Methodologies for monitoring fireflies in Hong Kong

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ABSTRACT

In total 241 field visits to 47 different sites in Hong Kong were conducted specifically for firefly survey, from 2009 to 2020. Various methods were used to record fireflies qualitatively and quantitatively. Local restrictedness of 29 species of Hong Kong fireflies are listed. Methods for accessing the population of different firefly species are discussed and recommended according to their distribution characteristic, flash and flight, and habitat. Using photography and videography to assist counting fireflies is introduced. Current limitations and further actions are proposed.

Key words: Fireflies, Lampyridae, Rhagophthalmidae, Hong Kong, local restrictedness, accessing population

INTRODUCTION

Fireflies are one of the most flashy and spectacular animal groups. IUCN SSC Firefly Specialist Group are working on assessing extinction risk of the 2000 and more firefly species of the world (Lewis and Wong, 2018). Fireflies are also proposed as potential flagship species and bio indicators for photo pollution (Hagen et al., 2015).

There are 29 species of fireflies (Lampyridae & Rhagophthalmidae) known in Hong Kong (Yiu, 2017), 26% of which are regarded as locally restricted or highly restricted (Yiu, 2013). 10 species are endemic to Hong Kong (Yiu, 2017). Hong Kong is densely populated with 7.5 millions of citizens (Census and Statistics Department, 2020) living in 1107 km² of land, of which 25% is developed and 40% is Country Parks and Nature Reserves (HKSAR Government, 2020). Demands on land development for housing have been major public concern for years (Task Force on Land Supply, 2018). Without a standardized and systematic methods for assessing Hong Kong fireflies, it would be hard to know the actual change of firefly populations over time.

MATERIALS & METHODS

Starting from 2009, intensive and extensive surveys specifically for fireflies have been conducted. More specifically, 241 field visits were conducted specifically for firefly survey, of which 220 visits were done at night and 21 were done in the day time. In total 47 different sites were visited in the 11 years of study, of which 4 sites have been visited yearly since 2009. Location of the sites and visiting frequency are shown in figure 4. In addition to site visits, various methods were used to record fireflies qualitatively and quantitatively, including:

a. Malaise traps. Ten traps were set for a general insects study in 2014 and small quantity of fireflies were collected;

b. Quadrat count and point count. Used in high visibility areas with concentration of flying fireflies displaying light at night. Area of the quadrats was measured by visual estimation, measuring tape or a Leica DISTO DXT Laser Distance meter. The observer stand along the margins of the quadrat to counts the number of fireflies displaying light ; or stand at the centre of the quadrat and count the number of fireflies displaying light in a 360 degree perspective – point count.

c. Transect count. This was usually done by walking slowly along a road, a trail or a path; fireflies occurring on both sides of the path were counted. Flying fireflies displaying light could be clearly visible from a distance up to 25m, depending on size of light spots, brightness of the light spots and the brightness of the ambient light. Stationary fireflies on low vegetation or on the ground could be visible up to 5m, depending on size of light spots, brightness of the light spots and the brightness of the ambient light.

d. Visiting permanent “bright light traps”. Wherever available, public toilets emitting light at night in remote area would be visited to check the fireflies trapped inside.

Identification and records of fireflies were done by direct observation, photography and videography. Olympus E3, E620 digital camera with a Olympus ZUIKO DIGITAL ED 50mm F2.0 Macro lens; a canon 550D are 5D Mark III camera with either a Canon EF-S 60mm f/2.8 Macro lens, a SIGMA MACRO 70mm F2.8 DG HSM lens or a EF 100mm f/2.8 Macro lens were used for photography. Videography was done by a Canon 5D Mark III camera with a Canon EF 17-40mm f/4.0L USM zoom lens or EF 100mm f/2.8 Macro lens; and a Sony A7S camera with a Mitakon Speedmaster 50mm f/0.95 lens. Sensitivity rating (ISO speed) of the cameras for videography of firefly flashes was set between ISO 12800 to ISO 102400.

Photo records on iNaturalist until Sept 30, 2020 were also considered. 453 observations with 17 species were checked.

For Local restrictedness assessment, the method proposed by Fellowes et al. (2002) defined local restrictedness as a measure of dependence of wild animals on particular locality, versus other localities of comparable size in Hong Kong. A locality is taken to measure 1 km². A highly restricted species is most vulnerable to local extinction through habitat loss or damage, and its very restrictedness is a reflection of high habitat specificity. Local restrictedness was simplified and assigned according to the following coding:

A = known to occur in this locality alone
B = know to occur in two localities
C = known to occur in three to four localities
D = known to occur in five to eight localities
E = known to occur in nine to 16 localities
F = known to occur in 17-32 localities.

Their proposition is that the threshold for local restrictedness is about 4% of area surveyed. Thus if about 100 km² have been surveyed for a given group, a species will only be considered highly restricted if the area of occupancy is 4 km² or less. B is used as the restrictedness threshold for all insect groups. To be consistent, the same is adopted here.

RESULTS

Local Restrictedness of Hong Kong Fireflies

Yiu (2013) listed the Local Restrictedness of 27 species of firefly, based on 152 field visits from 2009 to 2013. With 89 additional field visits and verified records on iNaturalist, the updated Local Restrictedness of 29 species of Hong Kong Fireflies is listed in Table 1.

Distribution characteristics (Table 2)

Populations of 17 species are usually confined or restricted to particular area(s), more or less a margin can be drawn to encompass the fireflies. Distribution of 9 species, on the contrary, are more diffused, this may be attributable to their comparatively higher mobility or of being less dependent to a particular habitat.

Flash & Flight (Table 2)

Yiu (2013) catergorized Hong Kong fireflies into 4 groups according to their flash patterns and sexual communication. For the purpose of applying suitable sampling methods, the same categorization can be used with slight modifications, in terms of visibility and detection of the different firefly species by human observers:

Mode 1: Diurnal fireflies fly during daylight (there may be weak luminescent signal). Male flies, female may or may not fly. Frequency of encountering theses fireflies in the daytime is comparatively low. *Cyphonocerus longicornus*, *Drilaster* sp., *Pyrocoelia sanguiniventer*, *Vesta sinuata* belong to this category.

Mode 2: Nocturnal fireflies with **flightless females emitting continuous glow** in unsheltered condition, could be directly visible in the dark from a distance of few meters. **Flying male is either non-luminous or produces only very weak light**, almost invisible in the field at night. *Rhagophthalmus hiemalis*, *R. motschulskyi*, *Diplocladon atripennis*, *Oculogryphus chenghoiyanae*, *Stenocladius bicoloripes*, *Lamprigera taimoshana* belongs to this group. *Stenocladius* sp. is presumed to be this category but female of which is not known yet. Male of *L. taimoshana* is more readily seen in the field because of its very large size and strong tendency of staying on open ground surface.

Mode 3: Nocturnal fireflies with **flightless females emitting continuous glow** in unsheltered condition, could be directly visible in the dark from a distance of few meters. However, frequency of encountering female of theses fireflies is extremely low. **Flying male produces prominent continuous glow**, clearly visible in the dark from a distance of up to 25 meters. Density of flying male displaying glow is high to moderately high. *Diaphanes citrinus*, *D. lampyroides*, *Pyrocoelia analis*, *P. lunata* belong to this category.

Mode 4: Nocturnal fireflies with **male displays distinctive flash patterns**, female also produces flashing light. Female flies, except *Luciola* nr. *nicollieri*. Male is often more numerous and active than the female of the same species. Density of flying male displaying light could be very high, up to hundreds per hectare. All members of Luciolinae belong to this category.

Habitat (Table 2)

Habitat for members of the Luciolinae is generally homogeneous (Fig. 1). *Abscondita terminalis* and *Curtos fulvocapitalis* are found in lowland grasslands and grassy abandoned farmlands; *Pygoluciola qingyu* is found along hill streams and *Pteroptyx maipo* is found along riversides in mangroves; *Aquatica* spp. are found in stagnant or slow running, shallow freshwater wetlands; other species in mature woodlands. Habitat for members of Rhagophthalmidae, Cyphonocerinae, Lampyrinae are generally heterogenous, usually involve closely connected woodlands, scrublands and grasslands (Fig. 2). Exceptions are *Diplocladon atripennis*, *Stenocladius bicoloripes* and *Vesta sinuata*. They are found in woodlands only.

DISCUSSION

Local Restrictedness of the fireflies

There are 5 species - 17% of all known species, are known to occur in only one locality; One species is known to occur in two localities; and 5 species are known to occur in three to four localities. Amongst the 10 endemic species, *Cyphonocerus longicornus* and *Luciola tuberculata* are only know in one locality; *Oculogryphus chenghoiyanae* is only know in 2 localities; *Rhagophthalmus hiemalis*, *Diplocladon atripennis* and

Medeopteryx hongkongensis are known to occur in 3 to 4 localities. These should draw our attention to the sustainability of these firefly species and the possibility of losing one or more species forever.

Concerning coverage, locations of the surveys are more inclined to Central New Territories, North East New Territories, and places around Ma On Shan. East, West and North New Territories were less visited. Except the 2 largest islands - Lantau Island and Hong Kong Island, all other Islands are not studied yet. Moreover, there could be more sites on Lantau Island and Hong Kong Island to be explored.

The survey sites are also heavily inclined to more natural environment with less human disturbance. However, some species are actually more frequently seen in human disturbed areas. For example, *Abscondita terminalis* and *Curtos fulvocapitalis* are often seen occurring in mass number in abandoned farmland or near villages, but seldom seen in any Nature Reserve or Country Park. Majority of the records of *Rhagophthalmus motschulskyi* are obtained in villages or farmlands, instead of less disturbed natural habitats. It was also very recently recorded in urban area. *Pyrocoelia analis* was also occasionally recorded in urban area. More surveys could be done in urban and sub-urban areas, as well as in villages in the New Territories.

Concerning frequency and season of visits. Total of 241 visits to 47 sites were conducted in the past 11 years. In average, 22 visits per year, only 1.8 per month. In average, each site was visited 5.1 times. Only 5 sites (10.6%) were visited in all months of the year; 16 sites (34.0%) were visited in both wet season and dry season; 20 sites (42.5%) were visited in wet season only; 7 sites (14.9%) were visited in dry season only. Apart from finding more new sites, visiting the existing sites more frequency could also provide more comprehensive data.

Daytime visits are also very limited and the number of records of diurnal fireflies is particularly scarce.

Much more work is needed. Hong Kong Firefly Survey Team was established in July, 2020. After training, the team would conduct about 150 firefly surveys in one year.

Methods for assessing the populations of fireflies with observable light emitting in the dark

There is no other living organisms emitting light at night like fireflies. In Hong Kong, only in rare cases, two or more species could be found displaying light in the same location at the same time. Even if this happens, different species can be easily distinguished by their different flash patterns. Therefore counting the number of light spots would tell the population of a particular firefly species quantitatively. Less mobile species can be counted by simple counting - Lewis and Wang, 1991; Yuma, 2007; De Cock and Guzmán-Álvarez, 2013; Firebaugh and Haynes, 2016; Atkins et al., 2017. For surveying and counting the high density of individuals giving the synchronous light display such as the congregating *Pteroptyx* spp. found on the mangrove trees in Malaysia and Thailand, Jusoh and Ibrahim (2011) proposed to compare the appearance of light spots of the fireflies with a series of percentage charts, ranging from 1% to 50%. Kirton et al. (2012) and Khoo et al. (2012) used digital night photography and image analysis to obtain an index of abundance.

There is no high density congregating firefly species in Hong Kong. Light emitting wingless female (Flash & Flight Mode 2) can be counted directly to get population data. Yet surveying female density of glow-worm firefly type of species by counting number of individuals is tricky. In European species of glow-worm fireflies like *Lampyris noctiluca* and *Lamprohiza splendidula* and also in the North American *Phausis reticulata* density of females is directly related to male densities, and at high male densities females are almost directly found by males and stop glowing immediately at mating; This could give observer the wrong impression that female densities are low or that the species is event absent at localities whereas in reality it might be a very good and dense population (Raphael De Cock, pers. comm.). For Flash & Flight Mode 3, light emitting females are often too scarce to be found. Flying males of such species occur sparse to moderately high densities. As the slowly flying males display with a continuous glow, it could be easy to separate different individuals in flight. The flying males of *Diaphanes citrinus* and *D. lampyroides* are only active for about 45 minutes each night during their flight period. It is important to count at the right time - the peak within the 45 minutes of active period.

For medium density of light displaying flying males, the recording by video for later playback and assessment enables future counting is also possible by using a camera and lens specialized for low night videography. Sensitivity rating (ISO speed) of the cameras should be set between ISO 12800 to ISO 102400, and aperature f/4 or larger.

For Flash & Flight Mode 4. If the density of flying males displaying flashes is low, direct count can be used. If the density is medium, for species displaying simple pulsations, including *Aquatica ficta*, *A. leii*, *Luciola kagiana*, *L.* nr. *laticollis*, *L.* nr. *nicollieri*, *L. tuberculata*, *Medeopteryx hongkongensis* and Species inquirenda 1, the path of movement of different individuals can be traced just like those showing continuous glow (Mode 3). However, for species showing flash train, including *Abscondita terminalis*, *Curtos fulvocapitalis*, *L. curtithorax*, and *Pteroptyx maipo*, distinguishing different individuals of this type could be more challenging since inter-flash intervals lasts for up to 4s. That is to say, the light signal disappears for 4s in the dark. To distinguish between different individuals of this type, one also needs to know how to distinguish the flash pattern of the species, together with sufficient training and practice. Taking high quality video records for future counting on playing back the video is also a good option. Another

alternative is taking long exposure photos. Divide the exposure time by duration of one flash cycle, times the number of flash train units recorded in the photo, can be regarded as the actual number of flying individuals in the study area during the period of recording (Fig. 3): N = Duration of 1 flash cycle/ photo exposure time x flash units detected on photo.

Pygoluciola qingyu is perhaps the easiest species to count since the flashing males tends to keep stationary during the whole night.

For any particular species, the population numbers will vary across the flight period. It is important to record repeatedly in different dates in order to find the peak population and the population density change during the flight period. The majority of the fireflies are only active for a short period of time, usually less than one hour at night, and the (visible) population also varies during the short period of time. It is also important to record at the right time or the recording duration should cover the peak time of light display.

Methods for assessing the populations of fireflies with inconspicuous or no light emitting in the dark

For male of Flash & Flight Mode 2. Chen and Cheng (2009) founded that flight interception trap is a very effective method to collect fireflies, better than using Malasie trap. Ho et al. (2012) used Malaise traps and sex-attraction by collected female to collect male *Rhagophthalmus* spp.. De Cock and Guzmán-Álvarez (2013) used lures and traps to attract nocturnal flying male glow-worm fireflies. The lures include LED lures, Phosphorescent light Lures, breaklight lures and betalight lures. This methodology is also used in behavioral and ecological studies on *Lampyris noctiluca* in Finland by Hopkins et. al. (2015). *Diplocladon atripennis*, *Stenocladius bicoloripes*, *Stenocladius* sp., *Pyrocoelia analis* are occasionally found in public toilets in remote areas, presumably be attracted by the bright light in the toilets. Using bright light trap is possible a method for finding these species, but this is not tested yet. Males of “glow-worm-type” firefly species react very differently to light lures depending on spectral and intensity characteristics, where some are only attracted to weak glowing lures of specific wavelength composition (color of light) while others are not so “choosy” - so the best option is to use several types of glow and light lure traps (Raphael De Cock, pers. comm.).

Compared with other methods, flight interception traps and Malaise traps are most destructive because all the collected fireflies would be inevitably killed, and occasionally very large number of individuals from a single species could be caught at the same time in a single trap. Additionally all other caught insects would be killed. If the population dynamics and local survival of a particular firefly species is not clearly understood, repeated and continuous use of a destructive method should be avoided.

Bright light traps, although not necessarily lethal to the collected insects, may also cause certain disturbance to the fireflies as well as the whole nocturnal insect community. Repeated or continuous use should be avoided.

Light lure traps or glow lure traps induce less disturbance to the firefly community on the condition that the caught fireflies are released immediately after examination.

It is not clear whether sweep netting is useful because the non-luminous males may be actively flying and searching for luminous females instead of staying on the vegetation. “Blind” sweeping in the air at different heights from vegetation or ground is a possible easy and cheap method to be tested.

For male of Flash & Flight Mode 1 - diurnal fireflies fly during daylight. Frequency of encountering theses fireflies in the daytime is comparatively low. The most frequently encountered *Vesta sinuata*, only has a few records per year; other species have one record for few years. Effectiveness of sweep netting is not tested. An alternative is to recruit more volunteers to greatly increase the number of field visits. This type of survey method also depends on training, expertise and development of a “search image” for these often less conspicuous diurnal fireflies by observers.

Transect or Quadrat?

Accessibility to the habitat, visibility of the habitat, as well as distribution pattern of the firefly species should be considered. For luminous species densely confined to homogeneous habitat with high visibility (e.g. grasslands and farmlands), no matter the accessibility, quadrat method is recommended, as their population can be assessed by direct counting of the light spots in the area. The assessor may stand in the middle of the quadrat (point count) or at the sides of the quadrat. To ensure clear visibility to the flash pattern, longest distance between the assessor and the firefly should not exceed 25m. A laser distance meter is a quick and accurate equipment to check distances in the dark.

For diffused and/or sparsely spaced, luminous species in homogeneous habitat, transect method (Fig. 4) is recommended to extend the sampling area. For luminous species in heterogenous habitat with low accessibility and low visibility, transect (walk along paths) method is also recommended.

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TABLES & FIGURES

Family, Sub-family	Species	Local Restrictedness #
Rhagophthalmidae	*Rhagophthalmus hiemalis* *	C
Rhagophthalmidae	*Rhagophthalmus motschulskyi* *	E
Rhagophthalmidae	*Diplocladon atripennis* *	C
Lampyridae, Cyphonocerinae	*Cyphonocerus longicornus* *	A
Lampyridae, Cyphonocerinae	*Drilaster sp.*	A
Lampyridae, Cyphonocerinae	*Oculogryphus chenghoiyanae* *	B
Lampyridae, Cyphonocerinae	*Stenocladius bicoloripes*	E
Lampyridae, Cyphonocerinae	*Stenocladius sp.*	D
Lampyridae, Lampyrinae	*Diaphanes citrinus*	E
Lampyridae, Lampyrinae	*Diaphanes lampyroides*	D
Lampyridae, Lampyrinae	*Pyrocoelia analis*	F
Lampyridae, Lampyrinae	*Pyrocoelia lunata* *	E
Lampyridae, Lampyrinae	*Pyrocoelia sanguiniventer*	D
Lampyridae, Lampyrinae	*Vesta sinuata* *	E
Lampyridae, Lampyrinae	*Lamprigera taimoshana* *	D
Lampyridae, Luciolinae	*Abscondita terminalis*	D
Lampyridae, Luciolinae	*Aquatica ficta*	No info.
Lampyridae, Luciolinae	*Aquatica leii*	D
Lampyridae, Luciolinae	*Asymmetricata circumdata*	A
Lampyridae, Luciolinae	*Curtos fulvocapitalis*	C
Lampyridae, Luciolinae	*Luciola curtithorax*	D
Lampyridae, Luciolinae	*Luciola kagiana*	A
Lampyridae, Luciolinae	*Luciola nr. laticollis*	C
Lampyridae, Luciolinae	*Luciola nr. nicollieri*	D
Lampyridae, Luciolinae	*Luciola tuberculata* *	A
Lampyridae, Luciolinae	*Medeopteryx hongkongensis* *	C
Lampyridae, Luciolinae	*Pteroptyx maipo*	C
Lampyridae, Luciolinae	*Pygoluciola qingyu*	F
Lampyridae, Luciolinae	Species inquirenda 1	D

Table 1. Local Restrictedness of Hong Kong Fireflies. [* = Endemic to Hong Kong; # = Local restrictedness: A = known to occur in this locality alone; B = know to occur in two localities; C = known to occur in three to four localities D = known to occur in five to eight localities; E = known to occur in nine to 16 localities; F = known to occur in 17-32 localities]

Species	Distribution	Flash & Flight #	Habitat	Recommended method(s)
*Rhagophthalmus hiemalis**	Confined, sparse	Mode 2	Heterogeneous; females often seen laying on the surface of sparsely vegetated slopes near woodland margins & road sides	Transect count, glow lures
Rhagophthalmus motschulskyi *	Confined, sparse	Mode 2	Heterogeneous; females often seen laying on the ground of open areas & sparsely vegetated road sides	Transect count, glow lures
Diplocladon atripennis *	Confined, sparse	Mode 2	Homogenous; well vegetated natural woodlands, male may be attracted to bight light	Transect count, glow lures
Cyphonocerus longicornus *	Confined, sparse	Mode 1	Heterogeneous; woodlands and scrubland around hill top	Transect count
Drilaster sp.	Confined, sparse	Mode 1	Heterogeneous; woodlands and scrubland around hill top	Transect count
Oculogryphus chenghoiyanae *	Confined, sparse	Mode 2	Heterogeneous; females often seen laying on the surface of sparsely vegetated slopes near woodland margins & road sides	Transect count, glow lures
Stenocladius bicoloripes	Diffused, sparse	Mode 2	Homogeneous; females often seen laying on the surface of sparsely vegetated slopes in woodlands	Transect count, glow lures
Stenocladius sp.	Diffused, sparse	Possibly mode 2	Heterogeneous; woodlands, and scrublands, occasionally found in public toilets, presumably attracted to bright light	Transect count, glow lures
Diaphanes citrinus	Diffused, moderately dense	Mode 3	Heterogenous, woodlands, scrublands and grasslands	Transect count
Diaphanes lampyroides	Confined, moderately dense	Mode 3	Heterogenous, woodlands, scrublands	Quadrat count, transect
Pyrocoelia analis	Diffused, sparse	Mode 3	Heterogenous, woodlands, farmlands, abandoned farmlands, mangrove, grasslands, occasionally found in public toilets, presumably attracted to bright light	Transect count
Pyrocoelia lunata *	Diffused, moderately dense	Mode 3	Heterogenous, woodlands, scrubland grasslands near hill top	Transect count
Pyrocoelia sanguiniventer	Diffused, sparse	Mode 1	Heterogenous, woodlands, scrublands	Transect count
Vesta sinuata *	Diffused, sparse	Mode 1	Homogenous, woodlands	Transect count
	Homogenous, woodlands	Transect count	Heterogenous, woodlands, scrubland and grassland near hill top	Transect count
Lamprigera taimoshana *	Confined, sparse	Mode 2	Heterogenous, woodlands, scrubland and grassland near hill top	Transect count
Abscondita terminalis	Confined, dense	Mode 4	Homogeneous. Lowland grasslands and abandoned farmlands	Quadrat count
Aquatica ficta	No local live record	Mode 4	Presumably similar to *Aquatica leii*	N.A.
Aquatica leii	Confined, sparse	Mode 4	Homogenous, stagnant or slow running, shallow freshwater wetlands	Quadrat count
Asymmetricata circumdata	No local live record	Mode 4	No information	N.A.
Curtos fulvocapitalis	Confined, dense	Mode 4	Homogenous, lowland grassland, abandoned farmland	Quadrat count
Luciola curtithorax	Diffused, dense	Mode 4	Homogeneous, mature woodland	Quadrat count

Luciola kagiana	Confined, moderately dense	Mode 4	Homogeneous, mature woodland	Quadrat count
Luciola nr. laticollis	Diffused, dense	Mode 4	Homogeneous, mature woodland	Quadrat count
Luciola nr. nicollieri	Diffused, dense	Mode 4	Homogeneous, mature woodland	Quadrat count
Luciola tuberculata *	Confined, moderately dense	Mode 4	Homogeneous, mature woodland	Quadrat count
Medeopteryx hongkongensis *	Confined, dense	Mode 4	Homogeneous, mature woodland	Quadrat count
Pteroptyx maipo	Confined, dense	Mode 4	Homogeneous, riversides in mangrove	Transect count, quadrat count
Species inquirenda 1	Confined, dense	Mode 4	Homogeneous, mature woodland	Quadrat count

Table 2. Distribution characteristic, flash & flight characteristic, habitat characteristic and recommended methods for assessing populations. [* = Endemic to Hong Kong; # = Modes of flash & flight: Mode 1, diurnal fireflies; Mode 2, flightless females emitting continuous glow, flying male is either non-luminous or produces only very weak light; Mode 3, flightless females emitting continuous glow, flying male produces prominent continuous glow; Mode 4, male displays distinctive flash patterns]

Figure 1. Homogenous habitat – grassy abandoned farmland. Photo by author.

Figure 2. Heterogenous habitat involving closely connected woodlands, scrublands and grasslands. Photo by author.

Figure 3. This photo is formed by overlapping a series of 10 photos taken at the same place, total exposure time is 50s. 365 flash units are found on the photo, each contains 2 closely connected light spots. Average duration of each flash cycle of this Curtos fulvocapitalis in Hong Kong is 2520 ms. Number of flashing male fireflies occurring = 2520/50000 x 365 = 18.3. Photo by author.

Figure 4. A typical woodland trail for transect count of firefly population. Photo by author.

Figure 5. Location of visited sites in Hong Kong and frequency of visits for firefly survey from 2009 to 2020.

