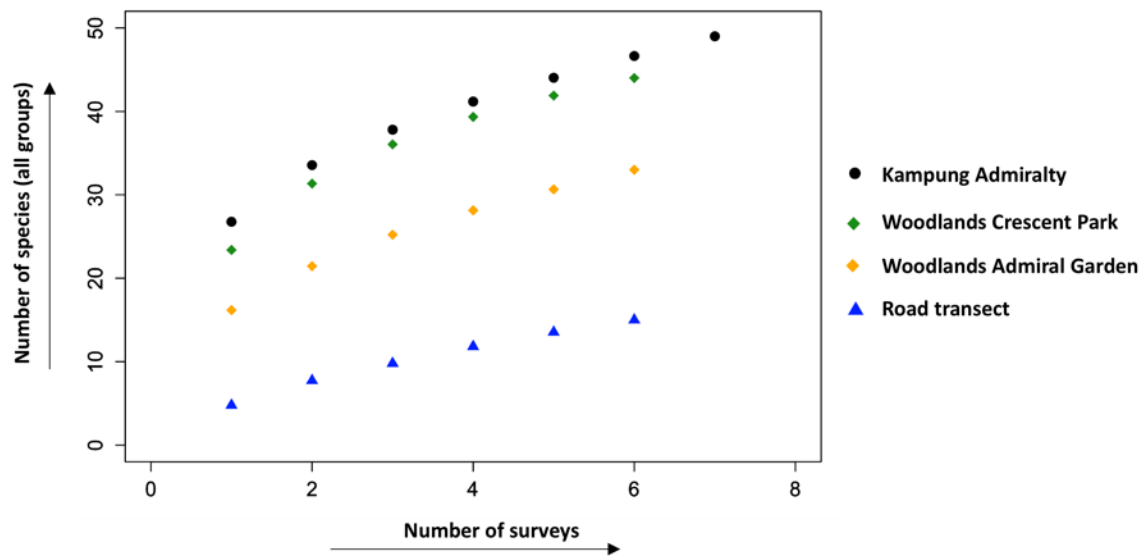
For mammals, Woodlands Crescent Park had the highest diversity (4 species) with both fruit and insect bats as well as the Plantain Squirrel and House Rat recorded. Kampung Admiralty had a healthy population of fruit bats observed on trees at level 6, 8 and above. An insect bat was recorded around level 1 of the building near the street lights.

Kampung Admiralty had the high diversity of amphibians, reptiles and fish because of the water features where non-native species such as the Red-eared Slider and Koi fish were observed.

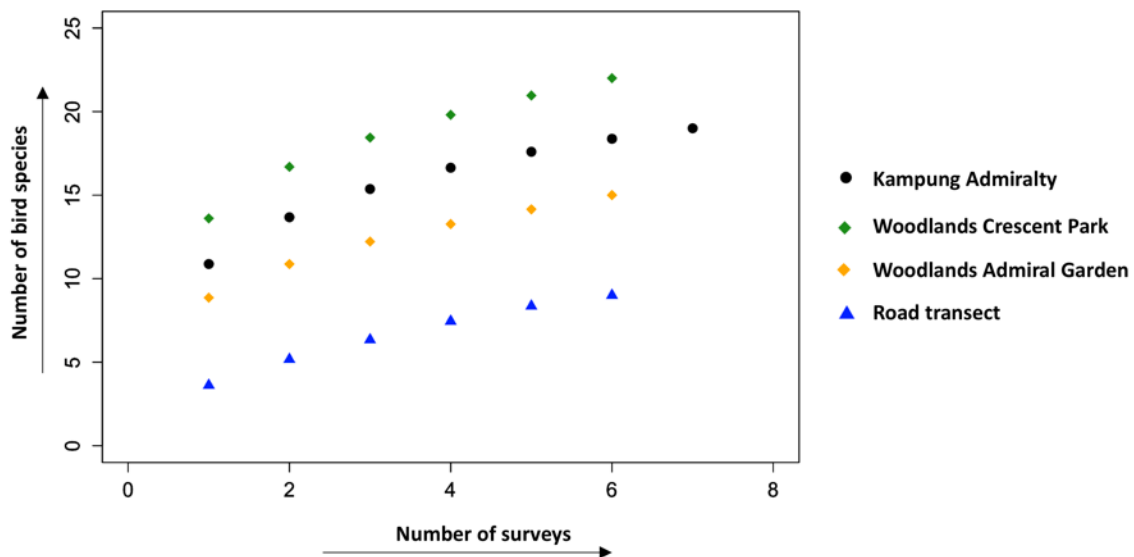
##### **Expected number of species across locations**

Figure 3 – 6 show that the species accumulation curves across the four locations. Statistical analyses suggest that KA may only have a few more species ( $56.5 \pm 4$  species; Table 2) suggesting we have captured over 80% that may be present there. The same applies to other locations.

A comparison of KA and OASIA shows that KA has nearly 3 times the total number of species and nearly 4 times the total number of birds as OASIA (Figure 7). KA had twice the insect diversity as OASIA. No bats were observed using OASIA despite that they were present on the grass patches around the building. In contrast, KA had a healthy assemblage of fruit and insect bats.



**Figure 3 – Species accumulation curves across four locations for all groups of animals** (birds, insects, mammals, etc.). The x-axis represents the number of surveys conducted at each site and the cumulative number of species present at those sites using the rarefaction technique.



**Figure 4 – Species accumulation curves across four locations for birds only**



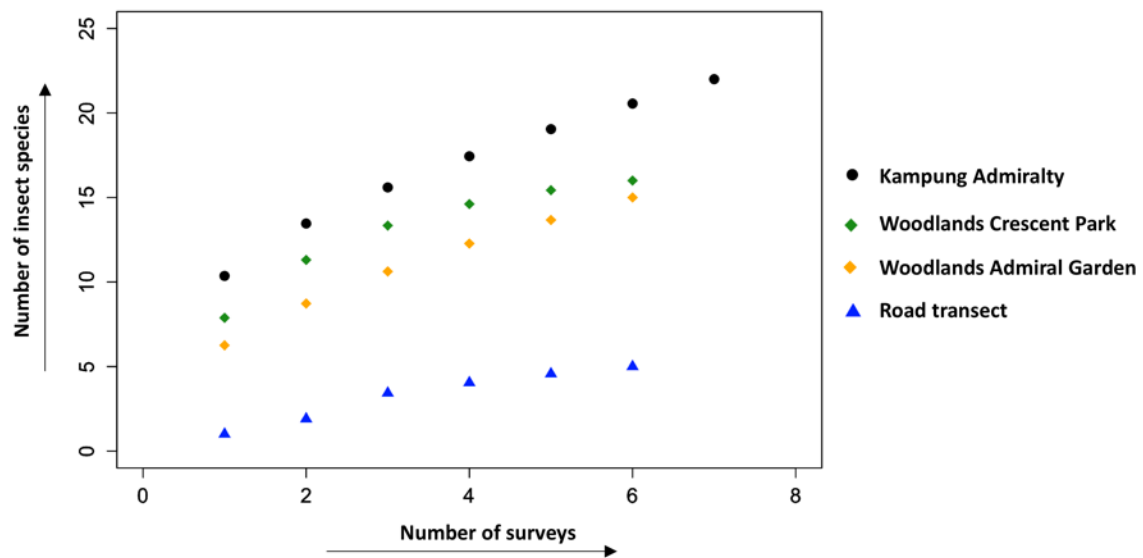


Figure 5 – Species accumulation curves across four locations for insects only

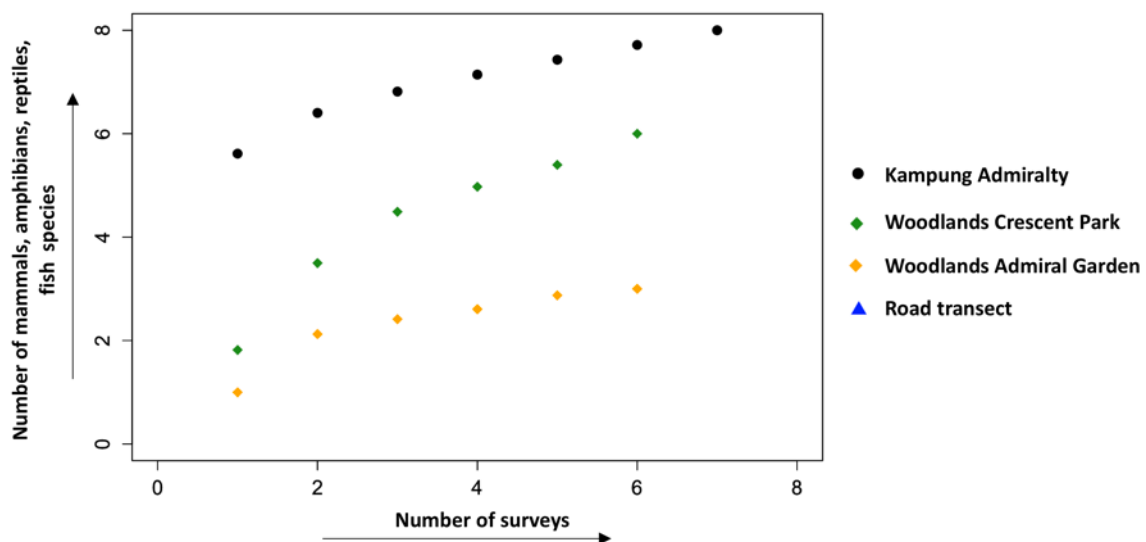
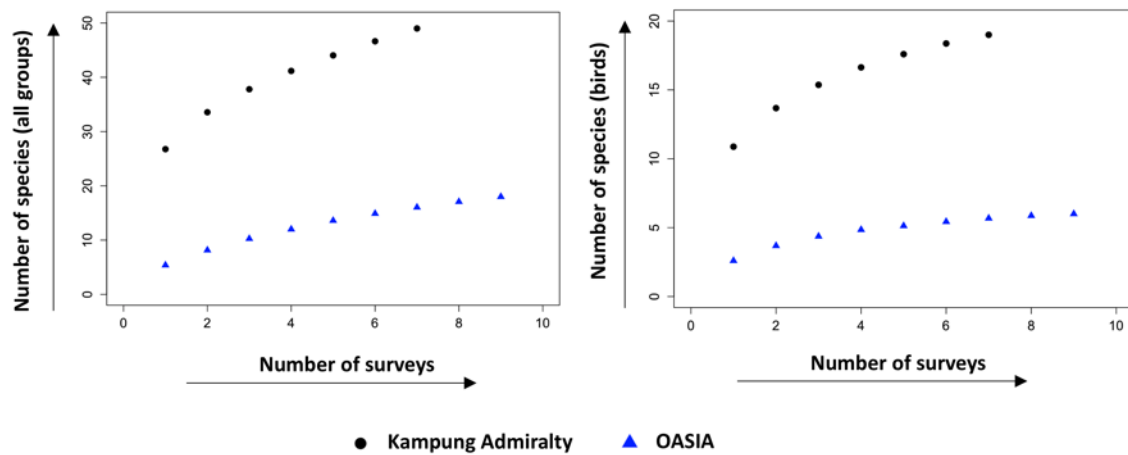


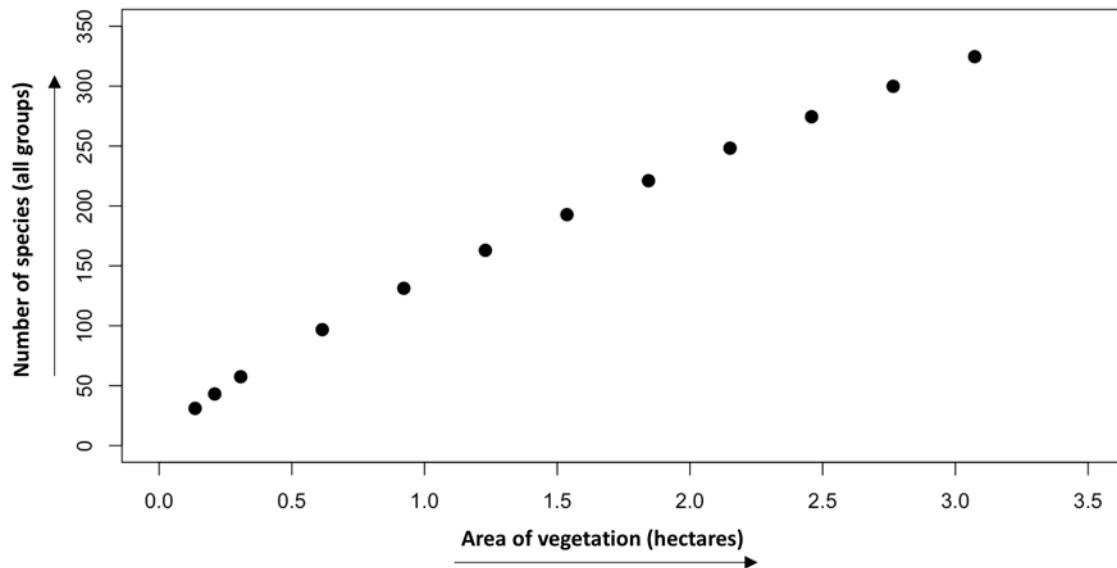
Figure 6 – Species accumulation curves across four locations for other groups (mammals, amphibians, reptiles and fish). Only one species of these groups was recorded on the Road transect.



**Figure 7 – A comparison of species accumulation curves for all groups and birds only at Kampung Admiralty and OASIA**

### 3.2 Biodiversity projections

Based on KA's data, the following species-area function was calculated  $S = 0.137 * A^{0.752}$  where  $S$  = number of species and  $A$  = area of vegetation. Figure 8 and Table 3 suggest that an increase in the area of vegetation will substantially increase the number of species.



**Figure 8 – Projected number of species with the area of vegetation based on Kampung Admiralty's data**

**Table 3 – Projected number of species if Kampung Admiralty (KA)’s were replicated**

<b>Number of KA</b>	<b>Vegetated area (hectares)</b>	<b>Number of species (all groups)</b>
1*KA	0.4	57
2*KA	0.8	97
3*KA	1.2	131
5*KA	2.0	193
10*KA	4.0	325
25*KA	10.0	647



### 3.3 Social surveys

Overall, 60 social surveys were conducted. Of these responses, a nearly equal number of respondents were male and female. Of the represented age groups, 45% were youth (< 25 years), 37% were middle-aged (25 – 55 years) and 18% were more than 55 years old (Figure 9). With regards to nature visitation rates, 26 out of 60 respondents (44%) do not or rarely visit a nature area. Remaining 56% visited a nature area sometimes or often (Figure 8). The majority of respondents either lived at KA (6 residents); or in the vicinity.

The majority of respondents (63%) liked level 8 or above (including the community farm) as their **favourite green area** (Figure 10). When asked about the **importance of having birds, butterflies and other biodiversity with greenery in a building**, 36 out of 60 respondents (60%) felt this was very important. Another 14 respondents (23%) felt this was somewhat important. 10 out of 60 respondents felt biodiversity did not matter or they did not like it (Figure 10). Six respondents complained about bird poop, noise created by roosting birds or powder from butterfly scales may harm humans.

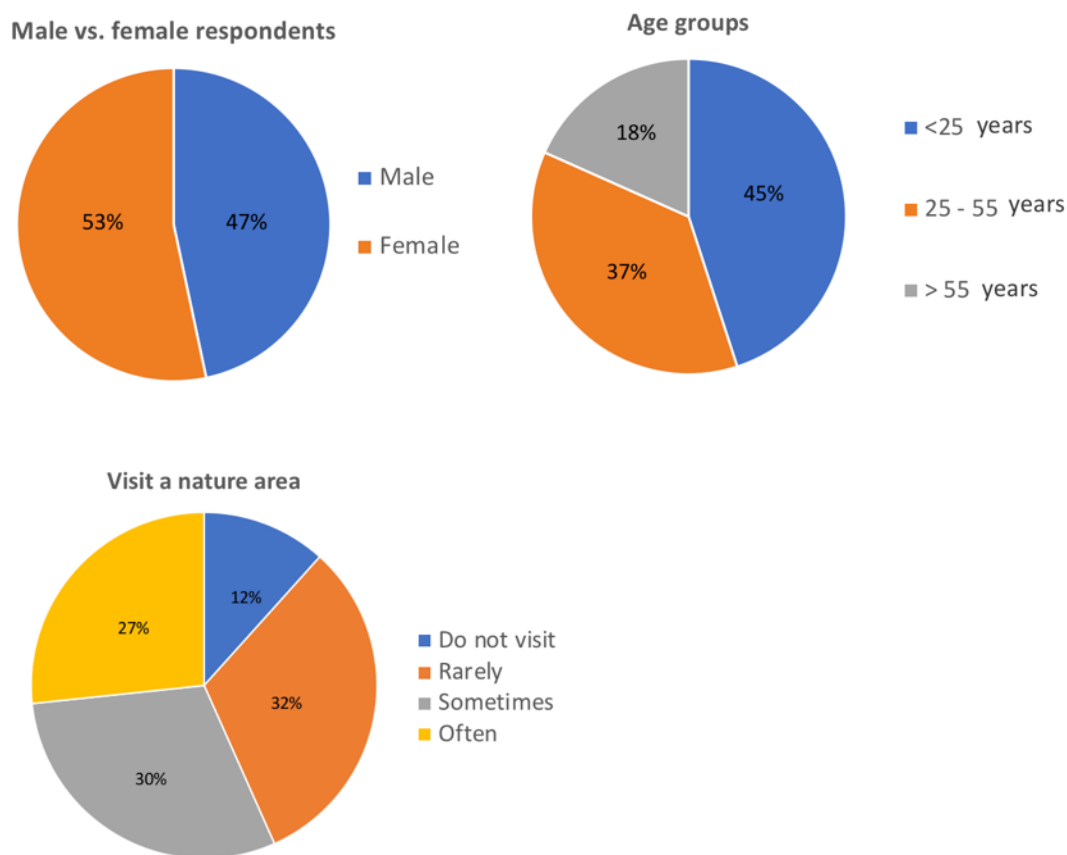
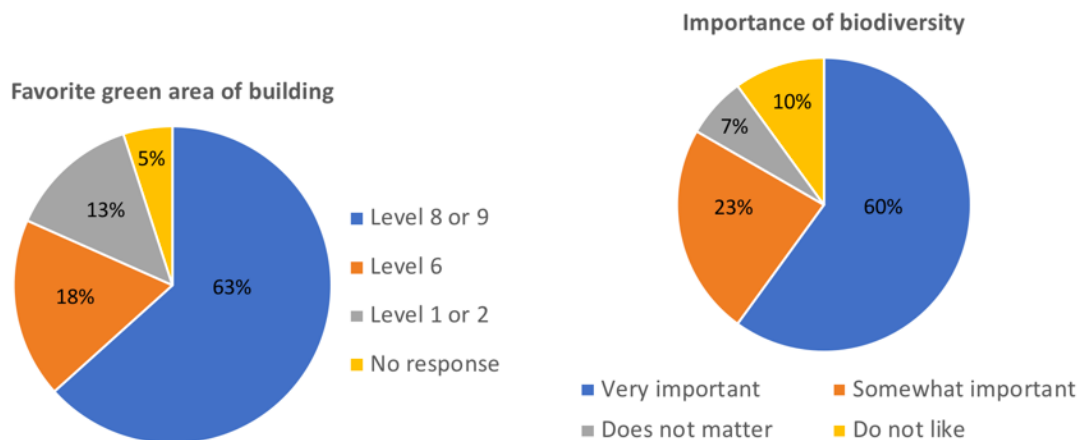


Figure 9 – No. of respondents by gender, age groups and nature visitation rates



**Figure 10 – No. of respondents by favourite green area of the building and the importance of biodiversity in a green building**

When asked the question **'thoughts about KA as a green building'**, 57 out of 60 respondents (95%) were supportive of the greenery whereas 3 respondents thought the greening brought about more mosquitoes and pests. A total of 22 out of 60 respondents (37%) liked the building for its convenience and integration of greenery with the hawker centre and other facilities. Here were some of the responses -

What are your thoughts about KA as a green building?

An elderly uncle said - *"In Singapore, there is only this type of place with natural environment and convenience. After exercise can go to hawker centre to drink coffee, especially for senior citizens. Besides MRT very convenient. No need to cross road."*

An elderly aunty said - *"Very practical, make the nation all together (different races)"*

A middle-aged female said- *"Like the convenience, medical, hawker, have everything in an integrated solution. Helps to reduce stress, relax. Keep telling my friends in the east to visit here"*

A young man said - *"Quite like the concept - never seen anything like that. Food court is breezy and nice"*

Another young man said - *"I think it is a pretty great idea to have such a building in Singapore and I enjoy it a lot. It feels like an urbanised garden /forest"*

A young female said - *"The building is perfect, it is not just a box but a perfect haven to refresh because of the surrounding trees"; another found - "it is very good for relaxation specially for elderly people"*

Another young female said – *"it brings serenity in the midst of the busy life for people of all ages"*

A student found it - *"Very cooling"; another felt there were "too much insects". Another student said – "To sit down to enjoy the scenery. There are interesting insects to observe and it is a view I don't often see."*

Some of the KA residents who volunteered at the community farm mentioned that this was their first time trying gardening which they much enjoyed. The volunteers also conduct exchange visits with other community gardening groups in the vicinity thereby, increasing knowledge exchange.

When asked about the **benefits/disadvantages of greenery in a building like KA**, the majority of respondents felt that greenery was vital as it allows them to *exercise and be healthy; relax, destress and enjoy the fresh air, helps enjoy nature, learn about plants*, and *experience gardening*. A few respondents raised issues about *maintenance, pests such as mosquitoes and overcrowding*.

Interestingly, people's response to the importance of biodiversity at KA was not related to how often they visit nature areas in Singapore (correlation coefficient = -0.005).

### 3.4 Ecosystem Services

The ecosystem services most relevant to urban design are presented in Figure 11 and Table 4. It is recommended that when reporting overall ecosystem services of KA, the scaled average numbers be used because they account for the ratio of green vs. plot area (see Table 4). Overall, with the exception of air nitrogen removal, the ecosystem services of KA (averaged across vegetation types) range from 8% – 30% of pristine rainforest of a size equivalent to KA's plot area.

KA's four vegetation types were comparable in terms of air particulate removal and erosion regulation. The largest difference in ecosystem service was in terms of air nitrogen removal where the vegetation types with trees outperform those with no trees because leaves were good at absorbing nitrogen (including those released by pollution). Similarly, carbon uptake was the highest for the ground vegetation and lowest for the green wall.

Air temperature regulation reduced with the height of vegetation. Similarly, transpiration (essentially evaporation of water from leaves) is expected to be higher for trees as they have greater number of leaves. The rate of evaporation was the highest for the green wall possibly because it had the most exposed soils of all the vegetation types. However, this may be an artifact of our calculation method which assumed to the climbers to be spread on the ground plane. In practice, the soil in green walls are not so exposed because the plants are effectively stacked up over one another at different levels which limits their exposure. Most green walls also use sophisticated irrigation methods to keep soils wet.

#### Amount of Oxygen released

The net oxygen released by vegetation (in kg/year) is a function of the net carbon sequestered. The ESII tool provided the relative carbon sequestration contributions of the four vegetation types in comparison with a tropical forest were calculated. The carbon sequestration contributions for the reference habitat, tropical rainforests in Southeast Asia, was calculated based on the above and below ground biomass calculations (Wijedasa L., Jain A., et al., unpublished data).

Oxygen released = constant \* Carbon uptake % performance (by each habitat type) \* Area \* (1+ Below ground biomass/Above ground biomass) \* Plot-level biomass for tropical forests in Singapore

The amount of Oxygen release by the 4 vegetation types are -

- a) Ground vegetation = 32.3 tons/year



- b) Multi-layered roof gardens = 21.1 tons/year
- c) Shrubs = 9.9 tons/year
- d) Green wall = 0.8 tons/year

The total oxygen released by KA's greenery (a + b + c + d) = 64.1 tons/year.

In comparison, if there was lowland rainforest standing in place of KA (plot area 8,980 m<sup>2</sup>), it would have released 678.9 tons/year which is 10.6 times more than KA's greenery.

#### **How does oxygen production scale up?**

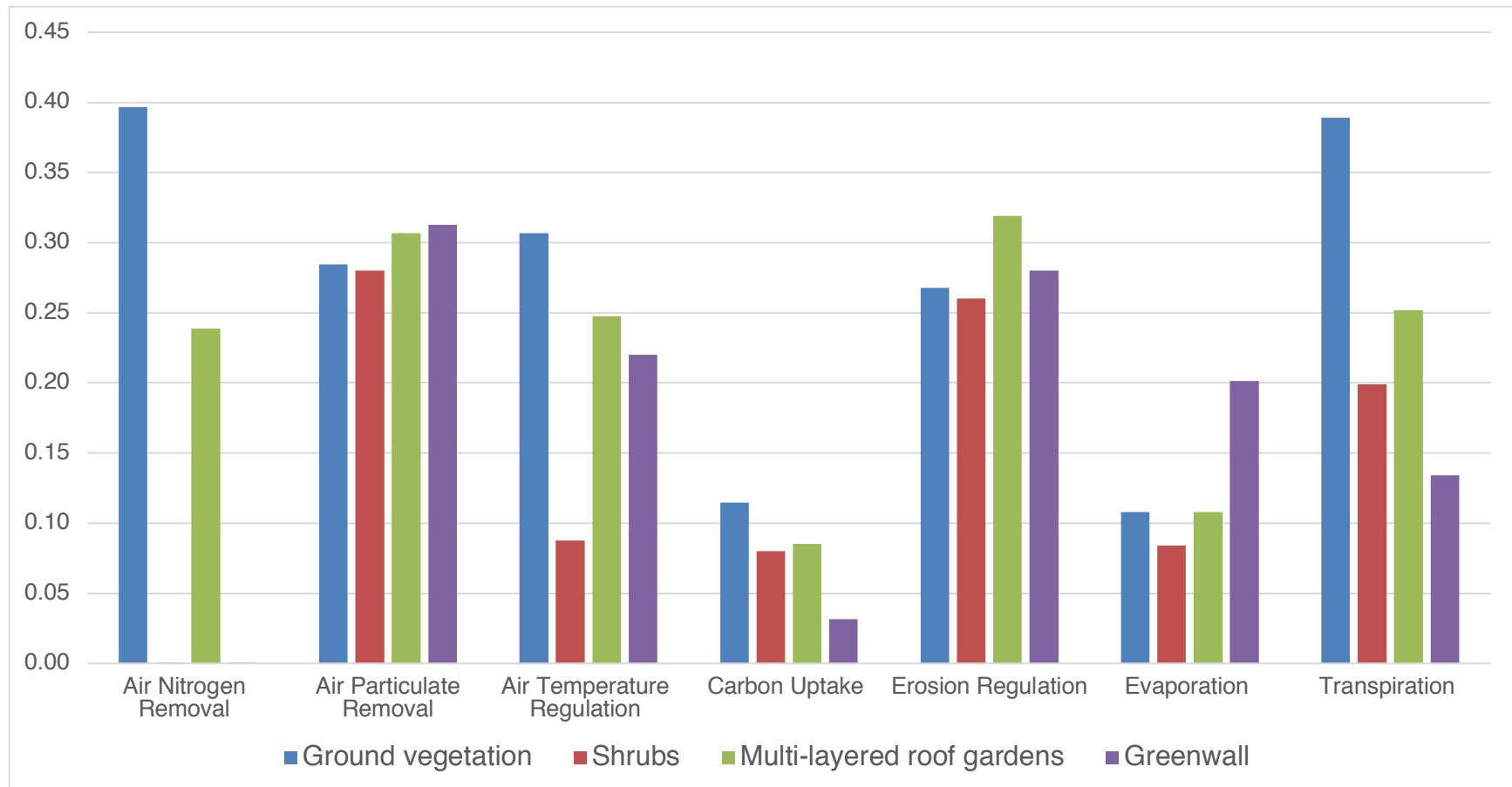
10 KAs would release ~ 641 tons/year. 25 KAs would release ~ 1602.5 tons/year

#### **Impact of shading on temperature**

The amount of heat energy reduced by KA's greenery per unit time as obtained from the ESII tool is –

- a) Ground vegetation = 581.2 kW
- b) Multi-layered roof gardens = 250.2 kW
- c) Shrubs = 84.5 kW
- d) Green wall = 3 kW

Total heat energy reduced by vegetation = 918.8 kW.



**Figure 11 – Scaled ecosystem services of Kampung Admiralty's vegetation types** presented as a percentage of pristine habitat at Singapore's geography and climate of the same size as Kampung Admiralty's plot area (8,980 m<sup>2</sup>).

**Table 4 – Key ecosystem services of Kampung Admiralty.** The actual % performance reflects how each vegetation type performs in comparison with pristine habitat (tropical rainforest at Singapore’s geography and climate) of size 4,730 m<sup>2</sup>. Average % performance imagines a vegetation type that is the average of a ground vegetation, shrubs, multi-layered roof gardens and green walls. The scaled % performance means the ecosystem services performed by the vegetation types in comparison with a pristine habitat that is equivalent of Kampung Admiralty’s plot size (8,980 m<sup>2</sup>).

Parameters	Actual					Scaled				
	Ground vegetation	Shrubs	Multi-layered roof gardens	Green wall	Average	Ground vegetation	Shrubs	Multi-layered roof gardens	Green wall	Average
Air Nitrogen Removal (% performance)	0.75	0.001	0.45	0.001	0.30	0.40	0.001	0.24	0.001	0.16
Air Particulate Removal (% performance)	0.54	0.53	0.58	0.59	0.56	0.28	0.28	0.31	0.31	0.30
Air Temperature Regulation (% performance)	0.58	0.17	0.47	0.42	0.41	0.31	0.09	0.25	0.22	0.22
Carbon Uptake (% performance)	0.22	0.15	0.16	0.06	0.15	0.11	0.08	0.09	0.03	0.08
Erosion Regulation (% Performance)	0.50	0.49	0.60	0.53	0.53	0.27	0.26	0.32	0.28	0.28
Evaporation (% performance)	0.20	0.16	0.20	0.38	0.24	0.11	0.08	0.11	0.20	0.13
Transpiration (% performance)	0.73	0.38	0.48	0.25	0.46	0.39	0.20	0.25	0.13	0.24



## 4.0 Discussion

### Why does KA have high biodiversity?

KA has a diverse planting palette with a rich mix of shrubs and trees providing fruits, nectar and host plants. Water features provide additional habitat for dragonflies and other water-associated species. The diversity and abundance of insects (particularly sun-loving insects such as bees and dragonflies) were particularly high at the community farm. We believe this is because the community farm area is not fumigated. On the contrary, managed habitats at other levels at KA and at other surveyed locations during this study (e.g., Woodlands Admiral Garden), attracted a lower diversity and abundance of insects. Fumigation decimates insect diversity and over time has cascading effects on insect-eating birds and other animals. The results suggest that as a general practice, a bright, open to sky fumigation free planted area could support high biodiversity in green buildings.

Dispersal is an important predictor to species colonisation in a habitat. After all, most animal species have to colonise a planted area from nearby green areas. KA is only 0.72 km away from a large and inaccessible wooded military area (bordering Woodlands Ave 12, SLE and Gambas Ave and Sembawang Air Base). This wooded area is only separated from Upper and Lower Mandai areas by SLE and Mandai Road. Therefore, the forested areas in the vicinity of KA could provide sufficient source populations of animals which might utilise KA for feeding. It is, however, also clear that without a sufficiently rich planting palette, neighbourhood locations such as the road transect and Woodlands Admiral Garden remain relatively low in biodiversity despite their proximity to the wooded area. So proximity to a forested area alone does not guarantee high biodiversity. A diverse planting palette particularly areas with no fumigation are needed.

### How to interpret the biodiversity projections?

The biodiversity projections based on KA's current data suggest a substantial increase in the species diversity with an increase in the area of vegetation. We have to treat this as a preliminary assessment and interpret this rate of increase with caution because of the limited dataset it is based upon. There is no building like KA which we could treat as an independent replicate for the projection calculations. Also, while it may be physically feasible for vegetated areas to support the projected number of species (in the hundreds; of which the majority would be insects), the actual numbers will be limited by what can be found in the vicinity and the landscape which should allow for these species to disperse and colonise the newly created green areas.

### Do people value biodiversity in green buildings and what are the challenges ahead?

Overall, there appears to be overwhelmingly positive support for greenery at KA. People particularly valued the integration of greenery with convenience mainly an affordably priced and well-designed hawker centre. Also, the majority of social survey respondents recognised the importance of biodiversity in a green building. Because KA has high (and visible) biodiversity, this should serve as a positive reinforcement for people who value biodiversity in a green area.

We also noticed a need to educate some members of the public whose reasons for not valuing biodiversity seemed rather irrational. A small number of people believed that having more birds at KA could create a nuisance. They need to be made aware that a diverse planting palette will allow for a variety of birds and other species to thrive in the area, beyond birds like the Javan Myna which are known to flock and create noisy roosts. Similarly, a few people believed that butterfly scales can be poisonous or cause irritation and therefore, having butterflies around can be dangerous to humans. There is no scientific basis for this reasoning.

Even though our study focused on the green aspects of KA, people inevitably praised the breezy and clean hawker center as well as the activity area at level 1. That said, we also found that some building users who only visited level 1 and 2, were unaware of or paid no attention to the greenery

at KA. Perhaps, there could be educational signs directing the users at level 1 and 2 to explore the lush sky gardens and community farms on the higher floors.

*How is the ecosystem service performance of KA?*

The performance of Kampung Admiralty ranges from 8 – 30% of a reference habitat of the same size. Of this, the largest contributions to desirable ecosystem services were by vegetation types with the most and biggest trees. As shown, plants can remove particulates and organic nitrates from the air, thereby, reducing the impact of pollution. They also support the regulation of heat energy/air temperature by evaporative cooling and produce large amounts of oxygen which in turn regulate micro- and macro- climate cycles.

**In conclusion**, our results that the carefully planned greenery at Kampung Admiralty has multiplier effects. It is not only a valuable habitat for biodiversity but is highly appreciated by visitors and residents. In addition, it provides significant ecosystem service benefits.

**Appendix 1: The abundance and diversity of birds observed across locations**

Common names	Scientific names	Kampung Admiralty				Road transect	Woodlands Admiral Garden	Woodlands Crescent Park
		Building total	Level 1	Level 3 - 6	Level 8 and above			
Very common urban birds								
Asian Glossy Starling	<i>Aplonis panayensis</i>	25	10	9	6	0	17	65
Common/Rock Pigeon	<i>Columba livia</i>	17	14	0	3	2	23	9
Eurasian Tree Sparrow	<i>Passer montanus</i>	16	13	2	1	2	22	17
House Crow	<i>Corvus splendens</i>	14	3	1	10	0	3	5
Javan Myna	<i>Acridotheres javanicus</i>	39	23	7	9	16	96	87
Spotted Dove	<i>Spilopelia chinensis</i>	2	1	1	0	1	20	43
Swiftlet & Swift spp.	<i>Apodidae sp.</i>	40	5	3	32	5	13	23
Zebra Dove	<i>Geopelia striata</i>	0	0	0	0	1	1	7
Common urban birds								
Ashy Tailorbird	<i>Orthotomus ruficeps</i>	0	0	0	0	0	0	1
Asian Koel	<i>Eudynamys scolopaceus</i>	8	1	4	3	1	1	2
Black-naped Oriole	<i>Oriolus chinensis</i>	7	3	2	2	4	7	7
Common Iora	<i>Aegithina tiphia</i>	0	0	0	0	0	0	1
Common Tailorbird	<i>Orthotomus sutorius</i>	2	0	1	1	0	0	3
Olive-backed Sunbird	<i>Cinnyris jugularis</i>	22	0	6	16	0	3	14
Oriental White-eye	<i>Zosterops palpebrosus</i>	3	0	1	2	0	0	3
Pink-necked Green Pigeon	<i>Treron vernans</i>	1	0	1	0	0	5	12
Scarlet-backed Flowerpecker	<i>Dicaeum cruentatum</i>	4	0	2	2	0	0	1
White-throated Kingfisher	<i>Halcyon smyrnensis</i>	0	0	0	0	0	1	0
Yellow-vented Bulbul	<i>Pycnonotus goiavier</i>	6	0	2	4	1	1	12
Uncommon urban birds								

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Common names	Scientific names	Kampung Admiralty				Road transect	Woodlands Admiral Garden	Woodlands Crescent Park
		Building total	Level 1	Level 3 - 6	Level 8 and above			
Brahminy Kite #	<i>Haliastur indus</i>	2	0	0	2	0	0	0
Long-tailed Shrike	<i>Lanius schach</i>	1	0	0	1	0	0	1
Oriental Magpie Robin	<i>Copsychus saularis</i>	0	0	0	0	0	0	1
Pied Triller	<i>Lalage nigra</i>	0	0	0	0	0	0	1
Red-breasted Parakeet	<i>Psittacula alexandri</i>	1	0	0	1	0	0	14
Sunda Pygmy Woodpecker	<i>Dendrocopos moluccensis</i>	0	0	0	0	0	1	0
White-bellied Sea Eagle #	<i>Haliaeetus leucogaster</i>	1	1	0	0	0	0	0
TOTAL BIRD SPECIES COUNT		19	10	14	16	9	15	22
TOTAL BIRD ABUNDANCE COUNT		211	74	42	95	33	214	329

# - Species were observed soaring above Kampung Admiralty but did not land on the building.

Appendix 2: The abundance and diversity of insects observed across locations

Common names	Scientific names	Kampung Admiralty				Road transect	Woodlands Admiral Garden	Woodlands Crescent Park
		Building total	Level 1	Level 3 - 6	Level 8 and above			
Butterflies								
Baron	<i>Euthalia aconthea</i>	0	0	0	0	0	1	0
Chocolate Pansy	<i>Junonia hedonia</i>	8	4	4	0	0	35	4
Common Grass Yellow	<i>Eurema hecabe</i>	3	3	0	0	0	3	7
Common Mormon	<i>Papilio polytes</i>	0	0	0	0	0	1	0
Common Palmfly	<i>Elymnias hypermnestra</i>	1	1	0	0	1	5	0
Grass Blue	<i>Zizerria/Zizina/Zizula sp.</i>	0	0	0	0	0	33	30
Lemon Emigrant	<i>Catopsilia pomona</i>	4	0	2	2	1	4	2
Leopard	<i>Phalanta phalantha</i>	18	0	1	17	0	1	4
Lime Butterfly	<i>Papilio demoleus</i>	0	0	0	0	2	18	1
Malayan Eggfly	<i>Hypolimnas anomala</i>	0	0	0	0	0	1	0
Painted Jezebel	<i>Delias hyparete</i>	1	0	0	1	1	0	10
Short Banded Sailor	<i>Phaedyma columella</i>	0	0	0	0	0	1	1
Small Branded Swift	<i>Pelopidas mathias</i>	0	0	0	0	0	0	1
Striped Albatross	<i>Appias libythea</i>	1	0	0	1	0	0	3
UnID butterfly	-	1	0	1	0	0	0	0
UnID skipper butterfly	<i>Hesperiidae</i>	1	0	0	1	0	0	0
Other insects								
Asian Honey Bee	<i>Apis cerana</i>	60	1	20	39	0	0	3
Black-dwarf Honey Bee	<i>Apis andreniformis</i>	2	0	1	1	0	0	0
Blue-banded Bee	<i>Amegilla sp.</i>	1	1	0	0	0	0	0
Carpenter Bee 1	<i>Xylocopa latipes</i>	21	0	7	14	2	3	3



# BioSEA

Common names	Scientific names	Kampung Admiralty				Road transect	Woodlands Admiral Garden	Woodlands Crescent Park
		Building total	Level 1	Level 3 - 6	Level 8 and above			
Carpenter Bee 2		1	0	0	1	0	0	0
Hubner's Wasp/Tiger Moth	<i>Amata heubneri</i>	0	0	0	0	0	1	0
Moth sp1	<i>Sameodes cancellalis</i>	1	0	1	0	0	0	0
Oriental Leafworm Moth	<i>Spodoptera litura</i>	1	0	0	1	0	0	0
Banded Paper Wasp	<i>Polistes sagittarius</i>	0	0	0	0	0	0	2
Blue Mud Dauber Wasp	<i>Chalybion bengalense</i>	15	2	4	9	0	1	3
Weevil sp.	<i>Curculionoidea sp</i>	1	0	0	1	0	0	0
Short-horned grasshopper	<i>Valanga nigricornis</i>	0	0	0	0	0	1	0
Common Parasol dragonfly	<i>Neurothermis fluctuans</i>	19	0	1	18	0	0	12
Yellow-tufted Skimmer	<i>Rhyothemis phyllis</i>	6	0	0	6	0	0	4
Black millipede	<i>Orthomorpha coarctata</i>	57	3	2	52	0	0	0
Housefly	<i>Musca domestica</i>	9	3	2	4	0	0	0
TOTAL INSECT SPECIES COUNT		22	8	12	16	5	15	16
TOTAL INSECT ABUNDANCE COUNT		232	18	46	168	7	109	90

### Appendix 3: The abundance and diversity of mammals, and other animal groups observed across locations

		Kampung Admiralty				Road transect	Woodlands Admiral Garden	Woodlands Crescent Park
Common names	Scientific names	Building total	Level 1	Level 3 - 6	Level 8 and above			
Mammals								
Lesser dog-faced fruit Bat	<i>Cynopterus brachyotis</i>	17	0	8	9	0	1	1
Lesser Asiatic Yellow House Bat	<i>Scotophilus kuhlii</i>	1	1	0	0	0	4	4
Plaintain Squirrel	<i>Callosciurus notatus</i>	0	0	0	0	0	0	1
House Rat	<i>Rattus rattus</i>	0	0	0	0	0	0	5
Amphibians, reptiles, fish, snails								
Red-eared Slider	<i>Trachemys scripta</i>	37	37	0	0	0	0	0
Changeable Lizard	<i>Calotes versicolor</i>	0	0	0	0	1	3	1
House gecko	<i>Hemidactylus frenatus</i>	1	0	0	1	0	0	3
Guppy fish	<i>Poecilia reticulata</i>	1	0	1	0	0	0	0
Cichlid fish	<i>Cichlidae sp.</i>	6	6	0	0	0	0	0
Koi fish	<i>Cyprinus carpio</i>	34	28	6	0	0	0	0
UnID fish sp	-	77	7	70	0	0	0	0
Giant African Snail	<i>Lissachatina fulica</i>	10	1	5	4	0	0	0
TOTAL MAMMALS, OTHER SPECIES COUNT		9	6	5	3	1	3	6
TOTAL MAMMALS, OTHER ABUNDANCE COUNT		184	80	90	14	1	8	15

**Appendix 4: Selected photographic records from Kampung Admiralty during the biodiversity surveys**



Left - Oriental White-eye at level 6; and Right - Olive-backed Sunbird which were most common at level 8.



Left - A family of Asian Glossy Starlings (parent in the centre and juveniles on both sides) observed at the M&E besides the Community Farm. The family is believed to be nesting at the building. Right – Scarlet backed Flowerpecker resting at level 6 sky garden.



Left – A Lemon Emigrant butterfly observed feeding on starfruit tree at the community farm. Right – Asian Honey Bee at level 8 garden.



Black Carpenter Bees (left) and Honey Bees (right) were observed feeding at the community farm.





Carpenter Bees (left) and Common Parasol dragonflies (right) were observed at the community farm. In the evenings, up to 12 dragonfly individuals of 2 species were observed circling around the community farm at any time.



Black-dwarf Honey Bee (observed at level 6, 8), Blue Banded Bee (observed at level 1) and Oriental Leafworm moths (observed at level 8 and above). Photos by Kerry Pereira.



Lesser-dog faced fruit bats were observed visiting trees at level 6, 8 and 9.



**Appendix 5: Selected photographic records during the social surveys**



Older couples and grandparents (mixed races) were observed bringing their grandchildren to the community farm.





Older folks (such as these who visit from Bukit Panjang and Ang Mo Kio) visit with friends at level 8 and 9 and often spend hours relaxing in the greenery





Older folks (such as this part-time taxi driver uncle) who lives here comes regularly to exercise at level 8 and 9.



Students enjoy studying amidst the greenery as it allows them to relax and destress.

## Appendix 6: Public perceptions towards the greenery of Kampung Admiralty

August - September 2018

WOHA Architects, the designers of **KAMPUNG ADMIRALTY**, have contracted BioSEA LLP to conduct an ecological assessment of **KAMPUNG ADMIRALTY** so as to better understand the biological and social impacts of greenery at the building. KAMPUNG ADMIRALTY is designed with a community park and community garden for residents to interact over gardening activities as well as enjoy its rooftop gardens. The objective of this brief survey is to understand how people who visit, live or work in the vicinity of **KAMPUNG ADMIRALTY** feel about its greenery and the impact it may have on biodiversity.

1. Please tell us about yourself:
  - a. Name (optional): \_\_\_\_\_
  - b. Profession (optional): \_\_\_\_\_
  - c. What brings you to this neighborhood? \_\_\_\_\_
  - d. How often do you visit here? \_\_\_\_\_
  
2. What are your thoughts about **KAMPUNG ADMIRALTY** as a green building? Example, integration of greenery with its facilities (medical, childcare, and elder care).  
 \_\_\_\_\_  
 \_\_\_\_\_
  
3. What is your favorite green area in **KAMPUNG ADMIRALTY** and why?  
 \_\_\_\_\_  
 \_\_\_\_\_
  
4. Please mention any benefits and/or disadvantages to having a green building like '**KAMPUNG ADMIRALTY**' in this neighborhood?  
 \_\_\_\_\_  
 \_\_\_\_\_
  
5. How important it is to have more birds, butterflies & other biodiversity with greenery in a building?  
 \_\_\_\_\_  
 \_\_\_\_\_
  
6. How often do you visit nature areas in Singapore and where (e.g., once every month)?  
 \_\_\_\_\_

***We greatly value for feedback. Thank you for your participation!*** I hereby understand, accept and acknowledge that by providing the above information, I give my consent to BioSEA LLP to collect, use and disclose data to any relevant third parties pertaining to the 'Ecological study of KAMPUNG ADMIRALTY'.

\_\_\_\_\_ Name/Signature